

Accounting of water

in different systems of rice cultivation

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Rice (Oryza sativa) requires highest amount of water per unit of crop produce and having lower water use efficiency as compared to other field crops. In this context and in era of sustainable use of natural resources, account of water used in different systems of cultivation is of immense importance. Results of two year study showed that, system of rice intensification (SRI) requires lowest water per kg of rough rice produced followed by aerobic rice system (ARS) in first year; while in second year ARS requires significantly lowest water (2,865 litres kg⁻¹) for production of 1 kg rough rice than SRI (3,275 litres kg⁻¹) and conventional puddled transplanted rice (PTR) (4,441 litres kg⁻¹). Total water requirement for production of one kg milled rice (6,400 litres/kg) was highest followed by brown rice (5,467 litres kg⁻¹) and lowest in rough rice (4,209 litres/kg). Irrigation water was more efficiently used in ARS than both SRI and PTR as ARS require lowest irrigation water per kg of rough (1,513 litres kg⁻¹), brown (1,996 litres kg⁻¹) and milled (2,346 litres kg⁻¹) rice produced. Among nutrient management treatments, recommended dose of nutrient (RDN) (120 kg N/ha and 25.8 kg P/ha) + Zn (5 kg/ha) require lowest total water for production of one kg of rough rice (3,900 litres/kg) which was a on par with 75% RDN + CRI (Anabaena sp.) + PR₃ (Providencia sp.) + Zn (3,932) and 75 % RDN + Anabaena-Pseudomonas (An-Ps) biofilmed formulation + Zn (3,930 litres/kg).

Key words: Cultivation, Rice, Water

RICE (*Oryza sativa*) is an aquatic guzzling crop and going to face severe competition to meet its water requirement in 21st century mainly due to two groups of factors. First group is related with decrease in water supply which was due to inadequate erratic and ill distributed rainfall, faster depletion of groundwater reserves, sea-water intrusion in coastal region and decrease in storage of water in artificial and natural above ground reservoirs. Second group of factors is increase demand of water from other agricultural activity and other sectors such as industries, energy generation plants, domestic uses etc. In this context three important things are need prioritization in rice cultivation. First one is to prepare an account of water used in production of rice at micro-level such as field level. Second

is to find out suitable solutions to get rid of natural as well as human induced water shortage in rice production. Third and last thing is to have optimum price tag on water 'a renewable but scarce natural resource'. Available water need to be used efficiently and effectively to produce more crop yield per unit of water used. In this context study was conducted for evaluation of three different management practices/input variables for their water saving potential viz. cultivation systems, microbial inoculation and zinc (Zn) fertilization.

Cultivation

Field experiment was conducted in *kharif* of 2013 and 2014 in research farm of Indian Agricultural Research Institute, New Delhi. Meteorological data were recorded in meteorological

observatory of Indian Agricultural Research Institute during crop growing period. During first year of 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. 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 were 806 mm during first year which was nearly same as that of annual mean pan evaporation (850 mm), while during second year evaporation losses were 1,075 mm which was 225 mm higher than annual mean pan evaporation (850 mm). Rainfall and relative humidity was higher while temperature was

Table 1. Effect of cultivation systems and nutrient management options on water requirement for production of rough and brown rice

Treatments (litres kg ⁻¹)	Water requirement of rough rice (litres kg ⁻¹)				Water requirement of brown rice			
	2013		2014		2013		2014	
	Total water	Irrigation water	Total water	Irrigation water	Total water	Irrigation water	Total water	Irrigation water
<i>Rice cultivation systems</i>								
PTR	5148.5	1807.1	4441.4	3271.4	6636.8	2329.5	5765.1	4246.3
SRI	4713.8	1399.6	3276.5	2130.6	6049.2	1796.0	4232.9	2752.5
ARS	4813.3	1357.1	2865.7	1668.9	6327.7	1784.1	3793.3	2209.1
SEm±	32.1	11.2	18.8	13.8	37.8	13.1	23.6	17.2
CD (<i>P</i> = 0.05)	125.9	44.1	73.7	54.1	148.3	51.5	92.7	67.5
<i>Nutrient management options</i>								
Control (N ₀ P ₀ Zn ₀)	6010.6	1873.2	4439.8	2971.4	8036.9	2504.1	5971.2	3995.2
RDN	4714.7	1465.8	3417.9	2283.0	6056.0	1881.2	4403.7	2938.4
RDN + Zn*	4562.0	1418.1	3238.9	2163.2	5827.1	1810.9	4160.8	2777.8
75 % RDN	5133.8	1595.8	3635.4	2427.9	6713.6	2084.4	4792.1	3196.5
75 % RDN + Zn	4915.6	1528.4	3560.9	2378.9	6421.2	1995.7	4683.3	3127.2
75 % RDN + CR1+ PR3**	4760.2	1479.6	3459.4	2310.2	6125.7	1902.9	4476.0	2987.0
75 % RDN + CR1+ PR3 +Zn	4586.7	1425.8	3277.8	2189.2	5875.4	1825.4	4219.7	2816.4
75 % RDN + An-Ps# biofilmed formulation	4760.5	1479.7	3442.5	2299.0	6126.3	1902.8	4442.5	2963.8
75 % RDN + An-Ps biofilmed formulation + Zn	4582.9	1424.8	3278.7	2190.0	5858.9	1821.4	4224.5	2821.4
SEm±	61.2	21.4	37.8	27.8	65.7	22.7	43.4	31.5
CD (<i>P</i> = 0.05)	174.0	61.0	107.6	79.1	186.7	64.6	123.3	89.7

Zn*: 5 kg Zn ha⁻¹ through ZnSO₄.7H₂O.

lower during initial growth of rice in main field and nursery during first year leads to better growing condition for rice in first year than second year. This variation in rainfall leads to different contribution of rain and irrigation water to the total water meet of rice in two different years. Hence, both rain and irrigation water used changes in both years.

Experiment was executed in split plot design with three main plots and nine sub-plots. Among three management practices/ input variables studied in this investigation systems of cultivation was assigned to main plot. Cultivation systems involve comparing puddled transplanted rice with system of rice intensification and aerobic rice system for their water saving potential. Other two input variable viz. microbial inoculation and Zn fertilization were applied in sub-plot with following nine treatments combinations to study their role in improving yield of rice and indirectly contributing to improvement in water productivity. These treatment combinations were: T₁- Control-No fertilizer (N₀P₀Zn₀), T₂- RDN (120 kg N ha⁻¹) and P (25.8 kg P ha⁻¹), T₃-T₂+ Zn (5 kg ha⁻¹), T₄- 75 % RDN, T₅- T₄+ Zn (5 kg ha⁻¹), T₆-

75 % RDN + CR₁ (*Anabaena* sp.) + PR₃ (*Providencia* sp.), T₇- T₆ + Zn (5 kg ha⁻¹) and T₈ - 75 % RDN + *Anabaena-Pseudomonas* (An-Ps) biofilmed formulation, T₉- T₈ + with Zn (5 kg ha⁻¹). Potassium was applied @ 49.8 kg K/ha in all plots. Whole quantity of Zn was soil applied at the sowing through zinc sulphate heptahydrate (ZnSO₄.7H₂O). Amount of water needed to produce 1 kg of rough, brown and milled-rice in all three systems were calculated and expressed in 6,400 litre/kg of final produce.

Research outcome

Amount of total water required to produce one kg of rough rice was higher during first year than second year. The PTR requires 707 litres more total water in first year than second year to produce one kg of rough rice; while in system of rice intensification and aerobic rice system, 1,437 and 1,947 litres more total water needed to produce 1 kg of rice in first year than second year (Table 1). Higher amount of total water in first year was mainly due to higher total rainfall leading to higher total water availability in first year than second year.

In case of irrigation water, reverse

trend was found. Higher amount of irrigation was used in second year than first year of rice production in all three systems of cultivations. This indicates that contribution of irrigation water to total water given to crop was higher during second year which was mainly due to low rainfall during second year. The piddled transplanted rice used 1,807 litres of irrigation water; while SRI and ARS used 1,399 and 1,357 litres of irrigation water to produce one kg of rough rice, respectively in first year. The PTR, SRI and ARS use 1,464; 731 and 311 litres less irrigation water in first year than second year.

Among the systems of cultivation, SRI method used less total water to produce 1kg rough rice which remained on a par with ARS. Both SRI and ARS required significantly less total water than PRT in first year. Irrigation water used in first year was least with ARS and remained on a par with SRI. PTR required significantly higher irrigation water to produce one kg of rough rice. This indicates that SRI and ARS were better to save water than PTR in first year with high rainfall due to their lower irrigation water demand.

In second year aerobic rice system



recorded significantly lower irrigation than system of rice intensification method per kg of rough rice produced; while system of rice intensification stand statistically superior to piddled transplanted rice in saving both total and irrigation water required to produce one kg of rough rice. This showed that in year of low rainfall, aerobic rice system was found better than both systems of rice intensification and PTR in reducing water need to produce one kg rough rice.

Among nutrient management treatments, amount of water saving per unit of rough rice produced is depend upon capacity of applied microbial inoculations and Zn fertilization to increase yield as the water used was remained same for all subplot treatments within a single method. Treatment containing RDN + Zn recorded lowest total and irrigation water per kg of rough rice and remained on a par with 75% RDN + CR₁+ PR₃+ Zn and 75% RDN + An-Ps biofilmed formulation + Zn. These three treatments recorded significantly lower water than treatment containing 75% RDN with and without Zn. This indicates that increase in yield due to both microbial inoculations leading to save more water than treatment containing the same quantity of chemical fertilizer application. Irrigation and total water used to produce 1 kg of rice in three

treatments viz. RDN + Zn, 75% RDN + CR₁+ PR₃+ Zn and 75% RDN + An-Ps biofilmed formulation + Zn was lower than same treatment without Zn application. This underlines the role of Zn fertilization in improving rice yield and ultimately saving of irrigation water.

Water required for production of 1kg of brown rice is higher than rough rice mainly due to lower yield of brown than rough rice, while total

and irrigation water used remained same. Total water required for production of one kg of brown rice in PTR, SRI and ARS was higher by 1,488; 1,335 and 1,514 litres than rough rice in first year and 1,323, 956, and 927 litres in second year, respectively (Table 1). Among systems of cultivation, SRI required significantly lower total water (6,049 litres kg⁻¹) than ARS, and ARS required significantly lower water

Table 2. Effect of cultivation systems and nutrient management options on water requirement of milled rice

Treatment	Water requirement of milled rice (litres kg ⁻¹)			
	2013		2014	
	Total water	Irrigation water	Total water	Irrigation water
<i>Rice cultivation systems</i>				
PTR	7705.1	2704.5	6804.5	5012.0
SRI	7022.2	2084.9	5006.9	3255.7
ARS	7373.8	2079.0	4487.9	2613.6
SEm±	62.1	21.5	33.6	24.1
CD (P = 0.05)	243.7	84.3	131.8	94.5
<i>Nutrient management options</i>				
Control (N ₀ P ₀ Zn ₀)	9454.9	2947.0	7106.5	4754.9
RDN	7019.6	2182.0	5195.1	3469.0
RDN + Zn*	6714.4	2085.6	4890.0	3263.2
75 % RDN	7859.9	2439.9	5694.4	3798.0
75 % RDN + Zn	7504.0	2333.1	5563.7	3716.4
75 % RDN + CR ₁ + PR ₃	7097.9	2201.3	5271.9	3511.5
75 % RDN + CR ₁ + PR ₃ + Zn	6782.2	2105.6	4954.8	3307.7
75 % RDN + An-Ps biofilmed formulation	7096.3	2202.7	5243.6	3496.0
75 % RDN + An-Ps biofilmed formulation + Zn	6774.1	2107.9	4977.9	3327.3
SEm±	130.3	45.5	74.1	54.2
CD (P = 0.05)	370.5	129.4	210.7	154.2

Zn*: 5 kg Zn ha⁻¹ through ZnSO₄·7H₂O.

(6,327 litres kg⁻¹) than PTR (6,636 litres kg⁻¹) in first year. In second year, ARS required significantly lower water (3,793 litres kg⁻¹) than SRI (4,232 litres kg⁻¹) and both these method found better than PTR (5,765 litres kg⁻¹) in saving water per unit of brown rice produced. Among the two deciding factors of water productivity viz. yield and water used, yield dominates to water used in first year and hence SRI is superior in saving water than ARS; while in second year water used is deciding factor for water productivity and hence ARS save more water than SRI per unit of brown rice produced.

In nutrient management treatment, three treatments viz. RDN + Zn, 75% RDN + CR1+ PR3+ Zn and 75% RDN + An-Ps biofilmed formulation + Zn remained statistically on a par and recorded significantly lower water per kg of brown rice produced as compared to other treatments. This showed the role of Zn fertilization and microbial inoculation not only in improving yield but also in improving hulling recovery of rice.

Water productivity of milled rice

gives exact quantity of water that we are consuming while taking 1 kg of rice in our diet as milled-rice was used for direct consumption and not brown and rough rice. Milled-rice required higher water than both rough rice and brown rice (Table 2). Conventional method required significantly highest total and irrigation water per kg of milled rice in both years. SRI required lowest total water (7,022 litres kg⁻¹) and aerobic rice required lowest irrigation water (2,079 litres kg⁻¹) per kg of milled rice produced during first year; while during second year, ARS required lowest total and irrigation water (4,487 and 2,613 litres kg⁻¹) to produce one kg of milled rice. Among nutrient management treatments, trend was similar as that of brown rice with the lowest water used in three treatments viz. RDN + Zn, 75% RDN + CR1+ PR3+ Zn and 75% RDN + An-Ps biofilmed formulation + Zn. These treatments stand statistically superior to all other treatments in saving both irrigation and rainwater per kg of milled rice produced.

SUMMARY

Accounting of water per unit rough, brown and milled-rice produced helps in selecting suitable system of cultivation and quantifying the effect of Zn fertilization and microbial inoculation on water saving. The system of rice intensification requires less water per unit of rice produced in first year due to lower water used than PTR per kg of rice produced and higher productivity than aerobic rice system; while in second year, aerobic rice system stand superior in reducing water requirement than both SRI and PTR due to lower water used in aerobic rice system per kg of rice produced. Yield improvement due to Zn fertilization and application of microbial inoculation indirectly contribute to saving water. Hence, need due consideration while deciding water saving rice production systems.

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