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EFFECT OF WATER AND NITROGEN MANAGEMENT PRACTICES ON PRODUCTIVITY AND ECONOMICS OF RICE (*ORYZA SATIVA*) IN INDO-GANGETIC PLAINS

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Abstract

Rice (*Oryza sativa*) is the most significant cereal food of the Indian and global human population. India has the maximum area under rice cultivation and in rice production, India is second only to China. Water and fertilizer management affects rice production significantly. In this study, the impact of water management and different sources of nitrogen on rice production and profitability is evaluated. A field experiment was performed with six treatments with two irrigation practices (CF-continuous flooding and intermittent flooding) and three N treatments (No-N, N application with Urea (Urea-N) and N application with neem oil coated urea (NOCU-N)). The highest grain yield was observed in NOCU-N treatment (4361 kg ha^{-1}) followed by urea-N treatment (4071 kg ha^{-1}). Irrigation did not have significant effect on grain yield ($p \geq 0.05$). The benefit to cost ratio was highest in NOCU-N treatment (2.28) and intermittent flood irrigation (2.35) indicating that the application of neem oil coated urea under intermittent irrigation can play a significant role in achieving the goal of sustainable rice production in a changing environment.

Key words: Indo-Gangetic plains, rice, neem oil coated urea, continuous flooding, intermittent irrigation, cost of cultivation, net returns.

Introduction

Rice (*Oryza sativa* L.) is mainly cultivated in Asian countries under different management practices (Jain *et al*., 2016, Gupta *et al*., 2016). Modern rice cultivars require adequate amount of nitrogen (N) fertilizer and water for economical production. The global production of paddy was approximately 769 million tons in 2017 (FAO, 2019) and it is consumed by more than half of the world population (Pramanik and Kim, 2017). Globally, 61% of paddy is produced by three countries namely China, India and Indonesia (FAO, 2019). A rise in demand for rice is felt at present in accordance with the increase in human population (Ranjan and Yadav, 2019). Increasing the paddy production while decreasing the cost of cultivation is the current challenge for researchers. Water and nitrogen (N) fertilizer management can play a significant role in the production of rice. Standing water or continuous flooding after root establishment in rice is considered to be a favorable environment. Rice can be cultivated in aerobic environment also, but weed management is a big challenge in such conditions. Water management practices such as mid-season drainage, system of rice intensification, intermittent irrigation, alternate wetting and drying are the advanced management practices for water conservation which affect the rice production (Jain *et al*., 2014, Wu *et al*., 2015, Thakur *et al*., 2014, Kassam *et al*., 2011). The type of N application also affects the production in rice. Studies on the impact of water and nitrogen management on growth and yield of rice are very scarce. The aim of this field experiment was to evaluate the impact of water (continuously flooded (CF) and intermittent flooding(IF)) and two different type of N fertilizers (urea and neem oil coated urea) on paddy production and profitability in the Indo-Gangetic plains of India.

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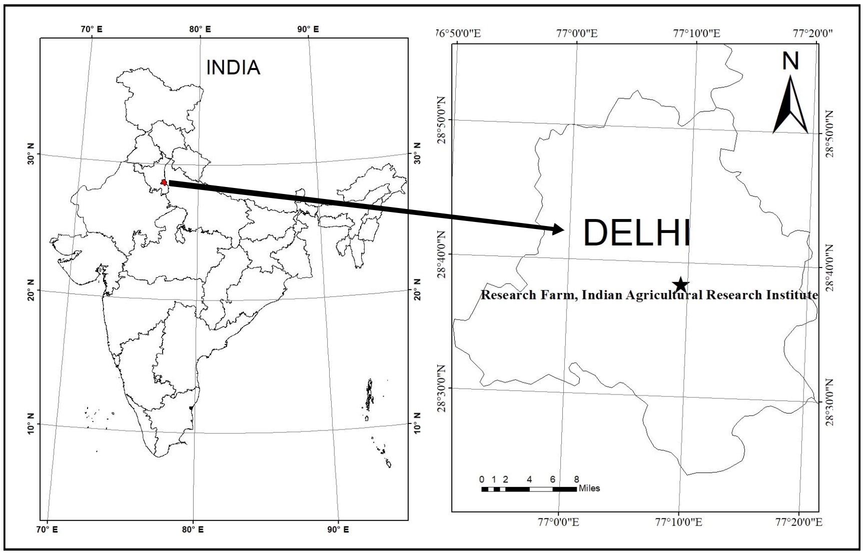

Fig. 1: Map of the study site.

Material and Methods

Experimental Site

A field experiment was carried out at the research farm of the Centre for Environment Science and Climate Resilient Agriculture (CESCRA), IARI in *Kharif* (rainy season), 2016. The research farm falls under the Indo-Gangetic plains of Northern India situated at 28^{O} 40′ N latitude and 77^{0} 12′E longitude (Fig. 1). This experimental site comes under subtropical region and has semi-arid climate with hot summers and dry, cold winters. Annual rainfall is around 750 mm and 80% rainfall is received from June to September. Weather information of the field experimentation site the cropping years has been represented in fig. 2. The average minimum and maximum temperature during the cropping year was 16.29°C and 30.80°C respectively (Fig. 2). The average rainfall per day during the cropping season was 3.68 mm (Fig. 2).

Soil collection and analysis

Soil was collected from plough layer of the experimental site (0-15 cm depth from top surface) just before the beginning of the experiment and after harvesting of the crop. The soil samples taken from the study site were used to estimate the various physico-chemical properties of soil as per the standard methods. The physicochemical properties of soil are presented in table 1.

Experimental design, treatment details and crop management

The experiment was conducted with 6 treatments (2 water regimes and 3 nitrogen treatments) with three replication each in randomized block design (RBD) with plot size of 3m × 2.5m. The rice variety PB 1121 was transplanted on 10 July, 2016. In all treatments, the full recommended dose of P (60 kg P_2O_5) and K (60 kg K_2O) fertilizers were applied before transplanting using SSP and MOP respectively. Nitrogen fertilizer was applied at the rate of 120 kg ha^{-1} in three splits (50% 3 days after transplanting (DAT), 25% at active tillering stage of rice and 25% at panicle initiation stage. Irrigation (±5 cm) was applied on alternate day in CF treatment and every 3-4 days in IF treatment. Manual management of weed was done as and when required during the cropping period. Weedicides and insecticides were not applied to avoid any additional impact on the production.

Measurement of growth and yield parameters

Growth parameters of rice like plant height, number of tillers and number of panicles per m^2 were recorded. Yield parameters like test weight, grain yield and harvest index were recorded at the time of harvest. Crop yields were determined from the total plot area. The grains were separated from the straw, dried and weighed. Grain and

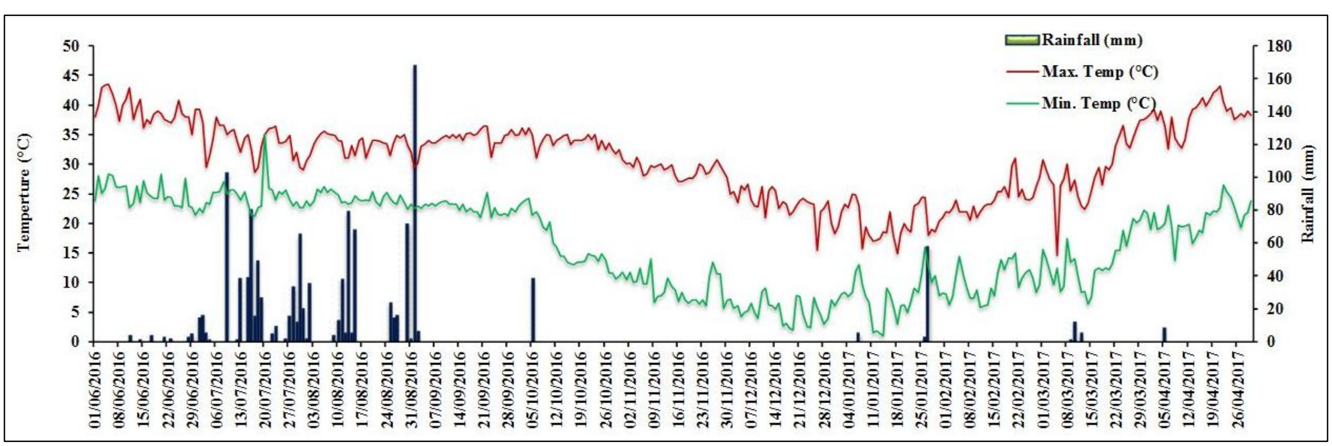

Fig. 2: Weather conditions at study site during cropping period, (Source: Weather observatory, Division of Agricultural Physics, IARI)

Table 1: Initial physicochemical properties of the soil of the experimental site.

S. No	Soil parameter	Value
1	Sand (%)	47
2	Slit (%)	31
3	Clay (%)	22
4	pH (1:2 :: soil: water)	8.1
5	EC (ds/m)	0.51
6	Organic C (%)	0.53
7	CEC (c mol kg^{-1})	7.3
8	Olsen P (kg ha^{-1})	19.93
9	NH_4^+-N (kg ha^{-1})	13.10
10	NO_3^--N (kg ha^{-1})	14.37
11	Ammo. acetate ex. K (kg ha^{-1})	349

straw moisture was determined immediately after weighing and subsamples were dried in the oven at 65°C for 48 hrs. and final dry weight was recorded. Harvest index was calculated as given below:

Harvest Index(%) = (Grain yield / Straw yield + Grain yield) × 100

Economic analysis of the treatments

After completion of the field experiment on rice, the economic analysis of the treatments were done to identify factors responsible for differences in economic benefit. The operational cost of cultivation was calculated by taking into account the cost of inputs (seed, fertilizers, biocide, diesel and electricity) and the hiring charges of services for various farm operations like land preparation, irrigation, fertilizer application and harvesting. The cost of cultivation was calculated using following formula:

Total cost of cultivation (Rs ha^{-1}) =Input cost (Seed cost + Fertilizer cost + Biocide cost + Energy cost (diesel and electricity)) + Cost of hiring services (human and machine)) + miscellaneous cost (@ 10% of total cost)

The cost of all parameters are in Rs ha^{-1}

Table 2: Details of the treatments used in the study.

S. No.	Treatment	Nitrogen	Water regime
1	Control	0 kg N ha^{-1}	Continuous flooding (CF)
2	Urea-N	120 kg N ha^{-1} (Urea)	Continuous flooding (CF)
3	NOCU-N	120 kg N ha^{-1} (Neem Oil Coated Urea)	Continuous flooding (CF)
4	Control	0 kg N ha^{-1}	Intermittent flooding (IF)
5	Urea-N	120 kg N ha^{-1} (Urea)	Intermittent flooding (IF)
6	NOCU-N	120 kg N ha^{-1} (Neem Oil Coated Urea)	Intermittent flooding (IF)

Table 3: Effect of irrigation and nitrogen management on growth and yield attributes of rice

Management	Plant height (cm)	Tiller /Hill	Hills (m^2)	No. of panicles (m^{-2})	Test weight (g)
Irrigation					
CF	112.6	13	17.78	241.1	27.0
IF	113.2	11	17.22	220.3	27.0
SEM (±)	1.7	0.5	0.77	3.2	0.3
CD(p=0.05)	NS	1.47	NS	9.8	NS
Nitrogen					
No N	100.0	9.2	14.8	206.3	26.7
Urea N	119.0	12.3	18.5	235.3	27.1
NOCU-N	119.7	15.0	19.2	250.5	27.2
SEM (±)	2.1	0.6	0.9	3.9	0.3
CD(p=0.05)	6.53	1.8	NS	11.8	NS
Irrigation × nitrogen	NS	NS	NS	NS	NS

Cost of energy (Rs ha^{-1}) = ((Diesel consumed by tractor (l ha^{-1}) × total duration of tractor operation (hrs. ha^{-1}) × price of diesel (Rs l^{-1})) + (Electricity consumed by electric pump for irrigation (kWh hr^{-1}) × total duration of pump operation (hrs ha^{-1}) × electric charge (Rs (kWh)$^{-1}$))

The current market price of all the inputs and hired services during respective season of cultivation were taken into account and derived from market survey. Gross income was the Minimum Support Price offered by the Government of India for rice in the respective year plus income from selling of residue obtained from market survey. The gross income was determined by the following formula:

Gross income (Rs ha^{-1}) = (Total grain yield (kg ha^{-1}) × Minimum support price of grain (Rs kg^{-1})) + (Total

Table 4: Effect of irrigation and nitrogen management on the yield and harvest index of rice.

Management	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kgha^{-1})	Harvest Index (%)
Irrigation				
CF	3686	5414	9089	40.12
IF	3499	5601	9233	39.21
SEM (±)	7.90	17.10	25.62	0.10
CD(p=0.05)	24.45	52.74	78.94	0.30
Nitrogen				
No N	2511.8	4121.0	6650	38.0
Urea N	3987.5	6223.2	10294	39.6
NOCU-N	4277.5	6178.2	10539	41.4
SEM (±)	9.70	21.00	31.38	0.12
CD(p=0.05)	29.94	64.59	96.69	0.37
Irrigation × nitrogen				
SEM (±)	16.80	36.30	54.35	0.21
CD (p=0.05)	51.86	111.87	167.46	0.64

Table 5: Effect of different management practices on net returns and cost benefit ratio.

Management	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C
Irrigation				
CF	45035	77315	32279	1.72
IF	32060	75234	43174	2.35
Nitrogen				
No N	37418	54415	16998	1.45
Urea N	38983	85105	46123	2.18
NOCU-N	39244	89302	50059	2.28

straw yield (kg ha^{-1}) × market price of straw (Rs ha^{-1}))

Net income of the farmers was calculated as the difference between gross income and total cost. Finally benefit to cost ratio was determined by the following formula:

Benefit to cost ratio (B:C) = (Gross income (Rs))/(Total cost (Rs))

Statistical analysis

Data were analyzed by applying the technique of 'analysis of variance (ANOVA)' for Randomized Block Design using SPSS (version 17.0) software. ANOVA with Duncan's Multiple Range Test (DMRT) at 5% level of significance was carried out to test whether the differences between means were statistically significant or not.

Result and Discussion

Growth parameters and yield attributes

Plant growth parameters such as plant height, tiller number and number of panicles may be affected by nitrogen application as well as irrigation in rice crops. Result showed that the there was no significant effect of irrigation plant height but N treatment had significant effect on plant height (Table 3). The plant height was lowest in no N treatment followed by Urea-N and NOCU-N. However there was no significant difference in Urea-N and NOCU-N treatments. Verma *et al*., (2018) have also reported effect of nutrient management on plant height. No significant difference was observed in number of hills per meter square in different irrigation and nitrogen treatments. The number of tiller per hill ranged from 9 to 15 (Table 3) among different irrigation and water treatments. In different N treatments application of N with urea and NOCU had 35.5 % and 47.3% more tillers respectively compared to No-N treatment. NOCU-N treatment had 21.6% more tillers compared to Urea-N treatment. Number of panicles per square meter were reduced by 8.6% in intermittent irrigation compared to continuously flooded treatment. In different N treatment number of panicles per square meter ranged between 206 (No-N) and 250 (NOCU-N). NOCU-N treatment had 6.4% higher number of panicle per square meter in comparison with urea-N treatment. There is no significant impact of water and nitrogen application on test weight of the grains. The test weight varied from 26.7 to 27.2 g (Table 3). The interactive effect of nitrogen and irrigation was non-significant in all the growth parameters and yield attributes.

Grain and straw yield and harvest index

The yield parameters and harvest index are given in table 4. Grain yield varied from 2529 to 4361 kg ha^{-1} among the N treatments and 3632 to 3675 kg ha^{-1} in different irrigation practices (Table 4). The highest grain yield (4361 kg ha^{-1}) was recorded in NOCU-N, followed by urea -N (4071 kg ha^{-1}). There was a yield advantage of 7.1% in NOCU-N over Urea -N treatment. The effect of irrigation was not significant on grain yield. Similar results are also reported by Pirmoradian *et al.,* (2004), Juan Li (2012) and Ashouri (2014). The nitrogen-management practices and irrigation practices significantly influenced straw and biological yields. Straw yield and biological yield ranged between 4121 kg ha^{-1} and 6223 kg ha^{-1} and 6650 kg ha^{-1} and 10539 kg ha^{-1} respectively. The harvest index was 2.3% higher in CF treatment due to more biomass yield. Within different N treatments harvest index was maximum in NOCU-N treatment (41.4%) followed by urea-N (39.6%) and No N treatment (38%). The NOCU-N treatment had 4.5% higher HI compared with Urea-N treatment. The interactive effect of nitrogen and irrigation was found to be highly significant ($p \geq 0.05$) for all the yield parameters.

Economics

The variations among the cost of cultivation, net returns and benefit cost ratio of PB1121 grown under different irrigation and nitrogen treatments is given in table 5. The total cost of cultivation among different management practices ranged from 32060 to 45035 Rs ha^{-1}. The net returns varied between 32279 and 43174 Rs ha^{-1} and the benefit to cost ratio was between 1.45 and 2.35 (Table 5). The benefit to cost ratio was significantly affected by nitrogen fertilizer as well irrigation practices. The cost of cultivation was reduced by 29% in intermittent irrigation treatment compared to continuous flooding treatments. This differences is due to the less number of irrigations in treatment IF as compared to CF. A benefit of Rs 10894 ha^{-1} was achieved with intermittent irrigation practices in net returns. The cost to benefit ratio was increased by 36.71% with intermittent irrigation in comparison with continuously flooded irrigation practice in rice (Table 5).

The total cost of cultivation and net returns in different N treatments ranged between Rs 37418 ha^{-1} and Rs 39244 ha^{-1} and Rs 16998 ha^{-1} and Rs 50059 ha^{-1} respectively. Highest gross returns, net returns and B: C ratio was obtained from NOCU-N treatment followed by Urea-N treatment and control treatment. NOCU-N treatment gave 8.5% higher net returns compared to Urea-N treatment because of higher grain yield.

Conclusions

The study revealed that intermittent irrigation practice instead of continuous flooding is an effective water management practice for growing rice in Indo-Gangetic plains. The recommended dose of neem oil coated urea is profitable as compared to urea fertilizer. Neem oil coated urea within intermittent irrigation showed the highest benefit to cost ratio which indicated that this management practices can play a significant role in achieving the goal of sustainable rice production in a changing environment.

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