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NUTRIENT UPTAKE AND ECONOMICS OF RICE BEAN (*VIGNA UMBELLATA* L.) AS INFLUENCED BY FOLIAR SPRAY OF NANO DAP

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ABSTRACT

A field experiment was conducted at College of Agriculture, Kalaburagi, during *kharif*, 2024 to study the nutrient uptake and economics of rice bean (*Vigna umbellata* L.) as influenced by foliar spray of nano DAP. The experiment was laid in RCBD design with 11 treatments and replicated thrice. The Nano DAP and conventional DAP were sprayed at 30 DAS. The results revealed that 100% RDF combined with nano DAP @ 4 ml l^{-1} recorded significantly higher nutrient uptake, higher gross returns (Rs. 83,875 ha^{-1}) and net returns (Rs. 55,531 ha^{-1}). However, 75% RDF combined with nano DAP @ 4 ml l^{-1} was also found on par with respect to nutrient uptake and economics. Further, lower economic returns was noticed in absolute control treatment.
***Keywords* :** Rice bean, Nano DAP, Nutrient uptake and Economics

Introduction

Rice bean (*Vigna umbellata* L.) is cultivated in India, Myanmar, Malaysia, China, Korea, Indonesia and the Philippines. Additionally, the West Indies, the United States, Australia, East Africa, Java, Fiji, Bangladesh, Sri Lanka and Nepal cultivate this crop. It is a neglected crop in India and is being cultivated on small areas by some hill farmers in North-Eastern India and its distribution is mainly confined to the tribal region of North-Eastern hills and hilly tracts of Western and Eastern Ghats. In the North-Eastern region of India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura), it is grown predominantly under rainfed conditions in mixed farming system, under shifting cultivation, terraces, kitchen garden and backyards (Bepary *et al.*, 2016).

The ideal NPK usage ratio in India is 4:2:1, but the practical usage ratio is 7:2.8:1. This imbalanced application of fertilizer is the main reason for the deterioration of soil health. Some of the important problems that induced include low fertilizers response ratio and low nutrient use efficiency. During 1970s', the fertilizer response ratio was 13.4 and now it is reduced to only 2.7. It means over the years though our fertilizer consumption is increasing the yield is stagnated (Anon., 2020).

Nano fertilizers are defined as materials on a nanometre scale (1-100 nm) containing macro and micronutrients that are delivered to crops in a controlled mode. In general, one nm scale means one billionth of a meter (10^{-9} m). In comparison to conventional fertilizers, nano-fertilizers have a large surface area and particles that are smaller in size than the pores in the plant's leaves and roots, which can boost penetration into the plant from the applied surface and increase uptake and nutrients use efficiency. These efficient fertilizers are expected to enhance crop growth, production and quality by reducing environment footprint (Liu and Lal, 2015).

A study is proposed to assess the "Nutrient uptake and economics of rice bean (*Vigna umbellata* L.) as influenced by foliar spray of nano DAP", focusing on its influence on nutrient content, gross returns and net returns.

Materials and Methods

The experimental site is located in the North Eastern Dry Zone of Karnataka, with medium deep clay soil. Soil samples were analyzed for physical and chemical properties before the experiment. Regarding chemical properties, the soil was alkaline in reaction (pH-8.02), low in EC (0.59 dS m^{-1}) and low in organic carbon content (0.49). The soil of the experimental site was low in available nitrogen (225 kg ha^{-1}), available phosphorus (45 kg ha^{-1}) and high in available potassium (372 kg ha^{-1}).

The experiment on nutrient uptake and economics of rice bean production as effected by foliar spray of nano DAP consisted of 11 treatments in a randomized complete block design with three replications. The treatments included: T_1: 50% RDF + nano DAP @ 2 ml l^{-1}, T_2: 50% RDF + nano DAP @ 4 ml l^{-1}, T_3: 75% RDF + nano DAP @ 2 ml l^{-1}, T_4: 75% RDF + nano DAP @ 4 ml l^{-1}, T_5: 100% RDF + nano DAP @ 2 ml l^{-1}, T_6: 100% RDF + nano DAP @ 4 ml l^{-1}, T_7: Nano DAP @ 2 ml l^{-1}, T_8: Nano DAP @ 4 ml l^{-1}, T_9: 100% RDF + water spray, T_{10}: 100% RDF + DAP @ 2% and T_{11}: Absolute control. The recommended doses of fertilizer includes nitrogen (20 kg ha^{-1}), phosphorus (40 kg ha^{-1}) and FYM @ 5 t ha^{-1}.

The seed and stover samples collected from each plot at harvest were dried in oven at 65 ^{o}C till a constant dry weight. These samples were grounded in laboratory mill, passed through 40 mm mesh sieve and used for estimating N, P and K contents. Total nitrogen was determined by Kjeldahl's method, Phosphorus was estimated by Vanadomolybdate method using Atomic Absorption Spectrophotometer (AAS) and Potassium was by Flame Photometer method as described by Jackson (1973). The economics was worked out based on the prevailing market price for the existing year. Data analysis and interpretation was done using Fisher's method of analysis of variance (ANOVA) technique as given by Panse and Sukhatme (1967). Further, the calculation of gross returns, net returns and BC ratio was made by using the following formula:

Gross returns (Rs. ha^{-1}) = (Yield of main product × price of main product) + (Yield of by product × price of by product)

Net returns (Rs. ha^{-1}) = Gross returns(Rs. ha^{-1}) – Cost of cultivation (Rs. ha^{-1})

$$B:C = \frac{\text{Gross returns (Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs. ha}^{-1}\text{)}}$$

Results and Discussion

Nutrient uptake

Nitrogen

Higher nitrogen uptake (42.0, 35.9 & 77.9 kg ha^{-1} in seed, stover & total, respectively) was observed in the treatment receiving 100% RDF + nano DAP @ 4 ml l^{-1}. It was on par with 100% RDF combined with nano DAP @ 2 ml l^{-1} (39.7, 33.6 & 73.3 kg ha^{-1} in seed, stover and total, respectively), 100% RDF with DAP @ 2% (37.3 , 29.3 & 66.6 kg ha^{-1}, in seed, stover & total, respectively) and 75% RDF with nano DAP @ 4 ml l^{-1} (35.2, 30.7 & 65.9 kg ha^{-1} in seed, stover & total, respectively). In contrast, lower uptake was recorded in absolute control (7.3, 3.3 and 10.5 kg ha^{-1}).

The ultra-fine particles facilitated rapid penetration through stomata and cuticular pathways, enhancing assimilation and translocation. Improved nitrogen uptake in the same treatment likely resulted from nitrogen-mediated stimulation of root activity and metabolic processes, promoting overall nutrient acquisition. These findings are consistent with Liu and Lal (2015) and Pruthvi (2018) who reported higher nutrient use efficiency with nano-fertilizer application in legumes.

Phosphorus

Higher phosphorus uptake (7.48, 9.75 & 17.23 kg ha^{-1} in seed, stover & total, respectively) was observed with 100% RDF + nano DAP @ 4 ml l^{-1}, which was statistically comparable to 100% RDF with nano DAP @ 2 ml l^{-1} (7.01, 9.12 & 16.14 kg ha^{-1} in seed, stover & total, respectively), 100% RDF with conventional DAP @ 2% (6.38, 7.56 & 13.94 kg ha^{-1} in seed, stover & total, respectively) and 75% RDF with nano DAP @ 4 ml l^{-1} (5.72 , 6.99 & 12.71 kg ha^{-1} in seed, stover & total, respectively). In contrast, absolute control recorded the lower uptake values (0.68, 0.54 & 1.45 kg ha^{-1} in seed, stover & total, respectively).

This effect is attributed to the nano-fertilizer's high surface area and particle size smaller than leaf pore openings, enabling efficient penetration through stomata and hydathodes. Such properties enhance direct assimilation of phosphorus and nitrogen, improving nutrient use efficiency and supporting vigorous growth. The observed response aligns with findings of Abdel-Salam (2018) and Sanjaya Kumar *et al.* (2024), who reported that nano-nutrients improve absorption and crop performance. The synergy between nano-scale phosphorus and plant physiological processes likely facilitated superior nutrient translocation, contributing to greater biomass production and yield.

Potassium

Significantly higher potassium uptake (8.86, 32.88 & 41.74 kg ha^{-1} in seed, stover & total uptake, respectively) was recorded in the treatment involving 100% RDF + nano DAP application @ 4 ml l^{-1} as compared to other treatments. However, this was in comparable with the treatment of 100% RDF + nano DAP @ 2 ml l^{-1} (8.37, 30.82 & 39.19 kg ha^{-1} in seed, stover & total uptake, respectively), 100% RDF + DAP @ 2% (7.71, 28.22 & 35.93 kg ha^{-1} in seed, stover & total uptake, respectively) and 75% RDF + nano DAP @ 4 ml l^{-1} (7.23, 27.35 & 34.57 kg ha^{-1}, in seed, stover and total uptake, respectively). In contrast, lower uptake was recorded in absolute control (1.65, 5.58 and 7.23 kg ha^{-1}).

The nano-scale dimensions confer a high specific surface area, enhancing contact with leaf surfaces and facilitating penetration through stomatal and cuticular openings. This property improves potassium bioavailability, accelerates assimilation and supports key physiological processes. The enhanced uptake efficiency aligns with report by Pragathi *et al.* (2024) confirming the potential of nano-fertilizers to optimize nutrient acquisition and contribute to higher crop productivity.

Economics

Cost of cultivation (Rs. ha^{-1})

The lower cost of cultivation (Rs. 22,550 ha^{-1}) was reported in the absolute control. However, in contrast to the higher cost of cultivation (Rs. 28,344 ha^{-1}) incurred with the treatment of 100% RDF + nano DAP application @ 4 ml l^{-1} followed by treatment receiving 75% RDF combined with foliar spray of nano DAP @ 4 ml l^{-1} (Rs. 27,746 ha^{-1}) and 50% RDF combined with foliar spray nano DAP @ 4 ml l^{-1} (Rs. 27,147 ha^{-1}). Similar findings were also reported by Prakash *et al.* (2023) and Sachin *et al.* (2024).

Gross returns and net returns (Rs. ha^{-1})

The gross returns exhibited substantial variation across the treatments whereas, higher gross returns (Rs. 83,875 ha^{-1}) was recorded for the treatment receiving 100% RDF + nano DAP at 4 ml l^{-1}. However, this was on par with 100% RDF + nano DAP @ 2 ml l^{-1} (Rs. 81,282 ha^{-1}), 100% RDF + of DAP @ 2% (Rs. 76,984 ha^{-1}) and 75% RDF + nano DAP @ 4 ml l^{-1} (Rs. 74,301 ha^{-1}). Conversely, significantly lower gross returns (Rs. 28,956 ha^{-1}) were observed with absolute control.

The maximum net returns (Rs. 55,531 ha^{-1}) was recorded with 100% RDF + nano DAP @ 4 ml l^{-1}. It was on par with 100% RDF with nano DAP @ 2 ml l^{-1} (Rs. 54,138 ha^{-1}), 100% RDF with DAP @ 2% (Rs. 50,770 ha^{-1}) and 75% RDF with nano DAP @ 4 ml l^{-1} (Rs. 46,555 ha^{-1}).

The higher gross returns and net returns obtained with 100% + nano DAP @ 4 ml l^{-1} of water was primarily due to increased yield under this treatment. Integration of nano-nutrients with soil-applied fertilizers markedly enhanced the crop productivity by improving nutrient availability and uptake. This synergistic effect translated into superior yield performance and, consequently, greater economic returns. Comparable results have been documented by Pruthvi (2018) and Pruthvi and Chandrashekar (2019) who reported that combining conventional fertilizers with nano-technology-based nutrient formulations improved the yield and profitability.

Benefit cost ratio (B:C)

The higher BC ratio (2.99) was recorded with the treatment 100% RDF + nano DAP spray at 2 ml l^{-1}. However, this outcome was on par with the treatment receiving 100% RDF + nano DAP application @ 4 ml l^{-1} (2.96), 100% RDF + conventional DAP @ 2% (2.94), 100% RDF along with water spray (2.67), 75% RDF + nano DAP spray at 4 ml l^{-1} (2.68) and 75% RDF + nano DAP spray at 2 ml l^{-1} (2.64) In contrast, absolute control recorded lower BC ratio (1.28).

The higher profit margins could be attributed to the synergistic benefits of an integrated nutrient management strategy, wherein the combination of nano fertilizers with recommended conventional fertilization enhanced both yield and produce quality while maintaining cost efficiency. This also could be attributed to lower Cost of cultivation and higher gross returns. These results align with earlier report by Pragathi *et al.* (2024) who also demonstrated that supplementing conventional nutrient regimes with nano-based formulations significantly improves economic returns in crop production systems.

Table 1 : Nitrogen, Phosphorus and Potassium uptake by rice bean as influenced by foliar spray of nano DAP

Treatment	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})		
	Seed	Stover	Total	Seed	Stover	Total	Seed	Stover	Total
T_1	20.9	11.5	32.4	2.35	1.31	3.66	4.09	13.88	17.97
T_2	23.2	12.4	35.6	2.62	1.52	4.15	4.79	14.70	19.49
T_3	31.2	21.1	52.3	4.18	3.22	7.40	6.22	23.20	29.42
T_4	35.2	30.7	65.9	5.72	6.99	12.71	7.23	27.35	34.57
T_5	39.7	33.6	73.3	7.01	9.12	16.14	8.37	30.82	39.19
T_6	42.0	35.9	77.9	7.48	9.75	17.23	8.86	32.88	41.74
T_7	12.6	6.5	19.1	1.02	0.88	1.91	2.79	9.50	12.29

T_8	13.5	7.4	20.9	1.17	0.92	2.17	2.98	9.62	12.60
T_9	30.1	20.7	50.8	4.26	3.89	8.15	6.57	22.94	29.18
T_{10}	37.3	29.3	66.6	6.38	7.56	13.94	7.71	28.22	35.93
T_{11}	7.3	3.3	10.5	0.68	0.54	1.45	1.65	5.58	7.23
S.Em. ±	**2.4**	**2.5**	**4.6**	**0.61**	**0.97**	**1.55**	**0.57**	**2.00**	**2.52**
CD @ 5%	**7.2**	**7.4**	**13.6**	**1.80**	**2.85**	**4.57**	**1.68**	**5.89**	**7.42**

Note: RDF: (20:40:0 - N: P_2O_5: K_2O kg ha^{-1}), Nano DAP and DAP sprayed at 30 DAS,
Treatment details are mentioned in material and methods

Table 2 : Economics of rice bean cultivation as influenced by foliar spray of nano DAP

Treatment	Cost of Cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	BC ratio
T_1	25947	54139	28192	2.09
T_2	27147	56080	28933	2.07
T_3	26546	70044	43498	2.64
T_4	27746	74301	46555	2.68
T_5	27144	81282	54138	2.99
T_6	28344	83875	55531	2.96
T_7	24750	41022	16272	1.66
T_8	25950	42057	16107	1.62
T_9	25944	69342	43398	2.67
T_{10}	26214	76984	50770	2.94
T_{11}	22550	28956	6406	1.28
S.Em. ±	**-**	**3349**	**3349**	**0.12**
CD @ 5%	**-**	**9880**	**9880**	**0.37**

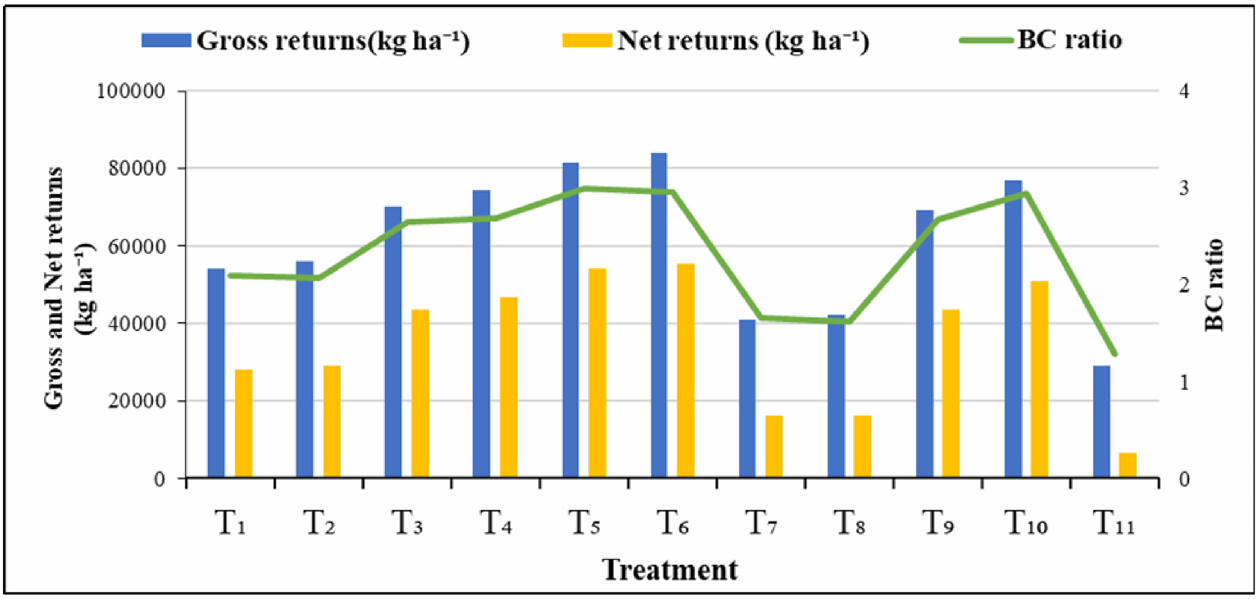

Fig. 1: Economics of rice bean as influenced by foliar spray of nano DAP

Conclusion

The treatment 100% RDF + nano DAP @ 4 ml l^{-1} sprayed at 30 DAS recorded significantly higher nutrient uptake and maximum gross returns, net returns over the rest of the treatments. However, 75% RDF + nano DAP @ 4 ml l^{-1} was found on par and recommendable as it was found economically feasible.

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