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Yield and Nitrogen Uptake of Wheat as Influenced by Nitrogen, Vermicompost and Biofertilizer Application at Rampur, Chitwan, Nepal

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ABSTRACT

High cost, unavailability, and imbalance use of chemical fertilizers and environmental degradation are challenging sustainability of wheat production in Nepal. Integration of vermicompost, biofertilizer (*Azotobacter chrococcom*) and chemical fertilizer can improve the situation. A field experiment was conducted to assess the combined application of vermicompost, chemical fertilizer and biofertilizer on the growth, yield, and nitrogen uptake of wheat at Rampur Chitwan from November 2021 to April 2022. The experiment was laid out in a strip-split plot design with five N levels as horizontal factors (0, 25, 50, 75, and 100% of recommended dose), two vermicompost levels (0 and 5 t ha^{-1}) as the vertical factor, and two biofertilizer levels (with and without application) as the sub-plot factor with three replications. Data on growth, yield attributes and yield of wheat, nitrogen uptake were collected, analyzed and presented. The research result revealed a significant influence of biofertilizer and nitrogen levels on grain yield of wheat. Full dose of nitrogen resulted a significantly higher grain yield (4441.71 kg ha^{-1}) than other nitrogen levels (0, 25, 50, 75 % of recommended dose with grain yield 2792.11, 2982.20, 3771.17. 4231.63 kg ha^{-1} respectively). Biofertilizer application had significantly higher grain yield (3726.76 kg ha^{-1}) compared with no biofertilizer application (3560 kg ha-1). There was significant interactions between biofertilizer application and nitrogen levels on number of grains per spike and sterility percent of wheat. The number of grain per spike was highest with 100% recommended N with biofertilizer application (47.52 grains/spike) followed by 75 % recommended N with biofertilizer application (46.53 grains/spike). The sterility % was lowest (6.47 %) with 100 % N with biofertilizer application followed by 75 % N with biofertilizer application (6.72 %). Total nitrogen uptake was significantly higher (119.04 kg ha^{-1}) for full dose of nitrogen as compared with lower nitrogen levels (0, 25. 50, 75 % recommended N levels). Biofertilizer application also resulted in significantly higher nitrogen uptake (89.89 kg ha^{-1}) as compared with no Biofertilizer application (79.89 kg ha^{-1}). Integration of biofertilizer, with chemical fertilizer 75 - 100 % recommended N level could increase the growth, yield, and nitrogen uptake of wheat in Chitwan.

Keywords: Chemical fertilizer, Vermicompost, Biofertilizer (Azotobacter chrococcom), Nitrogen uptake

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INTRODUCTION

Wheat is one of the most important winter crops and the third important cereal in Nepal, grown across diverse agro-climatic regions with an area of 0.7 million ha and a total production of 2.12 million MT (MoALD 2021). However, sustaining wheat production faces obstacles such as declining soil quality, reduced organic matter, and nutrient deficits (Singh et al 2012, Tulasa and Mir 2006). Nepal faces problems in meeting fertilizer demand due to the absence of a fertilizer industry and the rising costs of fertilizer. Integrated nutrient management (INM) emerges as a promising eco-friendly solution, enhancing soil health, nutrient availability, and mitigating soil degradation while safeguarding water and environmental quality, promoting carbon sequestration and reducing nutrient losses (Dudhat et al 1997, Jat et al 2005).

Major cereals in Nepal deplete soil nutrients significantly each year, but chemical fertilizers only supply a little quantity of nutrients, resulting in a net loss of soil nutrients (Vista et al 2022,). Chemical fertilizer supply and demand in the nation are constantly diverging , which has a negative impact on agricultural output (Bhandari and Neupane 2016). Nepal has one of the lowest rates of fertilizer application in the South Asian region (World Bank, 2020), despite a growing tendency toward the use of chemical fertilizers. Because there is no indigenous fertilizer industry, there is a significant reliance on imports, which causes prices to fluctuate dependent on global pricing and poses a serious danger to the national economy. Farmers must use Biofertilizer to improve soil fertility and decrease their reliance on imports of costly fertilizer.

Biofertilizer serves to improve soil fertility by fixing atmospheric nitrogen, soluble phosphorus, and other nutrients, as well as promoting plant growth by releasing growth hormones. Biofertilizer has a broad range of benefits that make them useful in sustainable agriculture (Barman et al 2017). They are shown to increase plant yield and development by 10% to 40% (Batista et al 2018).

Therefore, the present study was conducted with following objectives:

- To assess the effect of N levels, Vermicompost and Biofertilizer and their interactions on growth and grain yield of wheat
- To determine nitrogen uptake for N levels, vermicompost and biofertilizer and their interaction.

MATERIALS AND METHODS

2.1 Location

The experiment was done in the agronomy farm of Agriculture and Forestry University (AFU), Rampur, Chitwan starting from November 2021 to April 2022. Geographically site is situated at 27°37” North latitude and 84°19” East longitude with the elevation of 256 m above mean sea level.

2.2 Weather and climatic condition during experimentation

The metrological data for cropping season were taken from the metrological station of National Maize Research Program (NMRP), Rampur, Chitwan.

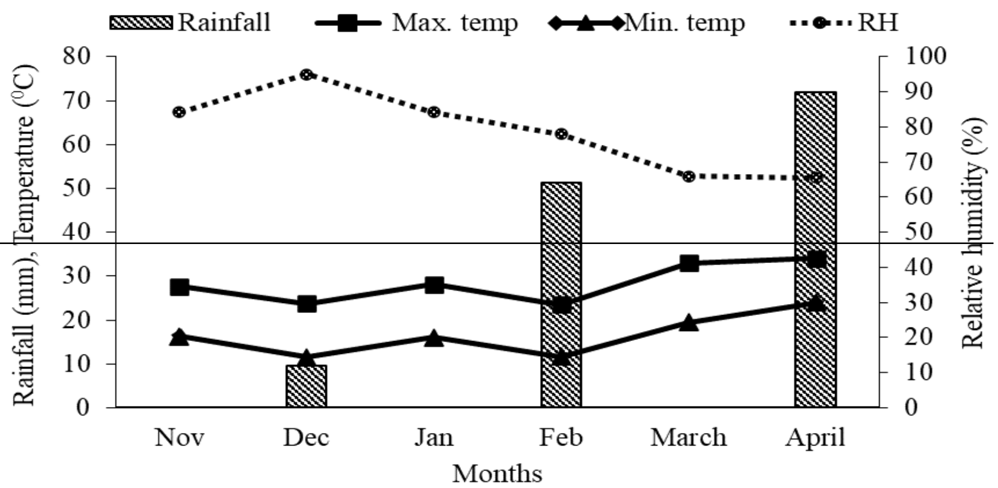

Figure 1. Weather conditions during the experimentation period (Nov 2021 to April 2022) at the agronomy farm of Agriculture and Forestry University, Rampur, Chitwan, Nepal.

The average maximum temperature ranged from 23.5 ^{0}C (February) to 34.1 ^{0}C (April). The average minimum temperature ranged from 11.6 ^{0}C (December) to 24.02 ^{0}C (April). The total rainfall during the experiment was 132.7 mm with the highest rainfall of 71.8 mm during April, along with 9.7 mm in December, and 51.2 mm in April. The average relative humidity was found to be 78.81% ranging from 65% (April) to 95% (April).

2.3 Physicochemical properties of soil

Soil of the experimental site was found to be sandy loam texture. The soil was moderately acidic with organic matter (3.05 %), and total Nitrogen (0.18 %) in medium range while the Phosphorus ($P_2 0_5$) (28.04 kg ha^{-1}) and Potassium ($K_2 0$) (87.06 kg ha^{-1}) were found to be in low range.

2.4 Experimental details

Table 1. Details of field experimental setup in Agronomy Farm, at AFU, Rampur, Chitwan, 2021-2022

Particulars	Specification
1. Design of experiment	Strip -split plot design
2. Total number of treatments	20
3. Number of replications	3
4. Individual plot size	3.5×2.5 m^2
5. Variety use	Borlaug 2020
6. Spacing	25 cm and continuous
7. Total number of rows $plot^{-1}$	14
8. Seed rate	120 kg ha^{-1}
9. Gross experiment area	768.75 m^2
10. Net plot size	2.25 × 2.5 m^2
11. Date of planting	29^{th} November, 2021
12. Recommended dose of fertilizer	120: 50: 50 kg NPK ha^{-1}
13. Number of irrigations	1 during grain filling period
14. Weeding	1 hand weeding at 25DAS
15. Date of harvesting	4^{th} April, 2022

2.5 Treatment details

The experiment was laid out in a Strip-split plot design which consists of Horizontal factor, vertical factor, and subplot factor randomized in each replication. Full doses of phosphorus and potash were applied at the time final land preparation whereas in case of 25 and 50 % recommended nitrogen was also applied as basal dose but in 75 and 100% of nitrogen doses were applied in two split 50 % as basal dose and remaining after 25 days after sowing..In case of biofertilizer 100 ml of inoculum (cfu count 5* 10^2 per ml)was applied with 5 kg of seed.

Horizontal factor: Levels of nitrogen fertilizer (% of recommended dose of nitrogen)

0 % recommended dose of nitrogen (N_0)
25% recommended dose of nitrogen (N_{25})
50% recommended dose of nitrogen (N_{50})
75% recommended dose of nitrogen (N_{75})
100% recommended dose of nitrogen (N_{100})

Vertical factor: Level of Vermicompost (t ha^{-1})

0 t ha^{-1} Vermicompost (VC_0)
5 t ha^{-1} Vermicompost (VC_5)

Sub-plot factor: Biofertilizer application

With Biofertilizer (*Azotobacter chroococcum*) (B)
Without application of Biofertilizer (B_0)

2.6 Statistical analysis

The entire set of collected data was subjected to analysis of variance and Duncan's Multiple Range Test (DMRT) for mean comparison at a probability threshold of 0.05(Gomez and Gomez ,1984). Microsoft Word 2007 was used for word processing. MS Excel was used for tables and graphs and R Studio was used for statistical analysis.

RESULTS AND DISCUSSION

3.1 Yield attributes of wheat

The mean number of grains spike^{-1} was 42.13 (Table 2). The main effect of Vermicompost was found not significant on number of grain spike^{-1} but it was found significantly influenced by nitrogen levels and biofertilizer application. The highest number of spike^{-1} was observed at 100% nitrogen level (46.07) which was statistically at par with 75% nitrogen level (45.06). Lowest number of grain spike^{-1} was observed in 0% nitrogen level (35.90). Biofertilizer application resulted into higher number of grain spike^{-1} (43) compared with without application of biofertilizer (41.02).The average effective tiller m^{-2} in the experiment was 290.78 (Table 2). The effective tillers m^{-2} ranged from 219.33-349.98 in the experiment. The Effective tillers m^{-2} was significantly influenced by nitrogen levels and biofertilizer application but not by vermicompost application (Table 2).

Table 2. Effective tillers m^{-2}, Grain number spike^{-1} and 1000 grain weight of wheat as influenced by nitrogen level, Vermicompost and Biofertilizer at AFU, Rampur, Chitwan, 2021-2022

Treatments	Effective tiller (m^{-2})	Number of grains spike^{-1}	1000 grain weight (g)
Nitrogen levels (% of recommended dose)			
0	219.33^{c}	35.90^{c}	45.51^{a}
25	245.33^{c}	40.70^{b}	45.32^{a}
50	298.10^{b}	42.31^{b}	44.58^{a}
75	341.16^{a}	45.06^{a}	42.62^{b}
100	349.98^{a}	46.07^{a}	42.10^{b}
F-test	**	**	**
LSD (=0.05)	37.60	3.03	1.46
SEm (±)	3.32	0.36	0.12
CV, (%)	13.73	5.00	3.53
Vermicompost (tha^{-1})			
0	287.62	42.00	44.04
5	293.94	42.02	44.01
F-test	NS	NS	NS
LSD (=0.05)	42.10	4.84	0.91
SEm (±)	0.74	0.63	0.03
CV, (%)	13.04	10.39	1.87
Biofertilizer			
Without Biofertilizer	282.65^{b}	41.02^{b}	43.55^{b}
With Biofertilizer	298.91^{a}	43.00^{a}	44.51^{a}
F-test	*	**	**
LSD (=0.05)	15.86	0.85	0.61
SEm (±)	0.98	0.08	0.03
CV, (%)	10.13	3.76	2.69
Grand mean	290.78	42.13	44.03

Means followed by the common letter(s) within each column are not significantly different at 5% level of significance by DMRT, NS = non-significant, the star *, and **, in the F-test indicate probability level of <0.05, and <0.01 respectively.

As the nitrogen level increased, there was a corresponding increase in effective tillers. The highest number of effective tillers m^{-2} were observed in 100% nitrogen level (349.98) which was statistically similar to 75% nitrogen level (341.16m^{-2}) and these two treatments had significantly higher number of effective tillers m^{-2} than 50, 25 and 0 % nitrogen level. The effective tiller m^{-2} in 50% nitrogen level was significantly higher than 0% and 25% nitrogen level. The lowest effective tiller was observed in 0% nitrogen level (219.33 m^{-2}).

Application of vermicompost had a non-significant effect on effective tillers m^{-2} but higher effective tillers m^{-2} was observed in vermicompost applied plot as compared to without vermicompost application. The application of biofertilizer resulted in significantly higher effective tiller numbers m^{-2} (298.91 m^{-2}) as compared with no application of biofertilizer (282.65 m^{-2}).

The mean thousand grain weight of wheat in the experiment was 44.03 g (Table 2). The thousand grain weight in the experiment ranged from 42.1 g- 45.51 g. Thousand grain weight was found significantly higher in 0% nitrogen level (45.51 g) which was statistically similar to 25% (45.32 g) and 50% (44.5 g) nitrogen level and least thousand grain weight was observed in 100% nitrogen level (42.10 g) which was statistically similar to

75% nitrogen level (42.62 g). Thousand grain weight showed the trend of decreasing value with increasing in nitrogen level.

Biofertilizer application significantly increased thousand grain weight (44.51 g) as compared with without biofertilizer application (43.55 g).

Table 3. Sterility percentage of wheat as influenced by interaction between nitrogen level and Biofertilizer application at AFU, Rampur, Chitwan, 2021-2022

Treatment	Sterility (%)				
	Nitrogen level (% of recommended dose)				
	0	25	50	75	100
Biofertilizer					
Without Biofertilizer	16.12^{f}	8.39^{bc}	8.14^{bc}	7.65^{cd}	7.05^{de}
With Biofertilizer	8.19^{bc}	8.76^{b}	7.61^{cd}	6.72^{e}	6.47^{e}
LSD(=0.05)	0.82				
SEm (±)	0.34				
CV, (%)	24.38				

Means followed by the common letter(s) within each column are not significantly different at 5% level of significance by DMRT, NS = non-significant

Sterility percentage was significantly influenced by the interaction between nitrogen levels and biofertilizer (Table 3). Sterility percentage was less when biofertilizer was applied with increasing nitrogen levels. The lowest sterility percentage was observed (6.47%) with biofertilizer and 100 % levels of N while the highest sterility was in 0% N levels and without biofertilizer (16.12 %). The sterility percent was intermediate in between above two treatments.

Table 4. Number of grains spike-1 of Wheat as influenced by interaction between nitrogen levels and biofertilizer during the winter season at AFU, Rampur, Chitwan, Nepal

Treatment	Number of grains spike^{-1}				
	Nitrogen level (% of recommended dose)				
	0	25	50	75	100
Biofertilizer					
Without biofertilizer	34.75^{g}	39.30^{e}	42.8^{cd}	43.58^{bc}	44.61^{b}
With biofertilizer	37.06^{f}	42.10^{cd}	41.7^{d}	46.53^{a}	47.52^{a}
LSD (=0.05)	1.761				
SEm (±)	0.41				
CV, (%)	3.76				

Means followed by the common letter(s) within each column are not significantly different at 5% level of significance by DMRT, NS = non-significant

Number of grain spike^{-1} was influenced significantly by the interaction between nitrogen level and biofertilizer application (Table 4). With biofertilizer application significantly higher number of grains spike^{-1} was obtained in 100% nitrogen level (47.52) which was statistically at par with 75% nitrogen level with biofertilizer application (46.53), and lowest grain number spike^{-1} was obtained in 0% nitrogen level (34.06) without biofertilizer followed by same level of N application with biofertilizer (37.06). Similarly, the highest grain number spike^{-1} was obtained in 100% nitrogen level (44.61) with biofertilizer which was statistically similar to 75% nitrogen level (43.58) with biofertilizer.

3.2 Grain yield of wheat

The mean grain yield of wheat was recorded 3707.58 kg ha^{-1} (Table 6). The grain yield in the experiment ranged from 2791.11 kg ha^{-1} (0% nitrogen level) to 4441.71 kg ha^{-1}(100% nitrogen level). The grain yield was significantly influenced by N levels and biofertilizer but not by vermicompost application (Table 5). Significantly higher grain yield was observed in 100% nitrogen level (4441.71 kg ha^{-1}) and the lowest grain yield was recorded in 0% nitrogen level. The grain yield of wheat due to nitrogen level followed the trend 100% N> 75% N> 50% N> 25% N> 0% N. The grain yield was found significantly higher with the application of biofertilizer (3726.7 kg ha^{-1}) as compared to without biofertilizer application (3560.96 kg ha^{-1}). Iqbal et al (2012) and Khanal et al (2022) also observed increase in wheat grain yield at higher nitrogen level. Me carty et al (2017) reported higher grain yield of wheat due to Azotobacter application. Similarly Dahal et al. (2017) also reported higher yield of winter maize with application of Azotobacter.

Table 5. Grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index of wheat as influenced by nitrogen level, Vermicompost, and Biofertilizer at AFU, Rampur, Chitwan, 2021-2022

Treatment	Grain Yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (HI)
Nitrogen levels (% of recommended dose)			
0	2792.11^{e}	4669.90^{c}	0.40
25	2982.20^{d}	5493.08^{bc}	0.37
50	3771.17^{c}	6545.75^{ab}	0.39
75	4234.63^{b}	7439.45^{a}	0.39
100	4441.71^{a}	7608.65^{a}	0.39
F-test	**	**	NS
LSD (=0.05)	152.51	1113.96	0.04
SEm (±)	736.48	341.58	0.01
CV,%	5.52	18.63	9.76
Vermicompost levels (tha^{-1})			
0	3661.70	6394.44	0.38
5	3626.02	6308.30	0.39
F-test	NS	NS	NS
LSD (=0.05)	476.32	1390.04	0.04
SEm (±)	59.038	228.63	0.01
CV,%	8.87	19.71	8.64
Biofertilizer			
Without Biofertilizer	3560.96^{b}	6508.26	0.38^{b}
With Biofertilizer	3726.76^{a}	6194.47	0.40^{a}
F-test	**	NS	**
LSD (=0.05)	101.54	367.46	0.018
SEm (±)	37.08	39.40	0.01
CV, %	5.57	10.74	7.74
Grand mean	3707.58	6351.37	0.39

Means followed by the common letter(s) within each column are not significantly different at 5% level of significance by DMRT, NS = non-significant, the star *and ** in the F-test indicate probability level of <0.05 and, <0.01 respectively.

3.3 Straw yield of wheat

The mean straw yield of wheat in the experiment was 6351.57 kg ha^{-1} (Table 5). The highest straw yield was observed in 100% nitrogen level (7608.65 kg ha^{-1}) which was statistically similar to 75% nitrogen level (7439.45 kg ha^{-1}) and 50% nitrogen level (6545.75 kg ha^{-1}). The lowest straw yield was observed in 0% nitrogen level (4669.90 kg ha^{-1}) which was statistically similar to 25% nitrogen level (5493.08 kg ha^{-1}). Vermicompost and Biofertilizer application did not influence the straw yield significantly.

3.4 Harvest index of wheat

The mean harvest index of wheat in the experiment was 0.39 (Table 5). Harvest index was not influenced by different levels of nitrogen and vermicompost while the application of biofertilizer had a significant effect on harvest index. Harvest index was found significantly higher with biofertilizer application (0.4) as compared with without biofertilizer application (0.38).

3.5 Nitrogen uptake in wheat

3.5.1 Nitrogen uptake in grain

The mean nitrogen uptake in grain was 67.19 kg ha^{-1} (Table 7). Nitrogen uptake in grain was significantly influenced by the level of nitrogen and Biofertilizer application but not by Vermicompost.The grain N uptake showed increase in N uptake with increasing N levels. The highest grain N uptake was observed in 100% nitrogen level (94.60 kg ha^{-1}) and the lowest N uptake was observed in 0% nitrogen level (42.15 kg ha^{-1}). The plot with 100% nitrogen level had significantly higher nitrogen uptake then all other levels of nitrogen application. The 75% nitrogen level had significantly lower uptake than 100% nitrogen level and was similar with 50% nitrogen level but higher than 0% and 25% nitrogen level. The nitrogen uptake in 0% nitrogen level and 25% nitrogen levels were statistically similar. Similarly, Biofertilizer application resulted in significantly higher grain nitrogen uptake (71.24 kg ha^{-1}) as compared with without Biofertilizer application (63.15 kg ha^{-1}). Vermicompost application did not have a significant influence on grain nitrogen uptake.

3.5.2 Nitrogen uptake in straw

The mean nitrogen uptake in straw was 17.65 kg ha^{-1} (Table 7). Nitrogen uptake in straw was significantly influenced by the level of nitrogen but not by Vermicompost and Biofertilizer application.The straw N uptake showed increase in N uptake with increasing N levels. The highest straw N uptake was observed in 100% nitrogen level (24.43 kg ha^{-1}) and the lowest N uptake was observed in 0% nitrogen level (11.29 kg ha^{-1}). The plot with 100% nitrogen level had significantly higher nitrogen uptake than 50%, 25% and 0% nitrogen level but was similar with 75% nitrogen level (21.94 kg ha^{-1}). The 75% nitrogen level had significantly higher uptake then 50, 25 and 0 % nitrogen level. The nitrogen uptake in 0% nitrogen level and 25% nitrogen level were statistically similar.

3.5.3 Total nitrogen uptake

The mean total nitrogen uptake was 84.85 kg ha^{-1} (Table 6). Total nitrogen uptake was significantly influenced by the level of nitrogen and biofertilizer application but not by vermicompost. The total N uptake showed increase in N uptake with increasing N levels (Table 6). The highest total N uptake was observed in 100% nitrogen level (119.04 kg ha^{-1}) and the lowest N uptake was observed in 0% nitrogen level (53.45 kg ha^{-1}). The plot with 100% nitrogen level had significantly higher nitrogen uptake then all other levels of nitrogen application. The 75% nitrogen level had significantly lower uptake than 100% nitrogen level and was higher than 50%, 25%, and 0% and nitrogen levels. The nitrogen uptake in 0% nitrogen level and 25% nitrogen level were statistically similar. Higher nitrogen uptake at higher dose of nitrogen application was also obtained by Khadka et al (2022).

Table 16. Nitrogen uptake in grain and straw of wheat as influenced by nitrogen level, vermicompost, and biofertilizer during winter season at AFU, Rampur, Chitwan, Nepal 2021-2022

Treatment	Nitrogen uptake (kg ha^{-1})		
	Grain	Straw	Total
Nitrogen levels (% of recommended dose)			
0	42.15^{c}	11.29^{c}	53.45^{d}
25	47.37^{c}	12.73^{c}	60.10^{d}
50	72.67^{b}	17.87^{b}	90.54^{c}
75	79.18^{b}	21.94^{a}	101.12^{b}
100	94.60^{a}	24.43^{a}	119.04^{a}
F-test	**	**	**
LSD (=0.05)	7.58	3.58	9.12
SEm (±)	0.67	0.31	0.80
CV, (%)	11.99	21.56	11.42
Vermicompost levels (tha^{-11})			
0	67.39	17.43	84.88
5	67.00	17.88	84.82
F-test	NS	NS	NS
LSD (=0.05)	2.91	0.71	7.03
SEm (±)	0.08	0.06	0.06
CV, (%)	17.75	10.77	2.39
Biofertilizer			
Without Biofertilizer	63.15^{b}	16.73	79.89^{b}
With Biofertilizer	71.24^{a}	18.57	89.89^{a}
F-test	*	NS	**
LSD (=0.05)	6.42	2.03	7.03
SEm (±)	0.39	0.12	0.43
CV, (%)	3.92	21.43	15.40
Grand mean	67.19	17.65	84.85

Means followed by the common letter(s) within each column are not significantly different at 5% level of significance by DMRT, NS = non-significant, the star *, and ** in the F-test indicate probability level of <0.05, and <0.01 a respectively.

Similarly, biofertilizer application resulted in significantly higher total nitrogen uptake (71.24 kg ha^{-1}) as compared with without Biofertilizer application (63.15 kg ha^{-1}). Vermicompost application did not have a significant influence on total nitrogen uptake.

CONCLUSION

The research result revealed that integration of biofertilizer with 75- 100 % recommended dose of nitrogen increased the number of grains per spike and lowered the sterility % of wheat. 75-100 % recommended nitrogen also increased the grain yield. and total nitrogen uptake. Similarly, application of biofertilizer increased the grain yield and total nitrogen uptake of wheat. Therefore, 75-100 % recommended nitrogen with biofertilizer application seems better option for increasing grain yield and nitrogen uptake of wheat in Chitwan.

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AUTHORS' CONTRIBUTION

The first author conducted the experiment in the field and analyzed the nitrogen content in the laboratory where as second and third authors played advisory roles in developing the concepts and writing the manuscript.

CONFLICTS OF INTEREST

There is no conflict of interest regarding this manuscript.

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