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Impact of sole and conjoint use of nitrogen on recovery efficiency of nitrogen in wheat - moongbean cropping system under subtropical region of Uttar Pradesh

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Abstract
This study was conducted from mid-2023 to 2025, under this study major focus on the sustainability of crop yields and maintaining the soil fertility. This research was conducted at the research form of Janta Mahvidyalay Ajitmal, Auraiya under the department of soil science and agricultural chemistry, CSJMU, Kanpur nagar, INDIA. In this study taking two factor (factor A contain different levels of RDN combination with nano urea while factor B contain combination of rhizobium and vermicompost) three replication and 28 treatments was employed with factorial randomized block design. This study was totally based on the RDN doses with organic fertilizer and bio-inoculant which are best for the crop as well as soil health and reduce the cost of cultivation in wheat moongbean cropping system.

Keywords: RDN, vermicompost, bio-inoculant, nano urea

1. Introduction

Agricultural sustainability relies on cropping systems that optimize resource use while preserving soil fertility and productivity. The wheat-moong bean rotation, popular in South Asia, combines wheat a major cereal with moong bean, a nitrogen-fixing legume that enriches soil. Integrating cereals with legumes enhances nutrient cycling, boosts soil organic matter, and stimulates microbial activity, promoting long-term soil health (Kumar *et al*., 2020) [4]. However, poor nutrient management and continuous wheat cultivation deplete soil nutrients, reduce organic matter, and harm microbial diversity. Incorporating nitrogen-fixing legumes into wheat systems offers a sustainable way to restore fertility, reduce synthetic fertilizer dependence, and sustain productivity (Singh *et al*., 2019) [6].

Moongbean (*Vigna radiata*), or green gram, is a short-duration pulse crop cultivated during the monsoon and summer seasons. Through symbiosis with Rhizobium bacteria, it fixes atmospheric nitrogen, enriching the soil naturally. With a maturity period of 60-75 days, it fits well into intensive cropping systems as a catch, intercrop, or sequential crop after wheat, thereby improving land-use efficiency and total farm productivity.

Moongbean is nutritionally rich in protein (24-26%), essential amino acids, vitamins, and minerals, making it important for human diets and as quality animal feed, supporting integrated farming systems (Tripathi *et al*., 2018) [7].

Wheat is nutritionally rich in carbohydrates and protein, making it essential for global food security. Economically, it plays a pivotal role in international trade, with major production centered in India, China, Russia, and the United States. However, intensive monocropping of wheat has led to soil nutrient depletion, reduced organic matter, and excessive dependence on synthetic fertilizers highlighting the urgency for sustainable nutrient management (Belete *et al*., 2023) [3]. Wheat requires substantial inputs of nitrogen, phosphorus, and potassium to support its growth and imbalanced fertilizer use can degrade soil health, contaminate groundwater, and reduce microbial diversity. Integrating wheat with leguminous crops like moongbean in rotational systems offers a sustainable alternative (Pahalvi *et al*., 2021) [5].

2. Methodology

2.1 Experimental Site

2.1.1 Geographic location

The present field experiment was conducted at the Research Farm of the Department of Soil Science and Agricultural Chemistry, Janta Mahavidyalaya, Ajeetmal, situated in Auraiya district, Uttar Pradesh (U.P.), India. This experimental site is geographically located in the semi-arid region of the Indo-Gangetic Plains, which is a significant agricultural belt of North India. The region holds importance due to its diverse cropping systems and the ongoing challenges related to sustainable nutrient management.

2.1.2 Agro-climatic conditions

The experimental site is located under a subtropical climate, marked by sultry summers and cool winters. The place receives nearly 850 mm of annual rainfall, most of which is received during the southwest monsoon, from June to September. Climatic extremes also characterize the area; atmospheric temperature in summer would reach as high as 42 °C to cause heat stress, whereas in winter, temperature falls to as low as 5 °C and thus might inhibit activities of microbes and nutrient transformation in soils. The influence of these agro-climatic conditions is thus, quite pronounced on nutrient dynamics, microbial activities, and cropping systems, making it a very suitable site for studying nutrient management in diverse seasonal environments.

2.1.3 Experimental year and season

The experiment was conducted over two complete agricultural years (2023 - 2025), covering two cropping seasons: Rabi (wheat) and Zaid (moongbean). The seasonal approach permitted evaluation of the direct effects during the wheat season and the residual effects during the moongbean season-on real field conditions.

2.1.4 Crop grown

The cropping system followed was some wheat-moongbean sequence, which is prevalent in the Indo-Gangetic Plains. During the Rabi season, wheat (Triticum aestivum) was cultivated, and in the Zaid season, moongbean (Vigna radiata) was grown. These two crops were selected due to their complementary nutrient requirements and their suitability for evaluating nutrient management strategies in a sequential cropping system.

2.1.5 Layout and replication

The study entailed a Factorial Randomized Block Design to test the separate and combined effects of inorganic nitrogen and biological nutrient sources on soil health and crop production. There were two factors in the experimental design: Factor A, which has 7 levels of inorganic nitrogen treatments, and Factor B, which has 4 levels of biological nutrient sources, making 28 treatment combinations in all. This treatment combination acquired three replications to assure accuracy and reliability. Each plot was 3.5 m wide and 4.0 m long, with buffer strips negotiated between plots to avoid runoff of nutrients and cross-contamination. All the agronomic operations were established alike across experimental plots with a sole exception made for nutrient treatment applications, which were in line with the experimental design.

Design	F- RBD
Number of replication	3
Total number of treatment	(7 x 4) = 28
Total number of plot	28 x 3 = 84
Gross plot size	4 x 2=8 m^2
Net plot Size	8 - 1.2 = 6.8 m^2
Irrigation channel	30 cm
Crop	Wheat - moongbean

Table 4: Factor A - Inorganic Nitrogen Treatments

Codes	Treatment Descriptions
F0	Control (No nitrogen application)
F1	50% Recommended Dose of Nitrogen (RDN)
F2	75% Recommended Dose of Nitrogen (RDN)
F3	100% Recommended Dose of Nitrogen (RDN)
F4	50% RDN + 2 foliar sprays of 2% Nano-Urea
F5	75% RDN + 2 foliar sprays of 2% Nano-Urea
F6	100% RDN + 2 foliar sprays of 2% Nano-Urea

Table 5: Factor B - Biological Nutrient Sources

Codes	Treatment Descriptions
B0	Control (No biological input)
B1	25% RDN through Vermicompost
B2	Rhizobium inoculation
B3	Rhizobium + 25% RDN through Vermicompost

2.2 Nitrogen Use Efficiency (NUE)

NUE was calculated to assess how effectively the crop utilized applied nitrogen under various treatments. Indices such as agronomics, recovery, and physiological efficiency were used. These metrics helped determine the contribution of inorganic, organic, and nano-nitrogen sources to yield (Al-Juthery *et al.*, 2021) [1].

3. Results and Discussion

In this study we found that the agronomic efficiency of wheat first year is 23% in T4 (100% RDN) treatment while T27 (75% RDN + Rhizobium+ 2 spray of nano urea) is significantly higher than all the treatment except T28 (100% RDN + Rhizobium+ 2 spray of nano urea) treatment because it's at par with each other. The treatment T27 and T28 are the best than other treatment for agronomic efficiency in wheat - moongbean cropping system and same trend was followed in second year wheat moongbean cropping system.

The recovery efficiency and physiological efficiency wheat first year is higher T4 (100% RDN) than control plot while T27 (75% RDN + Rhizobium+ 2 spray of nano urea) is significantly higher than all the treatment. Treatment T27 and T28 are at par with each other. Similar trend was found in second year of recovery and physiological efficiency of wheat- moongbean cropping system.

Table 3.1: Nutrient use efficiency of wheat under different combination of nitrogen resources

Treatments	Wheat Ist year			Wheat IInd year		
	Agronomic Efficiency (%)	Recovery Efficiency (%)	Physiological Efficiency (%)	Agronomic Efficiency (%)	Recovery Efficiency (%)	Physiological Efficiency (%)
T1	18.690	32.150	31.250	18.120	31.200	30.120
T2	19.600	38.900	39.500	19.600	38.900	39.500
T3	22.767	39.400	42.033	22.767	39.400	42.033
T4	23.650	40.120	43.500	23.650	40.120	43.500
T5	24.500	41.250	45.800	24.500	41.250	45.800
T6	26.300	41.890	47.300	26.300	41.890	47.300
T7	27.150	42.360	48.700	27.150	42.360	48.700
T8	22.663	33.650	33.120	22.100	32.400	32.100
T9	28.900	39.120	42.300	28.900	39.120	42.300
T10	30.500	41.120	43.250	30.500	41.120	43.250
T11	31.150	42.350	44.333	31.150	42.350	44.333
T12	32.150	43.520	45.800	32.150	43.520	45.800
T13	32.500	43.633	47.580	32.500	43.633	47.580
T14	33.150	46.300	48.950	33.150	46.300	48.950
T15	23.560	36.660	34.127	23.560	36.660	34.127
T16	27.600	43.120	40.333	27.600	43.120	40.333
T17	28.600	44.300	43.100	28.600	44.300	43.100
T18	28.900	45.280	46.033	28.900	45.280	46.033
T19	30.120	45.890	48.433	30.120	45.890	48.433
T20	32.150	46.980	49.900	32.150	46.980	49.900
T21	33.140	47.120	51.400	33.140	47.120	51.400
T22	24.150	38.170	36.890	24.150	38.170	36.890
T23	30.120	45.567	50.133	30.120	45.567	50.133
T24	30.467	47.833	52.333	30.467	47.833	52.333
T25	31.967	50.033	54.000	31.967	50.033	54.000
T26	33.167	52.100	55.933	33.400	52.300	56.100
T27	35.900	54.900	59.560	37.100	55.400	62.100
T28	34.467	53.933	57.467	34.467	53.933	57.467
CD (P>0.05%)	0.78	2.05	1.44	0.51	0.72	0.54

This study was concluded that the agronomic efficiency of moongbean first year is 18% in T4 (100% RDN) treatment while T27 (75% RDN + Rhizobium+ 2 spray of nano urea) is significantly higher than all the treatment except T28 (100% RDN + Rhizobium+ 2 spray of nano urea) treatment because it's at par with each other. The treatment T27 and T28 are the best than other treatment for agronomic efficiency in wheat - moongbean cropping system and same trend was followed in second year wheat moongbean cropping system.

The recovery efficiency and physiological efficiency moongbean first year is higher T4 (100% RDN) than control plot while T27 (75% RDN + Rhizobium+ 2 spray of nano urea) is significantly higher than all the treatment. Treatment T27 and T28 are at par with each other. Similar trend was found in second year of recovery and physiological efficiency of wheat-moongbean cropping system.

Table 3.2: Nutrient use efficiency of moongbean under different combination of nitrogen resources

Treatments	Moongbean Ist year			Moongbean Ist year		
	Agronomic Efficiency (%)	Recovery Efficiency (%)	Physiological Efficiency (%)	Agronomic Efficiency (%)	Recovery Efficiency (%)	Physiological Efficiency (%)
T1	15.230	24.300	27.320	16.230	28.900	28.150
T2	18.400	38.900	38.600	18.600	38.900	39.500
T3	22.300	38.900	41.300	23.100	39.400	42.033
T4	24.500	40.120	43.500	24.500	40.120	43.500
T5	24.500	41.250	45.800	24.500	41.250	45.800
T6	26.140	41.890	47.300	27.310	41.890	47.300
T7	27.150	42.360	48.700	27.150	42.360	48.700
T8	18.230	30.120	30.210	20.120	30.120	30.210
T9	28.310	37.120	40.120	30.100	39.120	42.300
T10	29.300	41.120	41.250	30.500	41.120	43.250
T11	31.100	42.350	43.500	32.100	42.350	44.333
T12	33.400	43.520	44.250	34.120	43.520	45.800
T13	36.120	43.633	47.580	36.120	43.633	47.580
T14	37.240	45.120	47.120	37.240	46.300	48.950
T15	19.650	32.120	30.120	21.310	34.500	32.500
T16	28.400	45.230	49.250	28.400	45.230	49.250
T17	29.800	49.210	51.100	29.800	49.210	51.100
T18	32.200	50.210	53.120	32.200	50.210	54.200
T19	33.500	52.310	55.210	33.500	52.310	56.100

T20	34.100	54.600	58.100	34.100	54.600	58.100
T21	34.800	55.310	58.400	34.800	55.310	58.400
T22	25.100	36.150	34.150	25.100	36.150	34.150
T23	32.400	56.120	58.260	32.400	57.150	60.120
T24	33.120	57.230	60.130	34.200	59.310	62.500
T25	34.450	58.230	62.400	35.120	60.230	64.500
T26	35.480	60.120	64.230	36.200	62.130	66.300
T27	38.900	65.120	68.520	39.500	67.500	72.300
T28	36.700	63.400	66.120	37.500	64.200	68.500
CD (P>0.05%)	1.34	2.64	2.49	1.34	2.64	2.49

4. Conclusion

This study is basically based on the loss of different form nitrogen from variable sources of nitrogen, so in this study we are found that the combination of organic, inorganic and bio inoculant is best for the agronomic, recovery and physiological efficiency of wheat- moongbean cropping system.

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