

Aerobic rice–zero tillage wheat

A way forward for enhancing income and resource use efficiency

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Rice-wheat cropping system occupies the largest area and therefore evaluating different avenues of cultivation methods and nutrient management strategies for potential income and resource are needed. The two years study showed that net returns in aerobic rice system followed by zero-tillage wheat (ARS-ZTW) were increased by 5,700 and 10,100 ₹/ha overpuddled transplanted rice followed by conventional drill sown wheat (PTR-CDW). The study showed potential of ARS-ZTW among cultivation methods, Zn fertilization, and microbial inoculations in increasing profitability and efficiency in energy, water and nutrient use.

Key words: Aerobic rice, Energy efficiency, Nutrient management, Zero-tillage wheat

IN RICE–wheat cropping system (RWCS), three concern areas are resource degradation, sustainability and diversification. The problem of resource degradation is more prominent in non-traditional rice–wheat cropping system in trans-Indo-Gangetic plains (Punjab, Haryana and western Uttar Pradesh); water degrades due to lower total rainfall, higher use of groundwater for irrigation and groundwater pollution; and soil degradation due to waterlogging and salinization which is a consequence of inefficient drainage, irrigation system and cultural practices such as puddling.

The decreasing organic carbon content, lower organic matter, higher uptake by high yielding varieties, low nutrient use efficiency, higher losses of applied fertilizer which adds to air and groundwater pollution and monopoly of chemical fertilizer are the major area of concern in case of nitrogen, phosphorus and potassium. Decreasing organic matter and no addition of micronutrient fertilizers leads to application of micronutrients such as zinc and iron. Hence, studying sources of microbial inoculations in various cultivation

methods is needed to increase economic returns per unit of nutrient applied along with increasing their use efficiency.

The second aspect is sustainability and it involves enhancing the productivity with due consideration of effect of agricultural practices on natural resource base; while the third aspect is diversification, which holds a key of sustainable agriculture. The diversification may be achieved by changing cultivation method as a whole or changes in individual management practice such as changes in source and rate of macro and micronutrient application. With this background, the study was planned to evaluate different sources and rate of nutrient application in diverse cultivation methods of rice and wheat.

Methodology

A field experiment was conducted in *kharif* and *rabi* season of 2013–14 and 2014–15 at research farm of ICAR-Indian Agricultural Research Institute, New Delhi. It is located at a latitude of 28°40' N, longitude of 77°12' E and altitude of 228.6 m above the mean sea level (Arabian

Sea) with sandy clay loam soil. During first year of the experiment, total rainfall received was 1,349.8 mm with 39 number of rainy days, while during second year 451.8 mm of rainfall was received with 22 rainy days. The rainfall during first year was 699 mm higher than normal long-term average rainfall of Delhi (650 mm). In contrast to that, total rainfall during second year was deficit by 199 mm. Along with better rainfall during first year, evaporative losses during first year were 806 mm which was nearly same as that of annual mean pan evaporation (850 mm), while during second year evaporation losses were 1075 mm which was 225 mm higher than annual mean pan evaporation (850 mm). The soil of experimental field had a pH of 7.6, organic carbon of 0.54%, and available N, P, K and DTPA-extractable Zn of 257 kg/ha, 17 kg/ha, 327 kg/ha and 0.85 mg/kg, respectively.

The experiment was conducted in split-plot design with three main plots as cultivation methods viz., puddled transplanted rice followed by conventional drill sown wheat (PTR-CDW), system of rice intensification

followed by system of wheat intensification (SRI–SWI) and aerobic rice system followed by zero tillage wheat (ARS–ZTW). The subplot treatments consisted of four nutrient management treatments viz., RDN (120 kg N/ha and 25.8 kg P/ha), 75% RDN, 75% RDN + *Anabaena* sp. (CR1) + *Providencia* sp. (PR3) and 75% RDN *Anabaena-Pseudomonas* (An-Ps) biofilm formulation applied with and without zinc (Zn) (5 kg Zn/ha) making total eight treatments and one control both in rice and wheat. The potassium was applied @ of 49.8 kg K/ha equally in all plots and whole quantity of Zn was soil-applied at the time of sowing through zinc sulphate heptahydrate ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$). The whole quantity of P was applied as a basal irrespective of treatment involved; while N was applied 1/3 as basal, 1/3 each at 25 days after transplanting (DAT) and 55 DAT in rice and 1/3 at basal, 1/3 each at 30 days after sowing (DAS) and 60 ADS in wheat. The cost of cultivation and net returns were calculated by considering prices of input and output during the year of experiments. The system net energy production and energy input were calculated based on the energy equivalent of all inputs and output.

Research outcome

Rice yield did not differ significantly among cultivation methods; while net returns were significantly higher in ARS–ZTW over other cultivation methods. The net returns in SRI–SWI were significantly superior over PTR–CDW (Table 1). The increase in net returns in ARS–ZTW was 5,700 and 10,100 ₹/ha over SRI–SWI and PTR–CDW, respectively; while SRI–SWI had 4,400 ₹/ha higher net returns than PTR–CDW. The variation in net returns was mainly due to different cost of cultivation (Fig. 1a) in all three systems as the rice yield did not differ significantly among them. In ARS, puddling, nursery raising and transplanting cost was not incurred, and in ZTW, initial cost of land preparation was not involved. This results into economic

Table 1. Effect of cultivation methods and nutrient management options on system productivity, profitability and resource use efficiency (mean of two years data)

Treatment	Rice equivalent system yield (t/ha)	System net returns ($\times 10^3$ ₹/ha)	System profitability (₹/ha/day)	System net energy production ($\times 10^3$ MJ/ha)	Partial factor productivity (kg grain/kg N applied)	Partial factor productivity (kg grain/kg P applied)	Total water productivity (rice) (kg/ha-mm)
<i>Methods of cultivation</i>							
PTR–CDW	6.59	106.9	350.6	291.9	39.5	183.8	2.12
SRI–SWI	6.59	111.3	365.0	291.5	39.3	182.9	2.60
ARS–ZTW	6.58	117.0	383.5	293.9	39.7	184.8	2.80
SE $\pm$	0.02	0.7	2.2	0.62	0.03	0.16	0.01
CD ($P=0.05$)	0.10	2.6	8.5	2.43	0.13	0.62	0.03
<i>Nutrient management options</i>							
Control ($\text{N}_0\text{P}_0\text{Zn}_0$)	5.42	85.3	279.7	252.1	-	-	2.01
RDN*	6.75	115.6	379.0	298.3	35.7	166.1	2.57
RDN + Zn**	7.04	122.1	400.3	309.1	37.3	173.3	2.69
75% RDN	6.30	104.4	342.3	280.8	44.5	207.1	2.40
75% RDN + Zn	6.45	107.5	352.4	286.5	45.5	211.7	2.47
75% RDN + MC1	6.66	113.9	373.3	294.8	47.0	218.5	2.54
75% RDN + MC1+ Zn	6.97	121.0	396.7	306.6	49.2	228.9	2.67
75% RDN + MC2	6.69	114.7	376.1	296.1	47.2	219.6	2.55
75% RDN + MC2 + Zn	6.98	121.2	397.4	307.2	49.3	229.2	2.67
SE $\pm$	0.05	1.3	4.4	1.53	0.08	0.37	0.01
CD ($P=0.05$)	0.14	3.8	12.5	4.34	0.23	1.05	0.04

RDN*, Recommended dose of nutrients (120 kg nitrogen/ha and 25.8 kg phosphorus/ha); Zn**, 5 kg Zn/ha through $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$; MC1, *Anabaena* sp. (CR1) + *Providencia* sp. (PR3) consortium; MC2, *Anabaena-Pseudomonas* biofilm formulation.

superiority of ARS–ZTW. The superiority of SRI–SWI was due to lower seed rate of both rice and wheat as well as less cost of irrigation in SRI than PTR. This justifies the significance of ARS–ZTW in cost of production. Among nutrient management treatments, highest system yield and net returns were recorded with application of 100% RDN + Zn and remained on par with 75% RDN + MC1+ Zn and 75% RDN + MC2+ Zn. These three treatments were significantly superior to all other treatments. The system yield enhancement due to application of 100% RDN was 450 and 1,620 kg/ha over 75% RDN and control, respectively. The application of MC1 and MC2 contributes 360 and 390 kg/ha to system yield and Zn fertilization increase system yield by 160 to 310 kg/ha. This higher yield was translated into increasing net returns by 11,200 and 30,300 ₹/ha in RDN over 75% RDN and control. This signifies the role of optimum fertilization over sub-

optimal fertilization and soil inherent nutrient supply in enhancing net returns. Similarly, application of Zn and microbial consortia increased net returns by 3,100–7,100 and 9,500–13,700 ₹/ha, respectively which was higher than increase in cost due to application of Zn and microbial consortia. The variation in cost of cultivation and net returns were reflected in significantly higher profitability in ARS–ZTW than other cultivation methods. Similarly, application of RDN (36.7 ₹/ha/day/ha), zinc (21.3 ₹/ha/day/ha) and microbial inoculation (31–33.8 ₹/ha/day/ha) significantly increased the profitability over their respective control.

With regards to energy, lowest energy input was recorded in control due to no fertilizer application; while highest energy input was recorded in 100% RDN + Zn (Fig. 1b). The increased in energy input due to Zn fertilization and application of microbial inoculation was 0.20×10^3 and 0.04×10^3 MJ/ha. The net

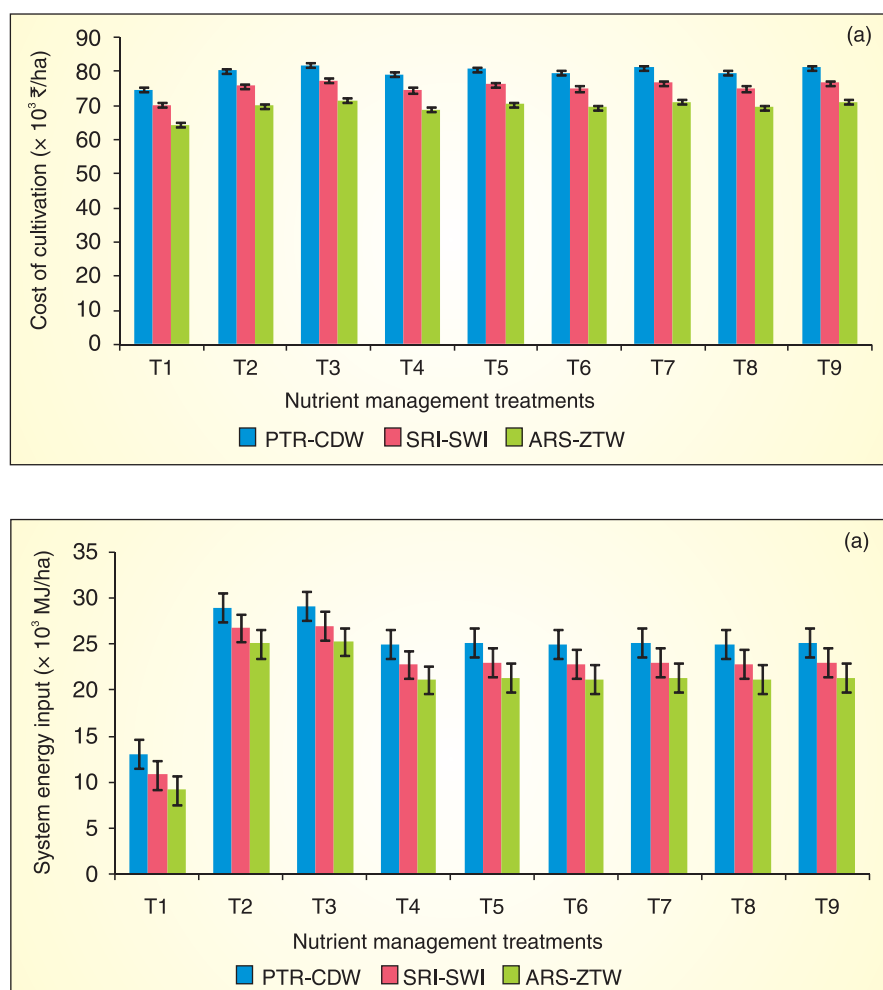


Fig. 1. Effect of cultivation methods and nutrient management options on cost of cultivation (a) and energy input (b) (Data averaged over two years). (T1, Control ($N_0P_0Zn_0$); T2, RDN*; T3, RDN + Zn**; T4, 75% RDN; T5, 75% RDN + Zn; T6, 75% RDN + MC1; T7, 75% RDN + MC1 + Zn; T8, 75% RDN + MC2 and T9, 75% RDN + MC2 + Zn).

energy production was highest with application of RDN + Zn and remained on par with 75% RDN + MC1 or MC2 + Zn. The net energy output in RDN ($309.1 \times 10^3 \text{ MJ/ha}$) was higher by 17.5 and $46.2 \times 10^3 \text{ MJ/ha}$ over 75% RDN and control, respectively. The increase in net energy production of system was 10.8, 11.8 and $11.1 \times 10^3 \text{ MJ/ha}$ due to application of Zn with RDN, 75% RDN + MC1 and 75% RDN + MC2, respectively. Similarly, application of MC1 and MC2 consortia increased net energy production by 14×10^3 and $15.3 \times 10^3 \text{ MJ/ha}$, respectively. The higher net energy production with application of RDN, 75% RDN + MC2 and 75% RDN + MC1 were due to higher gross energy output as energy input in these treatments were higher than their respective control

(75% RDN and control (no fertilization)). The ARS-ZTW was found significantly superior in terms of net energy production than both PTR-CDW and SRI-SWI; while SRI-SWI had a significantly higher net energy production over PTR-CDW. The net energy production in ARS-ZTW was 2×10^3 and $2.4 \times 10^3 \text{ MJ/ha}$ higher than PTR-CDW and SRI-SWI. This variation in energy production was primarily contributed by reduction in energy requirement in operations such as puddling, transplanting and field preparation in ARS-ZTW system and leading to make it energy efficient system.

The partial factor productivity (PFP) of nitrogen (N) was not significantly affected due to cultivation methods; while PFP of phosphorus (P) was significantly

higher in ARS-ZTW than both PTR-CDW and SRI-SWI. The PFP of P in PTR-CDW was statistically superior over SRI-SWI. The application of 75% RDN with MC1 or MC2 was significantly higher PFP of N and P than both 75% RDN and RDN; while PFP of 75% RDN was found superior to RDN. The higher PFP in inoculated treatments was due to higher yield than 75% RDN and lower rate of nutrient application over RDN. This signified the importance of microbial inoculation in nutrient management of rice. The variation in PFP among RDN and 75% RDN was due to rate of application. The total water productivity of rice was significantly increased by changing cultivation methods from PTR to SRI or ARS and increased in total water productivity in ARS was 0.68 and 0.48 kg/ha-mm over PTR and SRI. Among nutrient management treatments, increased in water productivity due to application of RDN was 0.17 and 0.56 kg/ha-mm over 75% RDN and control. Similarly, application of Zn and microbial consortia increased water productivity by 0.12 and 0.14 kg/ha-mm. This increase was mainly brought out by increasing yield due to application of Zn and microbial consortia.

SUMMARY

The study showed the importance of diversification of puddled transplant rice (PTR) followed by conventional drill sown wheat (CDW) with aerobic rice system (ARS) followed by zero tillage wheat (ZTW) due to its capacity to increase profitability, net energy production and total water use efficiency. The application of 75% RDN + *Anabaena-Pseudomonas* biofilm formulation (MC2) + Zn was found superior in enhancing profitability and resource use efficiency over application of RDN through fertilizer.

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