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Effect of water regimes and organic sources of nutrients for higher productivity and nitrogen use efficiency of summer rice (*Oryza sativa*)

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Field experiment was conducted at farmers' field of old alluvial zone (Manikchak, Malda) of West Bengal, India during winters of 2007-2009 to study the effect of water management practices with different combinations of integrated plant nutrient supply including lathyrus green manure, vermicompost, poultry manure, chopped rice straw on productivity and nitrogen use efficiency of irrigated rice (*Oryza sativa* L.). Growth and yield attributes of rice, *viz,* effective tillers/m^2, panicle length, number of grains/ panicle and 1000-grain weight were significantly highest in saturation from 15 to 35 days after transplanting followed by continuous ponding, among the water regimes and lathyrus green manuring 10 t ha^{-1}, among the organic sources of nutrients. Similarly highest grain yield was recorded in saturation of top soil (0-40 cm) (4.26 and 4.32 tones ha^{-1}) and lathyrus green manuring 10 t ha^{-1} (4.70 and 4.78 t ha^{-1}), which was at par with the combined application of lathyrus green manuring 5 t ha^{-1} + vermicompost 2.5 t ha^{-1} + poultry manure 2.5 t ha^{-1} (4.66 and 4.75 t ha^{-1}) and chopped rice straw 5 t ha^{-1} + lathyrus green manuring 5 t ha^{-1} (4.64 and 4.73 t ha^{-1}). Irrespective of organic nutrients sources, saturation of top soil (0-40 cm) recorded highest net return (Rs 19613/- and 20281) and benefit:cost ratio (1.76 and 1.78) and the treatment lathyrus green manuring 10 t ha^{-1} (Rs 24592/- and 25484/- and 1.98 and 2.02) recorded among the organic nutrient management. Irrespective of water regimes, statistically highest N and K uptake were found in lathyrus green manuring 10 t ha^{-1} (115.59 to 118.39 kg ha^{-1}) and (67.17 to 70.80 kg ha^{-1}), respectively; however, highest P uptake was found in lathyrus green manuring 5 t ha^{-1} + vermicompost 2.5 t ha^{-1} + poultry manure 2.5 t ha^{-1} (49.24 to 50.57 kg ha^{-1}). The nitrogen use efficiency indices such as agronomic efficiency, physiological efficiency, internal efficiency, recovery efficiency and partial factor productivity might be influenced when a part of nitrogen was supplied through organic sources. The highest water expanses efficiency was recorded in saturation of top soil (0 to 40 cm) (26.68 and 27.22 kg ha^{-1} mm^{-1}), however, highest water saving (5.45 and 5.70%) was found in intermittent ponding of water.

Key words: Lathyrus, nitrogen use efficiency, poultry manure, vermicompost, water expanses efficiency, water regimes.

INTRODUCTION

Rice (*Oryza sativa* L.) is an important cereal crop in global agriculture, it place in second (more than 150 million ha) after wheat in terms of area and provides 35 to 80% of total calorie intake (IRRI, 1997) and more than

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90% of the world rice growing area occurring in Asia. Rice production is known to be less water efficient; water consumption to produce 1 kg of rice is significantly greater than that of all other important grain crops (Bhuiyan, 1992). In Asia, food security is challenged by increasing food demand and threatened by declining water availability, because irrigated agriculture accounts for 90% of total diverted freshwater, and more than 50% of this is used to irrigate rice. The impacts of this are location and area specific. Therefore, researchers alike are looking for ways to decrease water use in rice production and increase its use efficiency.

Rice is the main crop of eastern region of India grown in different seasons. However, productivity in India is only 1.97 t ha^{-1} against the world average of 2.62 t ha^{-1} (FAO 2006). India has achieved self sufficiency in food during the past decades and now it is need to increase food production by at least 5 million tones and rice by 2 million tones every year to sustained self sufficiency (Sindhu et al., 1990). In India 44.8 million hectare out of total rice cultivation area, irrigated rice occupies 46 to 49% of area and consumes 66% of irrigation water. Boro (dry season) rice is one of the important crop in eastern Indian during winter (Rahaman and Sinha, 2012) that required about 1200 to 2000 mm of water with higher fertilizer doses showing profitable yield level, however, unscientific management of irrigation water and plant nutrients in Indian soil result in poor productivity and nutrient use efficiency of rice (Yadav and Kumar, 2009), because of majority of Indian soils are nitrogen deficient. Generally, inorganic fertilizers such as urea (46% N) that lost through run-off, leaching, ammonia volatilization and denitrification. Nitrogen is the key nutrient element required by rice in large quantities accounting for 67% of total fertilizer application to rice worldwide. If the increase of 1% nitrogen use efficiency in world wide lead to nitrogen fertilizer saved in an account of US$ 23,46,58,462 use (Raun and Johnson, 1999) than present situation. Therefore, technologies must be focused on increasing rice yield alone with nitrogen use efficiency. An integrated nutrient management (INM) practices involving the input of green manure (GM), farmyard manure (FYM) and crop residues and bio fertilizers are advocated to improve N use efficiency, soil organic carbon, crop productivity and soil health (Chaudhury et al., 2005). INM may play vital role in sustaining both the soil health and crop production on long term basis without degrading the natural resources. Organic manure provides regulated supply of plant nutrients by slowly released resulted in increasing yield of rice and nitrogen use efficiency (Sharma, 2002). Some scientist also reported that green manuring could be increased grain yield, nutrients uptake of the crops (Bajpai et al., 2004). Therefore, it is needed to gather information regarding identification of suitable resources and to quantify their impact on sustainable crop production. Hence, the present study was undertaken to study the influence of water regimes and integrated nutrient management on productivity, water use efficiency and nitrogen use efficiency in old alluvial zone of West Bengal, India.

MATERIALS AND METHODS

Study site

The experiment was carried out during winter of 2007-2008 and 2008-2009 in the farmers' field located at old alluvial (Manik Chak block of Malda district) zone of West Bengal, India (24°57'20" to 25°30'08" N latitude, 87°45'50" to 88°28'10" E longitude and 15 m elevation). The region is classified as humid subtropical with a monsoon climate, having an annual mean precipitation of 1650 mm. The daily temperature during a year varies widely between 7.5°C (January) and 35.5°C (July-August). Eighty percent of the annual rainfall is received from April to November. The soil was silty clay having pH 8.3, organic carbon 0.82%, available nitrogen (KMnO4), phosphorus (Olsen) and potassium (NH_4OHC) between 250 and 300 kg ha^{-1}, 22 and 39 kg ha^{-1} and 194 and 225 kg ha^{-1}, respectively.

Experimental design

The experiment consist of three main plot treatments that was water regimes *viz* I_1 -continuous ponding (CP) or farmers practice (5±2 cm), I_2 -Intermittent ponding {2 day after disappearance (DAD) 5±0 cm} from 15 to 35 DAT followed by CP and I_3 -Saturation of top 40 cm soil from 15 to 35 DAT followed by CP. The subplot treatments were sources of organic nutrient, OS0, Control (without organic or inorganic nitrogen), OS1, *Lathyrus* green manuring 10t ha^{-1} (fresh weight basis), OS2, Vermicompost 5 t ha^{-1}, OS3, Poultry manure 5 t ha^{-1}, OS4, chopped rice straw 5 t ha^{-1} (rainy season rice straw) + *Lathyrus* green manuring 5 t ha^{-1} and OS5, *Lathyrus* green manuring 5 t ha^{-1} + vermicompost 2.5 t ha^{-1} + poultry manure 2.5 t ha^{-1} and OS_6, inorganic fertilizers (120:60:60). The experiment was a split plot design with three replications. The 35 day old seedling of popular rice varieties 'Khitish' was transplanted in main plot size (5.0 × 6.0 m) in the last week of January with the spacing of 15 × 20 cm. The plots were occupied by "lathyrus" as green manuring crop at 50 days before the transplanting of summer rice with chemical fertilizer of 20:60:40 kg ha^{-1} of N, P2O5 and K_2O, respectively. All the organic sources of nutrients incorporated in to the soil one week before the submergence. Before incorporation N:P:K content in organic nutrients were analyzed. To fulfill the 120:60:60 kg ha^{-1} recommended dose of N, P_2O_5 and K_2O, organic manure were applied and rest of the nitrogen, phosphorus and potassium were applied as basal and top dressing in the form of urea, single super phosphate and murate of potashat basal, tillering and panicle initiation stage.

Sampling and analysis

Plant sampling

Plants and grains samples from the area of 0.25 m^2 were harvested by manual uprooting just before two days of harvesting and harvested plants were washed with tap water to dislodge the adhering soil, and then several times with deionized water to remove solute from ion free space. Plant samples were separated into root, straw and grain. The collected plant samples were first air dried and then oven dried at 70±5°C for 48 h. Dried plant samples were grinded and were passed through a 0.2 mm sieve for a nitric and perchloric digestion (HNO_3:: $HCLO_4$, 9::4, V/V/). The nitrogen content analyzed by modified Macro Kjeldahl method, and P and K by Jackson. The yield component was taken from one square meter of three times from each plot. However, grain and straw yield of rice were recorded for the whole plot at crop harvest and converted to tones/ha. Cost of cultivation and return of each treatment were calculated/ha on the prevailing cost of inputs and market prices. Different indices of nitrogen use efficiency were computed as per Dobermann and Fairhusrt (2000). Agronomic efficiency id defined as the grain yield (kg) in N treated plot minus grain yield (kg) in control (N-0) plot per unit amount of N applied (kg). Physiological efficiency is the grain yield in N treated plot (kg) minus grain yield in control (N-0) plot (kg) divided by total n uptake in N treated plot (kg) minus total N uptake in control (n-0) plot (kg). Internal efficiency is grain yield (kg) per total N uptake (kg) and recovery efficiency is the percentage of N uptake in N treated plot (kg) minus N uptake in control (N-0) plot (kg) divided by the amount of N applied (kg). Partial factor productivity is the grain yield (kg) per amount of N applied (kg). Water expanse efficiency (kg $ha^{-1}mm^{-1}$) is calculated by total grain yield (kg ha^{-1}) divided by irrigation water and effective rainfall (mm).

Soil sampling

Initial and bulk soil samples (0-0.15 m) from the experimental site at harvest were collected for composite soil samples. The collected soil samples were air dried, and visible roots and debris were removed and discarded. Then a portion of the larger and massive aggregates were broken by gentle crushing with a wooden hammer, and screened through a 0.2 mm stainless steel sieve. The sieved samples were then mixed thoroughly to make the composite sample. These soil samples were used for various analyses. Soil pH was determined by using soil suspension in water in the ratio of (1: 2.5) with a pH meter as described by (Jackson, 1973). The soil samples were treated with neutral normal ammonium acetate solution (pH 7.0) in (Soil: Extractant:: 1:10) after one hour shaking, followed by filtration, the leachate was used for the determination of K^+ and measure by using a Flame photometer Whereas, available nitrogen by modified Macro Kjeldahl method and P_2O_5 by Olsen method.

Statistical analysis

The experimental data were subjected to analysis of variance (ANOVA) by using the statistical software INDOSTATE 7.5 with a three replications of three main factor and seven sub factor to determine the statistically difference between treatments. The average values were compared using the least significant difference (LSD) test at the 5% level.

RESULTS AND DISCUSSION

Effect on yield and yield components

The data of yield attributing characteristics were presented in Table 1. The water management regimes and integrated sources of plant nutrients significantly influenced the yield component on rice. The data of yield components viz, productive tiller m-^{2}, grains panicle^{-1}, panicle length, panicle weight and test weight revealed that the water regime, saturation (0-40 cm) from 15 to 35 DAT followed by CP (continuous ponding) recorded significantly highest in terms of grain and straw yield (4.26 and 4.32 and 6.14 and 6.30 t ha^{-1}) than continuous ponding (CP) or farmers practice (4.06 and 4.12 and 5.73 and 5.93 t ha^{-1}) and intermittent ponding (2 DAD 5±0) from 15 to 35 DAT followed by CP (4.01 and 4.10 and 5.64 and 5.88 t ha^{-1}) (Table 2). Continuous ponding might reduce nitrogen use efficiency and growth due to excess water (Chandra et al., 2008), as well as long water scarcity reduced the tillering, emerged weeds, creation of hard pan on the soil surface in intermittent ponding. Bouman and Toung (2001) reported that the periods of non-submergence or intermittent ponding in place of continuous ponding can reduce the demand of irrigation water by rice. To maintain or even increased in rice yield recorded under systems of alternate submergence-non-submergence (Li, 2001). Present study also revealed similarly higher grain yield under saturation water treatments. However, in India the yield was often decreased, in comparison to the continuous ponding condition (Mishra et al., 1990). Organic alone or in combination revealed significantly higher yield attributes and grain yield (4.11 to 4.78 t ha^{-1}) over control (1.97-1.99 t ha^{-1}) (Table 2). That reflected the importance of nitrogen in determining the rice grain yields. Irrespective of water regimes, statistically highest grain and straw yield were recorded in lathyrus green manuring 10 t ha^{-1} (4.70 and 4.78 and 6.24 and 6.44 t ha^{-1}) which was at par with combined application of lathyrus green manuring 5 t ha^{-1} + vermicompost 2.5 t ha^{-1} + poultry manure 2.5 t ha^{-1} (4.66 and 4.75 and 6.24 and 6.46 t ha^{-1}) and chopped rice straw 5 t ha^{-1} + lathyrus green manuring 5t ha^{-1} (4.64 and 4.73 and 6.23 and 6.41 t ha^{-1}). This might be due to the biological nitrogen fixation in to the soil and its incorporations release it regularly and slowly Yoshiaki, 1982), that increased grain yield and nitrogen (use efficiency (Sharma, 2002). The inorganic fertilizer application significantly increased grain yield by 52 to 52.3% over the control. The grain yield increased significantly with the organics (4.64 to 4.78 t ha^{-1}) over the inorganic (4.12 and 4.19 t ha^{-1}) except single application of poultry manure. Sole application of vermicompost 5 t ha^{-1} (4.57 and 4.64 and 6.15 and 6.40 t ha^{-1}) was noted superior than poultry manure (4.11 and 4.18 and 5.71 and 5.92 t ha^{-1}) and on par with lathyrus green manuring 5 t ha^{-1} + vermicompost 2.5 t ha^{-1} + poultry manure 2.5 t ha^{-1} and chopped rice straw 5 t ha^{-1} + lathyrus green manuring 5 t ha^{-1}. Application of green manure with chemical fertilizer could better than sole application chemical fertilizer in term of grain yield increased (Subbaiah et al., 2000). The carry over effect of straw residue due to stable and slow mineralization might have resulted in gradual released of nitrogen besides improving soil health and thus reflected in higher grain yields over inorganic alone. Thuy (2004) found insignificant increase or even a decrease in grain yield under residue incorporation, especially without

Table 1. Effect of water regimes and organic source of nutrients on growth, yield attributing characters of dry season rice.

Treatments	Plant height (cm)		Productive tillers/ m^2		Grains/ panicles		Panicle length (cm)		Panicle weight (g)	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
I_1	93.02	93.16	291.7	293.0	97.4	97.6	25.90	26.03	2.91	2.96
I_2	92.74	92.91	287.4	288.6	96.3	96.5	25.88	26.01	2.95	2.99
I_3	93.51	93.65	311.3	312.7	102.3	102.7	26.16	26.29	3.22	3.26
LSD (p=0.05)	0.36	0.35	4.50	4.65	2.40	2.89	0.04	0.04	0.03	0.04
OS_0	85.25	85.41	171.8	173.1	70.1	70.2	25.08	25.21	2.56	2.61
OS_1	95.04	95.17	328.6	330.2	107.2	107.3	26.26	26.39	3.18	3.22
OS_2	94.41	94.58	318.4	319.9	102.9	103.2	26.16	26.30	3.11	3.16
OS_3	93.71	93.84	307.1	308.6	99.67	100.1	25.95	26.08	3.03	3.08
OS_4	94.70	94.86	323.1	324.1	105.1	105.2	26.21	26.34	3.13	3.18
OS_5	94.86	95.01	325.2	326.3	105.2	105.3	26.23	26.36	3.15	3.19
OS_6	93.65	93.81	303.3	304.7	100.6	101.2	25.93	26.06	3.01	3.06
LSD (p=0.05)	0.36	0.37	4.90	5.58	2.25	2.22	0.04	0.04	0.02	0.02

I_1, Continuous ponding (CP) or farmers practice (5±2 cm); I_2, intermittent ponding {2 day after disappearance (DAD) 5±0 cm} from 15-35 DAT followed by CP; I_3, saturation from 15-35 DAT followed by CP; OS0, control (without nitrogen); OS1, *Lathyrus* green manuring 10t ha^{-1} (fresh weight basis); OS2, vermicompost 5t ha^{-1}; OS3, poultry manure 5t ha^{-1}; OS4, chopped rice straw 5 t ha^{-1} (rainy season rice straw) + *Lathyrus* green manuring 5 t ha^{-1}; OS5, *Lathyrus* green manuring 5 t ha^{-1} + vermicompost 2.5 t ha^{-1} + poultry manure 2.5 t ha^{-1}; OS_6, inorganic fertilizers (120:60:60).

Table 2. Effect of water regimes and organic source of nutrients on grain and straw yield, harvest index, and economics dry season ric e.

Treatments	Test weight (g)		Grain yield ton/ha		Straw yield ton/ha		Harvest Index		Net return(Rs)		Benefit :cost ratio	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
I_1	21.40	21.41	4.06	4.12	5.73	5.93	40.94	40.45	17178	18491	1.68	1.72
I_2	21.39	21.39	4.01	4.10	5.64	5.88	41.05	40.48	16175	16655	1.60	1.61
I_3	21.54	21.62	4.26	4.32	6.14	6.30	40.42	40.13	19613	20281	1.76	1.78
LSD (p=0.05)	0.06	0.16	0.08	0.09	0.89	0.48	-	-	-	-	-	-
OS_0	18.09	18.11	1.97	1.99	4.54	4.59	30.41	30.42	647	923	1.03	1.04
OS_1	22.13	22.16	4.70	4.78	6.24	6.44	43.07	42.59	24592	25484	1.98	2.02
OS_2	22.03	22.06	4.57	4.64	6.15	6.40	42.79	41.84	18135	19033	1.60	1.63
OS_3	21.86	21.88	4.12	4.19	5.71	5.92	41.93	41.42	18613	19553	1.74	1.78
OS_4	22.08	22.11	4.64	4.73	6.23	6.41	42.72	42.36	18964	19959	1.63	1.66
OS_5	22.10	22.13	4.66	4.75	6.24	6.46	42.83	42.39	18162	19152	1.58	1.62
OS_6 (120:60:60)	21.82	21.83	4.11	4.18	5.72	5.92	41.84	41.45	18016	18788	1.70	1.73
LSD (p=0.05)	0.06	0.07	0.08	0.12	0.38	0.33	-	-	-	-	-	-

I_1, Continuous ponding (CP) or farmers practice (5±2 cm); I_2, intermittent ponding {2 day after disappearance (DAD) 5±0 cm} from 15-35 DAT followed by CP; I_3, saturation from 15-35 DAT followed by CP; OS0, control (without nitrogen); OS1, *Lathyrus* green manuring 10 t ha^{-1} (fresh weight basis); OS2, vermicompost 5t ha^{-1}; OS3, poultry manure 5 t ha^{-1}; OS4, chopped rice straw 5 t ha^{-1} (rainy season rice straw) + *Lathyrus* green manuring 5t ha^{-1}; OS5, *Lathyrus* green manuring 5t ha^{-1} + vermicompost 2.5 t ha^{-1} + poultry manure 2.5 t ha^{-1}; OS_6, inorganic fertilizers (120:60:60).

application of fertilizer nitrogen. Interactive management of lathyrus green manuring (10 t ha^{-1}) with saturated paddy field might be the best method of paddy cultivation for getting maximumprofit.

Nutrient uptake and nitrogen use efficiency indices

Total nitrogen uptake (88.09-118.39 kg/ha) was significantly higher in integrated nutrient management treatments over the control (28.54 to 28.84 kg/ha) (Table 3). Among the nutrient management treatments, lathyrus green manuring 10 t ha^{-1} recorded highest nitrogen uptake (115.59 to 118.39 kg ha^{-1}). The green manuring crop either alone or in combination of straw, vermicompost and poultry manure recorded significantly higher nitrogen uptake than inorganic (92.21 to 94.61 kg ha^{-1}) except single application of poultry manure (88.09

Table 3. Effect of organic source of nutrients on nutrients uptake (kg/ha) and partial factor productivity in dry season rice.

Treatments	Nitrogen (kg ha^{-1})		Phosphorus (kg ha^{-1})		Potash (kg ha^{-1})		Partial factor of productivity (kg grain per kg of nutrients added)			
							Nitrogen		Phosphorus/Potash	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
I_1	88.01	90.60	34.54	35.67	52.34	53.13	33.83	34.33	67.67	68.67
I_2	87.22	89.21	34.22	35.12	51.56	52.34	33.42	34.17	66.83	68.33
I_3	95.32	97.43	37.67	38.66	56.87	57.98	35.50	36.00	71.00	72.00
LSD (p=0.05)	2.34	2.65	1.12	1.43	2.11	2.34	1.12	1.02	2.04	2.43
OS_0	28.54	28.84	12.37	12.51	21.05	21.28	-	-	32.83	33.17
OS_1	115.59	118.39	38.82	39.78	69.17	70.80	39.17	39.83	78.33	79.67
OS_2	98.23	100.92	39.84	40.95	61.24	62.86	38.08	38.67	76.17	77.33
OS_3	88.09	90.34	33.88	34.78	53.99	55.34	34.33	34.92	68.67	69.83
OS_4	104.27	106.75	43.51	44.56	61.28	62.71	38.67	39.42	77.33	78.83
OS_5	106.88	109.74	49.24	50.57	62.09	63.69	38.83	39.58	77.67	79.17
OS_6	92.21	94.61	29.95	30.80	46.87	48.05	34.25	34.83	68.50	69.67
LSD (p=0.05)	4.29	4.36	3.44	3.54	1.98	2.04	1.23	1.21	2.11	2.55

I_1, Continuous ponding (CP) or farmers practice (5±2 cm); I_2, Intermittent ponding {2 day after disappearance (DAD) 5±0 cm} from 15-35 DAT followed by CP; I_3, Saturation from 15-35 DAT followed by CP; OS0, Control (without nitrogen); OS1, *Lathyrus* green manuring 10t ha^{-1} (fresh weight basis); OS2, Vermicompost 5 t ha^{-1}; OS3, Poultry manure 5 t ha^{-1}; OS4, Chopped rice straw 5t ha^{-1} (rainy season rice straw) + *Lathyrus* green manuring 5t ha^{-1}; OS5, *Lathyrus* green manuring 5 t ha^{-1} + Vermicompost 2.5 t ha^{-1} + Poultry manure 2.5 t ha^{-1}; OS_6, Inorganic fertilizers (120:60:60).

to 90.34 kg ha^{-1}). Higher nitrogen uptake by supplementing nitrogen through green manures in low land rice was also reported by Budhur and Palaniappan (1996) and better than straw. Faster decomposition and nitrogen release from legume residues due to high nitrogen content and narrow C/N ratio increases its uptake. Thus, organic sources substantially improved the N uptake. Similar trends also found in case of potassium uptake. However, statistically highest phosphorus uptake was recorded in lathyrus green manuring 5 t ha^{-1} + vermicompost 2.5 t ha^{-1} + poultry manure 2.5 t ha^{-1} (49.24-50.57 kg ha^{-1}) followed by chopped rice straw 5 t ha^{-1} + lathyrus green manuring 5 t ha^{-1} (43.51 to 44.56 kg ha^{-1}), vermicompost 5 t ha^{-1} (39.84-40.95 kg ha^{-1}) lathyrus green manuring 5t ha^{-1} (38.82-39.97 kg ha^{-1}) and poultry manure 5 t ha^{-1} (33.88 to 34.74 kg ha^{-1}), respectively. Irrespective of nutrient management, I_3 was recorded statistically highest NPK uptake (92.32-97.43 kg N, 37.67-38.66 kg P and 56.87-57.98 kg K ha^{-1}) than I_1 and I_2. Saturation of top soil might be facilities the mineralization process as well reduce leaching losses and fixation in the soil solution.

The partial factor productivity (PFP) of nutrients explained the yield produced for each kg of nutrients applied, it included both indigenous (soil) and fertilizer presented in Table 3. Statistically highest PEP of nitrogen was recorded in I_3 (71.00-72.00 kg grains kg^{-1} of N) due to the higher grain yield obtained from that treatments in comparison to I_1 and I_2. Similarly phosphorus and potassium PFP was highest in saturation of top soil. In integrated nutrient management, highest nitrogen (N) PFP was recorded in lathyrus green manuring 10t ha^{-1} (39.17 to 39.83 kg grains kg^{-1} of N) followed by lathyrus green manuring 5 t ha^{-1} + vermicompost 2.5 t ha^{-1} + poultry manure 2.5 t ha^{-1} (38.83-39.58 kg grains kg^{-1} of N), chopped rice straw 5 t ha^{-1} + lathyrus green manuring 5 t ha^{-1} (38.67-39.42 kg grains kg^{-1} of N) and vermicompost 5 t ha^{-1} (38.08-38.67 kg grains kg^{-1} of N), respectively in comparison to inorganic (34.25-34.83 kg grains kg^{-1} of N). P or K partial factor productivity was highest in organics (68.67-79.67 kg grains kg^{-1} of P or K) compared to inorganic alone (68.50-69.67 kg grains kg^{-1} of P or K). The agronomic efficiency indicated the additional grain yield produced for each kg of N applied over control. Significantly higher agronomic efficiency was recorded in all organics treatments (17.92 to 23.25 kg grain yield increased kg^{-1} of N) over inorganic fertilizer alone (17.83 to 18.25 kg grain yield increased kg^{-1} of N) presented in Table 4. Therefore, partial N supplementation through organics might be achieved optimum recommended agronomic efficiency value (20 to 25 kg grain yield increased per kg of N applied) (Dobermann and Fairhurst, 2000). Physiological efficiency of N explained the additional yield for each additional kg of N uptake over control, which was significantly higher in all organics (34.11 to 36.77 kg grain kg^{-1} of N taken) over chemical fertilizer alone (33.30 to 33.61 kg grain kg^{-1} of N taken) except lathyrus green manuring 10 t ha^{-1} because of highly availability of N could take up easily but, showed unsatisfactory grain yield due to the low yield potential of this varieties. Apparent nitrogen recovery or recovery efficiency

Table 4. Effect of organic source of nutrients nitrogen use efficiency indices in dry season rice.

Treatments	Agronomic efficiency or nitrogen use efficiency (kg grain yield increase per kg N applied)		Physiological efficiency or production efficiency (kg grain yield increase per kg N absorbed)		Apparent nitrogen recovery or recovery efficiency (%) (Increase in N uptake per unit n added or applied)		Internal efficiency (kg grain per kg N absorbed)	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
I_1	20.96	20.39	33.97	33.87	59.18	61.04	43.24	43.05
I_2	20.71	19.99	33.34	33.24	58.31	60.12	42.97	42.85
I_3	21.76	21.56	36.67	36.56	63.54	65.67	46.67	46.32
LSD (p=0.05)	0.56	0.69	1.15	1.17	2.65	2.54	1.65	1.46
OS_0	-	-	-	-	-	-	-	-
OS_1	22.75	23.25	31.36	31.16	72.54	74.62	40.66	40.38
OS_2	21.67	22.08	37.31	36.77	58.07	60.06	46.52	45.98
OS_3	17.92	18.33	36.10	35.77	49.63	51.25	46.77	46.38
OS_4	22.25	22.83	35.26	35.17	63.11	64.92	44.50	44.31
OS_5	22.42	23.00	34.34	34.11	65.28	67.42	43.60	43.28
OS_6	17.83	18.25	33.61	33.30	53.05	54.81	44.57	44.18
LSD (p=0.05)	1.24	1.28	1.11	1.12	2.21	2.23	1.15	1.21

I_1, Continuous ponding (CP) or farmers practice (5±2 cm); I_2, Intermittent ponding {2 day after disappearance (DAD) 5±0 cm} from 15-35 DAT followed by CP; I_3, Saturation from 15-35 DAT followed by CP; OS0, Control (without nitrogen); OS1, *Lathyrus* green manuring 10 t ha^{-1} (fresh weight basis); OS2, Vermicompost 5 t ha^{-1}; OS3, Poultry manure 5t ha^{-1}; OS4, Chopped rice straw 5t ha^{-1} (rainy season rice straw) + *Lathyrus* green manuring 5t ha^{-1}; OS5, *Lathyrus* green manuring 5 t ha^{-1} + Vermicompost 2.5 t ha^{-1} + Poultry manure 2.5t ha^{-1}; OS_6, Inorganic fertilizers (120:60:60).

explained that how much N applied was recovered and taken up by the crop was significantly highest in lathyrus green manuring 10 t ha^{-1} (72.54-74.62%) and combination treatments ranged from 63.11 to 67.42% compared to inorganics alone (53.05-54.81%). Moris et al. (1986) also found higher N recovery when applied green manure with top dressing of chemical N. The internal efficiency of N explained yield produced per kg of N taken up from both fertilizer and native (Soil) nutrients sources. The treatments poultry manure and vermicompost recorded significantly highest internal efficiency (45.98 to 46.77 kg grain per kg N taken) over inorganic alone (44.18 to 44.57 kg grain per kg N taken). However, all the treatments that contain lathyrus could shows lower value of internal efficiency (40.38 to 44.50 kg grain /kg N taken) even inorganic due to the higher N uptake and medium genetically yield potential of the variety.

The irrigation water requirement was recorded to the extent of 1560 to 1580, 1475 to 1490 and 1485 to 1500 mm under continuous, intermittent and saturation of top soil, respectively. The highest water expanses efficiency was found in saturation (0-40 cm) (26.68 and 27.22 kg ha^{-1}mm^{-1}) which was followed by intermittent ponding (25.27 and 26.00 kg ha^{-1}mm^{-1}) (Table 5). However, highest water saving was recorded in intermittent ponding (5.45 to 5.70%) followed by saturation of top soil (4.81 to 5.06%) compared to continuous ponding.

Economics

The effect of water regimes and organic nutrients on economics of the crop was recorded in Table 2. Among the water regimes, saturation of top soil (0 to 40 cm) recorded highest net return (Rs 19613/- and 20281) and benefit: cost ration (1.76 and 1.78) followed by continuous ponding (CP) or farmers practice (Rs. 17178/- and 18491/- and1.68 and 1.72) and intermittent ponding (2 DAD 5±0) from 15 to 35 DAT followed by CP (Rs 16175/- and 16655/- and 1.60 and 1.61). Among the nutrient management, highest net return and benefit: cost ration were recorded in lathyrus green manuring 10 t ha^{-1} (Rs 24592/- and 25484/- and 1.98 and 2.02) followed by inorganic fertilizer

Table 5. Effect of water regimes on water use efficiency (kg ha^{-1}mm^{-1}) and water saving (%) of dry season rice.

Treatments	Irrigation water (mm)		Rainfall (mm)		Water saving (%)		Water expanses efficiency (kg ha^{-1}mm^{-1})	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Continuous ponding (CP) or farmers practice (5±2)	1560	1580	112	87	-	-	24.28	24.72
Intermediate ponding (2 DAD 5±0) from 15-35 DAT followed by CP	1475	1490	112	87	5.45	5.70	25.27	26.00
Saturation from 15-35 DAT followed by CP	1485	1500	112	87	4.81	5.06	26.68	27.22

(Rs 22635/- and 23533/- and 1.88 and 1.92). Hence, it also interest to note that combined application of organic fertilizer recorded higher net return and benefit: cost ration in comparison to single application. This might be due to higher economic yield.

Conclusion

From the present study it can be concluded that:

(1) Imposition of saturation in place of continuous ponding (CP) during a single crop stage can save (4-5%) of irrigation water with highest grain yield and nitrogen use efficiency.
(2) Supplementation of organic nutrient in the place of inorganic fertilizer could increase the grain yield, nitrogen use efficacy and physiochemical properties of the soil.
(3) *In-situ* green manuring in combination of inorganic was more beneficial in terms of economics than crop residue due slow release of plant nutrients from its.

However, the present study envisage the need for further in-depth on water regimes as well as different possible sources organics for sustainability.

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