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Influence of Nitrogen Levels and Weed Management Practices on Nutrient Content, Uptake and Grain Quality of Wetland Rice (*Oryza sativa* L.)

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ABSTRACT

Nutrients and weeds are two important factors that influence the productivity of the rice. Azolla and BGA have ability to replace N fertilizers by 25% of the total crop requirement through biological N fixation. The Azolla covert may significantly inhibit weed infestation without harming the rice yield. A 2-year field experiment was conducted to study the influence of nitrogen (N) levels and weed management practices (WMP) on nutrient content, uptake, and grain quality of wetland rice during Kharif 2018 and 2019. The experiment was laid out in a split plot design having five nitrogen levels viz. control, 60, 90 &120 kg N ha^{-1} through inorganic source and 60 kg N ha^{-1} as farmyard manure (FYM) in main plots and four weed management practices viz. Azolla (2 t ha^{-1}), blue-green algae (BGA), two-hand weeding (2HW), and weedy in sub plots replicated thrice. Results indicated that the use of more N (120 kg N ha^{-1}) recorded the highest N content in rice grain and straw while phosphorous (P) & potassium (K) content was noticed higher with the use of 60 kg N ha^{-1} as FYM. Higher nitrogen application (120 kg N ha^{-1}) improved NPK uptake by grain and straw. Dual cropping of Azolla @ 2 t ha^{-1} leads to maximum nutrient (N, P, K) content and uptake by rice grain and straw. Quality parameters viz. kernel length & breadth before and after cooking were significantly influenced by N levels and maximum values were noted with the use of 120 kg N ha^{-1}. The WMP fails to exhibit any significant effect on the quality parameters of rice viz. kernel length & breadth before and after cooking. Length: breadth ratio before and after cooking, elongation ratio, and expansion ratio were also noted unaffected by N levels and WMP during the study period.

Keywords: *Azolla, BGA, FYM, Nutrients, Quality, Weed*

1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most popular cereal crops in the world cultivated in diverse climatic conditions and holds a promising place in food grain production, and consumption and is a staple food for the world's half of the population [1]. Rice occupies about one-third of the world's total area of cereals which provides 35 to 60% of the calories consumed by 2.7 billion people. The kernels of rice contain about 6-12% protein, 70-80% carbohydrate, 1.2-2.0% mineral matter, and a significant amount of fat and vitamins. It supplies 23% of global human per capita energy and 16% of per capita protein requirement [2], [3], [4]. In India, the area under rice cultivation is around 43.78 m ha with 118.87 million tonnes of production during 2019-2020 [5]. Therefore, sustainable rice production is necessary to meet the increasing demands of global population.

Nutrients and weeds are two important factors that influence the productivity of the rice. Nitrogen is a most yield-limiting nutrient in rice production [6], [7] essential for the growth, yield, and quality of rice; plays a key role in grain filling, photosynthetic capacity, and promotes carbohydrate accumulation in culms and leaf sheaths [8]. Nitrogen is an integral part of protoplasm, protein and chlorophyll plays a remarkable role in increasing the yield and quality of rice.

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Excessive use of nitrogenous fertilizer may cause lodging, delayed maturity, susceptibility to insect-pests and ultimately reduce yield [9]. Therefore, understanding of nitrogen rates is essential for optimizing rice production and quality besides protecting the environment. Ten years of study suggested better prospects for biofertilizers and emphasized the need for core strategy for its technological adoption by farmers [10].

Weeds are an integral part of the agricultural systems and are the major constraint to achieving high yield of rice [11]. Weeds remove about 21-42 kg N, 10-13.5 kg P and 17-27 kg K ha^{-1} in transplanted rice however, these losses depends upon soil, condition of cropping and location [12]. There is no doubt that the maximum benefit from inputs like fertilizers in rice can be fully derived when the crop is kept free from weed.

The *Azolla* covert may significantly inhibit weed infestation without harming the rice yield [13]. The suppressive effect of *Azolla* on weeds depends on the thickness of the mat and the density of weed flora present in a field. Therefore, *Azolla* may be considered a biological control agent of paddy weeds. The suppressive effect of BGA (algal blooms) on weeds is often advocated in literature but information on the effect of BGA on weeds is lacking [14]. Both, BGA and *Azolla* multiply fast, decompose easily and have ability to replace N fertilizers by 25% of the total crop requirement [15] through biological N fixation. Besides, there are several benefits of biofertilizers which generates much interest to improve the efficiency of applied urea fertilizer. Thus, the present study was undertaken to find out the suitable dose of nitrogen along with appropriate weed management practices for improvement in nutrient content, their uptake, and grain quality of wetland rice.

2. MATERIALS AND METHODS

2.1 Description of the experimental site

The experiment was carried out at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P) during the *kharif* season for two consecutive years (2018 and 2019). Geographically the experimental area was located at 2532' N latitude and 8297' E longitudes in the Northern Gangetic alluvial plains of Varanasi. The experimental soil was well drained, homogeneous in soil fertility with even topography, assured irrigation facilities, and other required conveniences. Random soil samples were taken from a depth of 0-15 cm of soil depth to judge the mechanical composition, initial fertility status, and physicochemical properties of experimental soil with the help of a screw auger before starting experimentation each year. The collected soil samples were analyzed with prescribed methods. The results of analysis for soil parameters showed that the soil of the experimental site was sandy clay loam in texture, well-drained, slightly alkaline in reaction (pH 4.41 and 7.46), low in available nitrogen (240.55 and 252.70 kg ha^{-1}) and organic carbon (0.462 and 0.491 %), medium in available phosphorus (18.24 and 19.12 ka ha^{-1}), potassium (181.85 and 197.24 kg ha^{-1}) and zinc (0.51 and 0.57 mg kg^{-1}) in respective years of 2018 and 2019.

2.2 Planting materials

The cultivar used in the experiment was Malaviya Basmati Dhan 10-9 (HUBR 10-9) developed at Banaras Hindu University, Varanasi (U.P.). Variety HUBR 10-9 is semi-dwarf in height, aromatic, long fine grains, and medium duration. The average yield of the test cultivar ranged from 55-60 q ha^{-1}. The nursery was raised adopting the seed rate 30 kg ha^{-1} broadcasted uniformly over well-prepared seed beds during both seasons.

2.3 Experimental design and treatments details

The experiment was laid out in a split-plot design consisting of twenty treatments replicated thrice, where N levels were allocated in main plots and WMP in sub-plots. Treatments were randomly allocated to each main and subplots. Details of treatments with corresponding symbols used during experimentation are given in Table: 1.

Table 1: Treatment details

S. No.	Treatments		Symbols
A	**Main plot treatments (Nitrogen levels)**		
	i.	Control (0 kg N ha^{-1})	N_1
	ii.	60 kg N ha^{-1} (through inorganic)	N_2
	iii.	60 kg N ha^{-1} (through FYM)	N_3
	iv.	90 kg N ha^{-1} (through inorganic)	N_4
	v.	120 kg N ha^{-1} (through inorganic)	N_5
B	**Sub plot treatments (Weed management practices)**		
	i.	*Azolla* (2 t ha^{-1})	W_1
	ii.	BGA (1.25 kg ha^{-1})	W_2
	iii.	2HW (2 hand weeding at 20-25 and 40-45 DAT)	W_3
	iv.	Weedy	W_4

DAT= days after transplanting

2.4 Manure and fertilizer application

Well-decomposed FYM having 0.51-0.19-0.50 % and 0.49-0.18-0.48 % N-P-K content determined on dry weight basis used in 2018 and 2019, respectively. To supply 60 kg N ha^{-1} the quantity of FYM was calculated based on its N content and applied before transplanting during each season. Nitrogen through an inorganic source was applied as per treatments (60, 90, and 120 kg ha^{-1}). The full dose of FYM and the recommended dose of phosphorus (60 kg ha^{-1}), potassium (60 kg ha^{-1}), and zinc (5 kg ha^{-1}) were applied as basal. The nitrogen was applied in three splits *i.e.* half (50%) basal, 25 % at active tillering, and 25 % at the panicle initiation stage.The sources used for N, P, K, and zinc urea, single super phosphate, muriate of potash, and zinc sulfate monohydrate, respectively.

2.5 Bio-inoculants (*Azolla* and BGA) application

The fresh inoculums of *Azolla microphylla* were collected from IARI, New Delhi and to obtain the required quantity of *Azolla* it was multiplied in pits before the layout of an experiment. *Azolla* was applied @ 2 t ha^{-1} in respective treatments in standing water at seven DAT followed by incorporation at 30 DAT. The dried and powdered composite algal culture (*Calotherix, Anabaena & Aulosira*) collected from IARI, New Delhi was applied @ 1.25 kg ha^{-1} as per treatment in standing water seven DAT.

2.6 Soil preparation and transplanting

The experimental area was deeply and plowed with a moldboard plow in summer and left open to expose weed seeds, eggs, and larvae of harmful insects and diseases. The field was again plowed in the first week of July and dry weeds and stubbles were removed. Thereafter, puddling was done twice by cross with a cultivator and once with a rotovator in about 10 cm standing water and finally, the experiment was laid out to meet the experimental design.

2.7 Data collection

2.7.1 Plant sample analysis

At harvest, plant samples were collected for nutrient (NPK) content and their uptake by the crop. The collected samples were separated into grains and straw, dried under shade for 2-3 days, and thereafter transferred into a hot air oven at 60°C and dried till constant weight. The dried samples (grain and straw) were ground separately into fine powder in a Willey mill, passed through a 2 mm sieve, and stored in butter paper envelops. Nitrogen, phosphorus, and potassium content in rice plants (grain and straw) were analyzed separately by the Micro Kjeldahl method [16], Vanadomolybdo phosphoric acid yellow color method, and Flame photometer method [17], respectively.

Nutrient uptake by rice grain and straw was calculated in kg ha^{-1} by using the following formula.

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient content (\%)} \times \text{Dry matter/Yield (kg /ha)}}{100}$$

2.7.2 Grain Quality Analysis

After milling ten heads of rice grains were taken from each experimental unit to record the kernel length breadth before cooking with *graph paper.* Kernels were pre-soaked in a 100 ml test tube with 20 ml distilled water for 15 minutes and heated at 98^{0}C for 10 minutes (optimum cooking time). Cooked kernels were separated from water and transferred into Petri plates covered with filter paper and put on graph paper to record the kernel length and breadth after cooking. The recorded values of all kernels were averaged and expressed in millimeters (mm).

The length: breadth ratio (L: B ratio) before and after cooking of rice kernel were computed with the following equations.

$$\text{L: B ratio before cooking} = \frac{\text{Length of raw kernel (mm)}}{\text{Breadth of raw kernel (mm)}}$$

$$\text{L: B ratio after cooking} = \frac{\text{Length of cooked kernel (mm)}}{\text{Breadth of cooked kernel (mm)}}$$

To calculate the elongation ratio and expansion ratio of kernels following formula was used

$$\text{Elongation ratio} = \frac{\text{Length of cooked kernel (mm)}}{\text{Length of raw kernel (mm)}}$$

$$\text{Expansion ratio} = \frac{\text{Breadth of cooked kernel (mm)}}{\text{Breadth of raw kernel (mm)}}$$

2.7.3 Statistical Analysis

Statistical analysis (ANOVA) was performed on the data collected by applying the procedure of split-plot design (SPD) as described by Gomez and Gomez (1984) to assess the significance of the treatments [18]. The treatment means are compared based on the least significant difference (LSD). The standard error of the mean ($SEm_{\pm}$) and least significant difference (LSD) were calculated if the F-test was found to be significant at a 5% level of significance.

2.3 Result and Discussion

Nutrient (NPK) content varied significantly due to various N levels and weed management practices (Table 2). The highest N content in grain and straw measured with the highest level of nitrogen (120 kg N ha^{-1}) remained on par with 60 kg N ha^{-1} through inorganic and 90 kg N ha^{-1}. The highest N level resulted in greater N content in grain and straw which might be due to increasing N levels considerably enhancing its availability and uptake by crop. Malav and Ramani (2016) and Shivay *et al.* (2016) also noted the highest nitrogen content due to the use of enhanced N levels [19], [20]. Nevertheless, higher P and K content in grain and straw was found with the application of 60 kg N ha^{-1} through FYM being at par with 90 kg N ha^{-1} and 120 kg N ha^{-1} during both experimental years. The higher content of P & K in grain and straw was noted with 60 kg N ha^{-1} through FYM. The addition of 0.19 & 0.18 % P and 0.50 & 0.48 % K content by FYM in respective years (2018 & 2019) improved availability and uptake was mainly responsible for higher P and K accumulation in grain and straw of test crop. The results are in close agreement with the findings of [21]. Weed management practices significantly varied with respect to NPK content in grain and straw at harvest. The highest nutrient (NPK) content in grain and straw resulted in the application of *Azolla* @ 2 t ha^{-1} during both experimental years. Nevertheless, it was found at par with BGA @ 1.25 kg ha^{-1} with respect to P & K content only. The higher nutrients content with *Azolla* treated plots might be due to the fact that *Azolla* had 2.09 and 2.17 % N, 0.33-0.39 % P and 0.95-0.98 % K on a dry weight basis during 2018 and 2019, respectively which after decomposition readily released and improved availability of nutrients to plants. It was expected that the treatment with higher availability of these nutrients may exhibit higher content in grain and straw. Similar findings were reported by Setiawati *et al.* [22].

The maximum NPK uptake by both grain and straw achieved with the use of 120 kg N ha^{-1} remained on par with 90 kg N ha^{-1} with respect to potassium (K) removal only (Table 3). The nutrient (NPK) uptake by straw was also highest with a maximum dose (120 kg N ha^{-1}) of N however; it was comparable with 90 kg N ha^{-1} during both experimental years. The nutrient removal by the crop is the multiplicative function of total dry weight and respective nutrient content. Thus, variations in dry weight and their nutrient content caused differences among N levels for nutrient uptake. The findings of Mannan and Kumar confirm the above results [23], [24]. Among WMP, *Azolla* @ 2 t ha^{-1} exhibits maximum uptake of nutrients (NPK) by grains and straw. This might be due to the increased availability of nutrients associated with incorporated *Azolla* [25], [26]. Application of *Azolla* improves nutrient (NPK) uptake that was duly supported by earlier workers [27], [26].

The quality parameters like kernel length & breadth before and after cooking were significantly affected with N levels and maximum value was noted with 120 kg N ha^{-1} that was found to be at par with 90 kg N ha^{-1} (Table 4). The WMP fails to exhibit any significant effect on kernel length & breadth before and after cooking. Other quality parameters of rice *viz*. length: breadth ratio before and after cooking, elongation ratio, and expansion ratio did not vary by N levels and WMP in successive years (Table 4). Shravan and Singh also noted that N levels and bio-inoculants could not affect the quality parameters like length: breadth ratio before and after cooking, elongation ratio, and expansion ratio of rice [28].

2.4 Conclusion

It may be concluded from the above investigation that rice crops harvested maximum nutrients (NPK) by grains as well as straw with application of 120 kg N ha^{-1}. Similarly, amongst weed management practices use of *Azolla* @ 2 t ha^{-1} resulted in higher NPK content and uptake by wetland rice.

2.5 Future prospects

Nitrogen levels and weed management in wetland rice holds significant potential to improve not only the yield and quality of rice but also to enhance environmental sustainability and socio-economic benefits for farmers. Developing farmer-friendly guidelines and policies to encourage the adoption of optimized nitrogen use and integrated weed management practices, thereby improving farm productivity and profitability.

2.6 Acknowledgment

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2.7 Conflict of Interest

Authors have declared that no competing interests exist.

Table 2: Effect of nitrogen levels and weed management practices on NPK content (%) in grain and straw of wetland rice.

Treatments	Nutrient content (%) in grain						Nutrient content (%) in straw					
	Nitrogen		Phosphorus		Potassium		Nitrogen		Phosphorus		Potassium	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Nitrogen levels												
N_1: Control	1.194	1.184	0.150	0.146	0.248	0.222	0.315	0.302	0.046	0.045	0.560	0.530
N_2: 60 kg ha^{-1} (inorganic)	1.268	1.275	0.154	0.152	0.283	0.253	0.393	0.388	0.050	0.047	0.565	0.548
N_3: 60 kg ha^{-1} (FYM)	1.239	1.254	0.177	0.172	0.307	0.283	0.373	0.364	0.053	0.053	0.625	0.612
N_4: 90 kg ha^{-1} (inorganic)	1.276	1.271	0.156	0.152	0.301	0.274	0.410	0.398	0.051	0.049	0.578	0.551
N_5:120 kg ha^{-1} (inorganic)	1.343	1.329	0.159	0.156	0.305	0.278	0.422	0.400	0.051	0.050	0.603	0.575
SEm±	0.027	0.023	0.004	0.003	0.013	0.011	0.014	0.017	0.001	0.001	0.006	0.009
LSD (p=0.05)	0.088	0.076	0.013	0.011	0.041	0.037	0.044	0.057	0.003	0.003	0.020	0.029
Weed management practices												
W_1: *Azolla* (2 t ha^{-1})	1.379	1.375	0.166	0.164	0.312	0.287	0.423	0.402	0.052	0.052	0.622	0.599
W_2: BGA (1.25 Kg ha^{-1})	1.266	1.265	0.162	0.157	0.295	0.269	0.391	0.382	0.051	0.050	0.594	0.571
W_3: 2HW	1.221	1.219	0.156	0.156	0.280	0.254	0.367	0.359	0.050	0.048	0.583	0.560
W_4: Weedy	1.190	1.191	0.153	0.145	0.263	0.238	0.349	0.337	0.048	0.045	0.545	0.522
SEm±	0.024	0.022	0.003	0.003	0.010	0.010	0.014	0.016	0.001	0.001	0.012	0.013
LSD (p=0.05)	0.069	0.063	0.008	0.009	0.028	0.029	0.041	0.045	0.003	0.002	0.034	0.037

Note: 2HW: 2 hands weeding at 20-25 and 40-45 DAT

Table 3: Effect of nitrogen levels and weed management practices on NPK uptake (kg ha-1) by grain and straw of wetland rice.

Treatments	Nutrient uptake (kg ha^{-1}) by grain						Nutrient uptake (kg ha^{-1}) by straw					
	Nitrogen		**Phosphorus**		**Potassium**		**Nitrogen**		**Phosphorus**		**Potassium**	
	2018	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**
Nitrogen levels												
N_1: Control	42.19	39.31	5.33	4.86	8.90	7.48	17.09	15.73	2.47	2.32	30.00	27.27
N_2: 60 kg ha^{-1} (inorganic)	58.84	56.89	7.20	6.80	13.26	11.41	25.06	23.79	3.16	2.88	35.96	33.68
N_3: 60 kg ha^{-1} (FYM)	56.41	55.26	8.06	7.59	14.03	12.50	22.95	21.58	3.29	3.13	38.49	36.23
N_4: 90 kg ha^{-1} (inorganic)	64.73	62.11	7.92	7.44	15.49	13.67	28.06	26.19	3.52	3.21	39.50	36.26
N_5:120 kg ha^{-1} (inorganic)	73.56	70.17	8.67	8.21	16.71	14.68	30.69	27.67	3.64	3.44	43.79	39.78
SEm±	2.09	2.22	0.20	0.15	0.73	0.72	1.30	1.38	0.17	0.09	1.37	1.57
LSD (p=0.05)	6.82	7.23	0.64	0.48	2.38	2.34	4.23	4.51	0.55	0.28	4.48	5.13
Weed management practices												
W_1: *Azolla* (2 t ha^{-1})	69.56	67.19	8.31	7.98	15.85	13.97	28.94	26.59	3.56	3.38	42.24	39.22
W_2: BGA (1.25 Kg ha^{-1})	58.11	55.58	7.46	6.89	13.72	12.03	24.81	23.31	3.18	3.00	37.39	34.52
W_3: 2HW	59.06	57.04	7.57	7.27	13.80	12.15	24.31	22.75	3.26	3.04	38.13	35.11
W_4: Weedy	49.86	47.19	6.42	5.78	11.35	9.64	21.03	19.33	2.86	2.56	32.43	29.72
SEm±	1.44	1.23	0.15	0.15	0.43	0.37	1.10	1.14	0.11	0.09	0.95	0.95
LSD (p=0.05)	4.16	3.54	0.42	0.42	1.24	1.06	3.19	3.28	0.32	0.25	2.74	2.74

Note: 2HW: 2 hands weeding at 20-25 and 40-45 DAT

Table 4: Effect of nitrogen levels and weed management practices on grain quality of wetland rice

Treatments	Kernel length before cooking		Kernel length after cooking		Kernel breadth before cooking		Kernel breadth after cooking		Length: Breadth ratio before cooking		Length: Breadth ratio after cooking		Elongation ratio		Expansion ratio	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Nitrogen levels																
N_1: Control	6.78	6.30	12.11	11.46	1.85	1.72	3.00	2.86	3.60	3.59	4.05	4.02	1.79	1.82	1.63	1.67
N_2: 60 kg ha^{-1} (inorganic)	6.98	6.49	12.31	11.65	1.88	1.76	3.04	2.90	3.79	3.61	4.08	4.05	1.77	1.80	1.63	1.67
N_3: 60 kg ha^{-1} (FYM)	6.79	6.33	12.17	11.49	1.91	1.78	3.05	2.91	3.65	3.64	4.02	3.97	1.79	1.82	1.61	1.65
N_4: 90 kg ha^{-1} (inorganic)	7.14	6.65	12.44	11.79	1.91	1.78	3.07	2.94	3.80	3.79	4.08	4.05	1.75	1.78	1.62	1.66
N_5: 120 kg ha^{-1} (inorganic)	7.41	7.00	12.75	12.09	1.95	1.82	3.11	2.97	3.81	3.80	4.10	4.07	1.72	1.76	1.60	1.64
SEm±	0.13	0.15	0.12	0.12	0.11	0.09	0.09	0.11	0.20	0.14	0.12	0.11	0.02	0.02	0.05	0.03
LSD (p=0.05)	0.44	0.47	0.40	0.40	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed management practices																
W_1: *Azolla* (2 t ha^{-1})	7.16	6.74	12.49	11.83	1.93	1.80	3.09	2.95	3.75	3.76	4.06	4.03	1.75	1.78	1.61	1.65
W_2: BGA (1.25 Kg ha^{-1})	6.95	6.49	12.27	11.65	1.87	1.75	3.03	2.89	3.73	3.72	4.09	4.07	1.77	1.80	1.63	1.67
W_3: 2HW	7.04	6.55	12.41	11.72	1.92	1.80	3.09	2.95	3.68	3.66	4.03	3.98	1.77	1.79	1.61	1.64
W_4: Weedy	6.93	6.44	12.25	11.59	1.87	1.74	3.02	2.87	3.75	3.61	4.08	4.05	1.77	1.81	1.63	1.67
SEm±	0.09	0.09	0.08	0.09	0.06	0.07	0.07	0.09	0.09	0.10	0.08	0.07	0.01	0.01	0.02	0.02
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: 2HW: 2 hands weeding at 20-25 and 40-45 T

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