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Influence of Nitrogen Levels and Weed Management Practices on Soil Quality of Wetland Rice

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Rice (*Oryza sativa* L.) is one of the most popular cereal crops serves as the staple food for world's half of the population**.** Nutrients and weeds are two important factors that determine the productivity of wetland rice. Nitrogen (N) is major nutrient that contributes in rice production. Weeds are the major constraint limiting high productivity of rice. Weeds may remove considerable quantity of nutrients besides competing for light; space and moisture thus become a major constraint in wetland rice. Considering these, a field experiment was conducted for two successive *kharif* seasons of 2018 and 2019 at Agricultural Research Farm, B.H.U., Varanasi, UP (India). The study included influence of nitrogen levels and weeds management practices (WMP) post harvest soil quality of wetland rice. The experiment was laid out in split plot design involving five nitrogen levels *viz*. control, 60 kg N ha^{-1} through inorganic, 60 kg N ha^{-1} as farmyard manure (FYM), 90 kg N ha^{-1} & 120 kg N ha^{-1} in main plots and four weed management practices *viz*. *Azolla* 2 t ha^{-1}, BGA 1.25 kg ha^{-1}, two hand weeding (2HW) at 20 & 40 days after transplanting (DAT) along with weedy in sub plots and replicated thrice. The results showed that the FYM treated plots exhibited maximum residual NPK and organic carbon with comparatively less pH in post harvest soil of wetland rice. Post harvest soil studies indicated that among weed management practices *Azolla* facilitated higher residual NPK and organic carbon and least pH in wetland rice field.

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1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most popular cereal crops in the world since it serves as the staple food for world's half of the population. About 90 % of world's area under rice is in Asia and also about 90 % of world rice is produced and consumed in Asia. Rice is a prime food crop for more than 65% of the people and provides livelihood security to 70% of Indian population [1]. In India the area under rice cultivation is around 43.77 million hectares (M ha) with 112.87 million tonnes of production and 2.57 tons ha^{-1} productivity. Uttar Pradesh is the major rice producer having an area, production and productivity of 5.81 million ha, 13.27 million tons and 2.28 t ha^{-1}, respectively [2].

Among the growth factors, nitrogen (N) fertilization and weed management assume prime importance for higher rice production. Nitrogen becomes an integral part of chlorophyll consequently; it plays a vital role in improving the growth, yields and quality of rice. Besides these, N helps in improving photosynthetic capacity, grain filling and promoting carbohydrate accumulation in culms and leaf sheaths [3]. The great response of N to growth and yield of rice is considered as a yield-limiting nutrient in rice production [4]. An increase in nitrogen supply significantly increases the plant height, number of tillers $hill^{-1}$, dry matter, straw yield and NPK uptake by crop [5]. Wetland rice removes substantial amount of major as well as minor nutrients from the soil. Inadequate N in soils show reduced leaf area limiting light interception thereby causing reduced photosynthesis which finally has an effect on biomass growth and yields of crop [6]. Excessive nitrogen fertilization is a serious problem in rice producing areas in India, contributing to soil degradation, groundwater pollution and the emission of ammonia and greenhouse gases. The unnecessary use of nitrogenous fertilizer may cause adverse effects on rice production *viz.,* lodging, delayed maturity, susceptibility to insect-pests and ultimately reduces yield [7]. Excessive nitrogen fertilization is a serious problem in rice producing areas in India, contributing to soil degradation, groundwater pollution and the emission of ammonia and greenhouse gases. Additionally, improper use of N fertilizer is becoming expensive and leading the cost of production. Therefore, understanding of suitable nitrogen rates is not only essential for optimizing rice production and quality but also important for protecting the environment. The balanced fertilization to soil also affects the soil quality *viz.* organic matter content, pH and concentration of mineral nutrients and their availability in soil solution [8,9]. Organic manures/FYM plays a vital role in maintenance of physical and biological condition of soil. It is not only the source of major and micronutrients, but also increases the efficiency of applied nutrients in soil.

Weeds are undesirable plants interfering with natural resources and limiting the yields of rice [10]. Weeds are complex in nature and have negative effects on profitable rice crop production. Yield losses due to weeds vary according to crops, weed species and farming practices however, in wetland rice it may reduces about 20-50 % in yield. Weeds removed about 21-42 kg N, 10-13.5 kg P and 17-27 kg K ha^{-1} in transplanted rice [11]. Hence, weed control is a major component for fully driven of applied fertilizers in crop production.

The floating water fern *Azolla* have a potent source of organic fertilizer in rice production. Similarly, the fertilizing value of blue-green algae (BGA) in rice fields is well-known and has been utilized over India. The N-fixing BGA are the most important bio-fertilizers in improving the productivity of rice fields and maintaining the soil health. Growth of rice viz. plant height, number of tillers $hill^{–1}$, dry matter production $hill^{–1}$ were significantly affected by use of bio-fertilizers [12]. Application of bio-fertilizers improves in growth parameters due to improve the availability of nitrogen and growth promoting substances which ultimately augmented the plant growth [13]. The mat of *Azolla* could significantly reduce weed flora [14] however, this effect depends on thickness of mat and density of weed flora present in field. The smothering effect of BGA (algal blooms) on weeds is often advocated in literatures but information regarding the effect of BGA on weeds is lacking [15]. It has, therefore, become necessary to look for alternative renewable resource for N supply as well as weed management in wet land rice.

Due to complex weed flora and poor nutrient and weed management practices the rice cultivation is still vulnerable and risky in India. Thus the present study was undertaken to find out the suitable dose of N along with appropriate WMP for better post harvest soil quality of wetland rice.

2. MATERIALS AND METHODS

2.1 Description of the Experimental Site

A field investigation was carried out during rainy seasons of 2018 and 2019 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (25°32' N latitude and 82°97' E) in Northern Gangetic alluvial plains of Varanasi. The soil of the experimental site was sandy clay loam in texture, well drained, slightly alkaline in reaction (pH 7.40 and 7.35), low in available nitrogen (205.67 and 213.48 kg ha^{-1}) and organic carbon (0.475 and 0.491 %), medium in available phosphorus (15.63 and 17.10 ka ha^{-1}), potassium (181.60 and 197.11 kg ha^{-1}) and zinc (0.51 and 0.57 mg kg^{-1}) in respective years of 2018 and 2019. Total rainfall received during the both year of experimental crop growing period, 2018 and 2019 was 780.1 mm and 1368.3 mm, respectively. Prior to start of experiment, composite soil samples were drawn randomly (0-15 cm) from 10 places with the help of screw auger, dried them and passed through 2.0 mm sieve and subjected to chemical analyses.

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2.2 Experimental Description

Malaviya Basmati Dhan 10-9 (HUBR 10-9) is a semi dwarf aromatic variety of rice, was used in experiment. Seeds were broadcasted at the rate of 30 kg ha^{-1} over well prepared seed bed for raising the nursery during both years of experiment. The experiment was laid out in split plot design, where main plot consisted of five nitrogen levels (Control, 60 kg N ha^{-1} through inorganic, 60 kg N ha^{-1} through FYM, 90 kg N ha^{-1}, 120 kg N ha^{-1}) and four weed management practices (*Azolla* at the rate of 2 t ha^{-1}, BGA at the rate of 1.25 kg ha^{-1}, 2 HW at 2 hand weeding at 20 and 40 DAT and weedy check) in subplot replicated thrice during both study years.

2.3 Manure and Fertilizer Application

As per treatment, well decomposed FYM (11.76 tha^{-1} and 12.24 t ha^{-1}) was applied on the basis of their nitrogen (N) content (0.51 and 0.49 %) in 2018 and 2019, respectively. Nitrogen through inorganic was applied as per treatments (60, 90 and 120 kg ha^{-1}). The half dose (50 %) of inorganic N and full dose of FYM and recommended dose of phosphorus (60 kg ha^{-1}), potassium (60 kg ha^{-1}) and zinc (5 kg ha^{-1}) was applied as basal. The remaining half (50%) inorganic N was applied in to two splits *i.e.* basal 25 % at active tillering and 25 % panicle initiation stage.

2.4 Bio-inoculants (*Azolla* and BGA) Application

The species of *Azolla* used during experiment was *Azolla microphylla* collected from IARI, New Delhi. To obtain the required quantity of *A. microphylla* was multiplied in pits at Agricultural Research Farm, I. Ag. Sc., BHU, Varanasi (UP). As per treatment *Azolla* was applied at the rate of 2 t ha^{-1} at 7 days after transplanting (DAT) in standing water and incorporated at 30 DAT during both study years. The dried and powdered composite algal culture (*Calotherix, Anabaena & Aulosira*) was applied at the rate of 1.25 kg ha^{-1} in standing water at 7 DAT.

2.5 Soil Preparation and Transplanting

After harvesting of rabi crop the experimental area was deep ploughed with MB plough in summer. Again field was in first week of July and dry weeds and stubbles were removed from field. Thereafter, puddling was done by twice cross ploughing with cultivator once with rotavator and in about 10 cm standing water and finally layout the experiment was laid out as per experimental design. Two seedling $hill^{-1}$ transplanted at a distance of 20 × 15 cm during both study the years.

2.6 Data Collection

2.6.1 Soil sampling and processing

To know the soil fertility status of post harvest soil of experimental field, the five random soil samples were taken from a depth of 0-15 cm from ten places of with the help of screw auger after harvest of test crop in each year of field experimentation. The collected samples were thoroughly mixed to make a composite soil sample of 1000 g weight.

The soil samples were kept in polythene bag and labeled them as per treatment. The tagged samples were brought to the laboratory, shade dried, grounded and passed through 20 mm mesh sieve. Obtained soil samples were analyzed for chemical characteristics *viz.,* EC, pH, organic carbon and available soil NPK and the methods employed for each analysis have been given below (Table 1).

Table 1. The chemical analyses of post harvest soil of experimental field

Particulars	Method employed	Reference
Chemical properties		
Soil reaction pH (1:2.5 soil : water suspension)	Glass electrode digital pH meter	[16]
Electrical conductivity(d Sm^{-1}) at 25^0C	Systronics electrical conductivity meter	[16]
Organic carbon (%)	Walkley and Black's rapid titration method	[17]
Available nitrogen (kg ha^{-1})	Alkaline permanganate method	[18]
Available phosphorus (kg ha^{-1})	0.5 M $NaHCO_3$ extractable Olsen's method	[19]
Available potassium (kg ha^{-1})	Ammonium acetate extractable flame photometer method	[16]

2.6.2 Statistical analysis

Analysis of variance (ANOVA) was performed to the data collected by applying the procedure of split plot design (SPD) as described by Gomez and Gomez [20] to identify the treatment effects. The means between treatments were compared with the least significant difference (LSD) to test significant variations between treatments. The standard error of mean (SE±M) and least significant difference (LSD) were calculated if F-test was found to be significant at 5% level of significance.

3. RESULT AND DISCUSSION

Different nitrogen levels could not exert significant effect on electrical conductivity (EC) of soil after harvest of crop. Nevertheless, nitrogen levels had significant effect on soil pH, soil organic matter and available soil NPK after harvest of crop during both years (Tables 2 and 3). It is clear from data that application of 60 kg N ha^{-1} through FYM resulted least soil pH which was found to be at par with 120 kg N ha^{-1} in 2018 and 90 kg N ha^{-1} and 120 kg N ha^{-1} during 2019. The least soil pH in FYM treated plots might be due to organic acids produced during degradation of organic materials that resulted into lower soil pH. Mehandi et al. [21] also reported lowest soil pH with application FYM after harvest of rice. Similar observation was recorded by Sunita Gaind [22]. The use of 60 kg N ha^{-1} through FYM caused significantly higher soil organic carbon content over rest of the treatment during both experimental years. Remaining levels of nitrogen *viz.,* $N_{1,}$ N_2 N_3 & N_4 was remained on par with each other in respect to organic carbon content during both the years. Presence of organic carbon in FYM is mainly responsible for higher organic carbon content in post harvest soil of FYM treated plots. Similar findings were reported by pervious worker [23]. Significantly maximum residual nitrogen & phosphorus in soil was found with 60 kg N ha^{-1} through FYM however, found at par with 90 kg N ha^{-1} & 120 kg N ha^{-1} only in 2018. Higher available potassium in soil was also exert in 60 kg N ha^{-1} through FYM treated plot which was found significantly superior over 120 kg N ha^{-1} and 90 & 120 kg N ha^{-1} in 2018 and 2019, respectively. The higher residual NPK in post harvest soil with FYM application might be due to solubility action of organic acids produced during organic materials decomposition increases the release of native NPK in soil. Improvement in soil available phosphorus with FYM application could be credited to many factors, such as the addition of P through FYM and retardation of soil P fixation by organic anions formed during FYM decomposition [24]. Similar observations were found by pervious worker [23].

Various weed management practices could not achieved the level of significance in respect to effect on electrical conductivity (EC) of soil. Nevertheless, weed management practices effect significantly on soil pH, soil organic matter and available soil NPK after harvest of crop (Table 2 and Table 3). Among weed management practices application of *Azolla* at rate of 2 t ha^{-1} recorded least soil pH remained on par with use of BGA at rate of 1.25 kg ha^{-1} during both study years and significantly superior over rest of the treatments. The use of *Azolla* 2 tha^{-1} and BGA resulted inferior from initial value of pH. The addition of organic acids during the biomass decomposing is major factors to

Table 2. Effect of nitrogen levels and weed management practices on pH, Electrical Conductivity (EC) and organic carbon (%) post harvest soil

Treatments	pH		EC		Organic carbon (%)	
	2018	2019	2018	2019	2018	2019
Nitrogen levels						
N_1: Control	7.494	7.242	0.272	0.303	0.452	0.460
N_2: 60 kg ha^{-1} (inorganic)	7.466	7.236	0.273	0.296	0.456	0.466
N_3: 60 kg ha^{-1} (FYM)	7.190	7.000	0.264	0.284	0.550	0.601
N_4: 90 kg ha^{-1} (inorganic)	7.381	7.142	0.268	0.291	0.466	0.467
N_5:120 kg ha^{-1} (inorganic)	7.319	7.088	0.262	0.285	0.473	0.472
SEm±	0.053	0.051	0.006	0.007	0.015	0.010
LSD (p=0.05)	0.175	0.166	NS	NS	0.048	0.034
Weed management practices						
W_1: *Azolla* (2 t ha^{-1})	7.271	7.053	0.262	0.286	0.595	0.613
W_2: BGA (1.25 Kg ha^{-1})	7.352	7.123	0.269	0.293	0.482	0.495
W_3: 2 HW	7.451	7.215	0.271	0.295	0.429	0.438
W_4: Weedy	7.405	7.174	0.269	0.292	0.412	0.426
SEm±	0.036	0.034	0.003	0.006	0.013	0.012
LSD (p=0.05)	0.103	0.097	NS	NS	0.036	0.034
Initial values	7.400	7.350	0.279	0.286	0.475	0.491

Note: 2 HW = 2 Hand weeding at 20 and 40 DAT during both the years

Table 3. Effect of nitrogen levels and weed management practices on residual NPK status (kg ha^{-1}) of post harvest soil

Treatments	Available nitrogen (kg ha^{-1})		Available phosphorus (kg ha^{-1})		Available potassium (Kg ha^{-1})	
	2018	2019	2018	2019	2018	2019
Nitrogen levels						
N_1: Control	199.05	205.52	16.81	18.70	159.04	166.40
N_2: 60 kg ha^{-1} (inorganic)	208.77	214.30	16.57	17.89	157.05	162.57
N_3: 60 kg ha^{-1} (FYM)	215.10	224.52	17.52	20.14	162.03	173.05
N_4: 90 kg ha^{-1} (inorganic)	210.82	217.23	15.72	16.40	155.59	159.94
N_5: 120 kg ha^{-1} (inorganic)	212.92	220.75	15.06	16.26	143.74	147.55
SEm±	1.45	1.04	0.33	0.55	3.54	3.36
LSD (p=0.05)	4.73	3.40	1.07	1.80	11.55	10.97
Weed management practices						
W_1: *Azolla* (2 t ha^{-1})	214.44	221.57	17.22	18.81	166.01	172.33
W_2: BGA (1.25 Kg ha^{-1})	210.46	217.00	16.36	17.95	155.27	163.13
W_3: 2 HW	208.12	215.89	16.04	17.83	151.69	158.16
W_4: Weedy	204.30	211.39	15.73	16.91	149.00	153.99
SEm±	0.91	0.71	0.25	0.28	2.21	2.19
LSD (p=0.05)	2.64	1.27	0.73	0.79	6.39	6.34
Initial values	205.67	213.48	15.63	17.10	181.60	197.11

Note: 2 HW = (2 Hand weeding at 20 and 40 DAT during both the years)

reduction of soil pH in *Azolla* and BGA treated plots. Similar findings were also reported by Pabby et al. [25]. Use of *Azolla* 2 t ha^{-1} resulted maximum organic matter content which was found significantly superior over rest of the treatments during both study years. The highest organic matter content with *Azolla* treated plots might be due to direct addition in soil after decomposition of *Azolla* biomass. Kotpal et al. [26] reported similar findings. The use of *Azolla* at rate of 2 t ha^{-1} proved significantly superior in respect to available NPK in post harvested soil. Residual soil N with BGA at rate of 1.25 kg ha^{-1} & weed free treatment were found to be at par with each other and superior over weedy check during the years. In respect of residual phosphorus and potassium, use of BGA @ 1.25 kg ha^{-1} resulted significantly superior over weedy check only in 2019. Higher residual nutrients in terms of N, P and K were noted with *Azolla* treated plots that might be due to on dry weight basis, *Azolla* had 2.09 and 2.17 % nitrogen, 0.33-0.39 % phosphorous and 0.95-0.98 % potassium during 2018 and 2019, respectively which after decomposition is readily released in soil and increased soil urease & phosphatase activity [27] which might be factors for release and addition of more nutrients in soil. These findings were duly supported by Cheng et al*.* [28] and Oyange et al*.* [29].

4. CONCLUSION

The post harvest soil studies in wetland rice indicated that use of 60 kg N ha^{-1} through FYM exhibited maximum residual NPK and organic carbon. Similarly, among weed management practices use of *Azolla* at rate of 2 t ha^{-1} favored higher residual NPK and organic carbon during both experimental years.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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