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Productivity, nutrient uptake, microbial activity and economics of pigeonpea (*Cajanus cajan* L.) as influenced by foliar application of nano fertilizers

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Abstract
A field experiment was conducted at Zonal Agricultural Research Station, Kalaburagi, during *kharif* season of 2022 to study the growth and yield of pigeonpea as influenced by foliar application of nano DAP. The experiment consisted with split plot design consisting of three levels of RDF in main plots *viz*., 50% RDF (M_1), 75% RDF (M_2) and 100% RDF (M_3) and four levels of nano DAP spray in sub plots *viz*., 2 ml litre^{-1} of water (S_1), 4 ml litre^{-1} of water (S_2), 6 ml litre^{-1} of water (S_3) and Seed treatment with Nano DAP @ 5ml kg^{-1} seeds (S_4). The results revealed that among different treatment combinations application of 100 percent RDF with foliar spray of nano DAP @ 4 ml litre^{-1} of water recorded significantly higher seed yield (1167 kg ha^{-1}), stalk yield (4173 kg ha^{-1}), N uptake (121.40 kg ha^{-1}), P uptake (17.34 kg ha^{-1}), K uptake (79.87 kg ha^{-1}), gross returns (Rs. 75843 ha^{-1}), net returns (Rs. 37444 ha^{-1}) and B:C ratio (1.98) as compared to other treatment combinations.

Keywords: Pigeonpea (*Cajanus cajan*), nano DAP, foliar application, recommended dose of fertilizer (RDF), seed treatment, split plot design

Introduction
Pigeonpea [*Cajanus cajan* (L) Millsp.] is a protein rich pulse crop native to the Indian sub-continent, belongs to the family leguminaceae and is also known as arhar or tur or redgram. It is the fifth prominent grain legume in the world and second in India after chickpea. In India, it is occupied an area of 90 percent of world's pigeonpea area and 85 percent of production. The pigeonpea occupies an area of 4.55 m ha, production of 3.38 m t and productivity of 729 kg ha^{-1} (Anon., 2018a) [1]. Pigeonpea holds first place in Karnataka both in area (1.48 m ha) and production (0.94 m t) with a productivity of 647 kg ha^{-1} (Anon., 2018b) [1]. It is largely grown in northern Karnataka, especially in Kalaburgi, Vijayapur, Bidar and Raichur districts. The rainfall is not only scanty but also erratic. Thus, soil moisture becomes most important limiting factor in pigeon pea production. Pigeonpea is mainly cultivated in marginal lands which are low in fertility. The mineral nutrient deficiency limits biological nitrogen fixation and ultimately reduces the yield. Both major and micronutrients are important for nodulation. In pigeon pea, fertilizers are applied as basal doses. It is a long duration crop and over the period the nutrients are lost and during its critical growth stages, nutrient deficiency is observed. In addition to causing losses, an excessive use of nitrogen fertilizers results in the decline in pulse nodulation. To avoid this, foliar spray of nano DAP at critical stages could be a sustainable alternative practice.

Among the major nutrients, phosphorus is the most essential nutrient required for crop growth and development. As Indian soils deficit in phosphorus, it is mainly supplied through fertilizers. Di-ammonium phosphate (DAP) is the phosphorus fertilizer commonly used in agriculture contains 18 percent nitrogen and 46 percent phosphorus and have the nutrient use efficiency (NUE) of around 15 - 20 percent. This indicates that up to 80 percent of phosphorus is lost and it is a major threat for the environment and human health. To reduce phosphorus fertilizer consumption nano phosphorus can be used. The nano-phosphorus fertilizer of IFFCO (Indian Farmers Fertilizer Cooperative) is a phosphorus-based formulation where phosphorus is coated

with polymer to make nano size particles. The nano phosphorus fertilizer is recommended to apply as a foliar spray and is said to contain 8 percent nitrogen and 16 percent phosphorus. At critical periods of crop growth, spraying nano phosphorus at a rate of 2-4 ml litre^{-1} of water prompts crop response, satisfies its nutritional need, and enhances nutrient availability in the rhizosphere. Due to its nano size, nano DAP fertilizer easily absorbs and enters through stomata when applied to leaves (Kumar *et al*., 2021) [3]. The present study on "Yield, nutrient uptake and economics of Pigeonpea (*Cajanus cajan* L.) as influenced by foliar application of nano DAP" aims to provide farmers with a practical and affordable option for maintaining sustainable crop yields with improved crop quality and increased nutrient use efficiency in the pigeon pea. This evaluation compares performance of the pigeon pea crop in response to the foliar application of nano DAP with conventional DAP.

Materials and Methods

A field experiment was conducted during kharif season, 2022 at Zonal Agricultural Research Station, Kalaburagi (Karnataka) to assess the growth, yield and quality of pigeonpea (*Cajanus cajan* L.) as influenced by foliar application of nano DAP. The soil of experimental field is clay loam soil with neutral soil pH (6.86), medium in available nitrogen (297.5 kg ha^{-1}), phosphorous (34.20 kg ha^{-1}) and potassium (34.20 kg ha^{-1}). The experiment was laid out in split plot design with three replications. The experiment consisted of 12 treatment combinations ***viz***., three levels of RDF (50, 75 and 100%) and four levels of nano DAP (2, 4, 6 ml per liter of water and seed treatment with nano DAP @ 5 ml per kg seed). Equal quantity of farm yard manure at the rate of 3 t ha^{-1} was applied to each plot three weeks prior to sowing**.** The nutrients *viz*., nitrogen, phosphorus and potassium were applied in the form of urea, DAP and MOP, respectively. At the time of sowing, for all the treatment combinations 50 percent of nitrogen and phosphorus and 100% potassium was applied for the plots. The remaining 50 percent nitrogen and phosphorus was supplied through foliar spray of nano DAP @ 2, 4 & 6 ml litre^{-1} of water in two splits at 30 & 45 DAS. Fodder sorghum variety GRG-811 was sown in line 60 cm apart. The crop was sown during last week of July and harvested when pods are completely dried. Five plants were randomly selected in each net plot area for taking observations on growth, yield and quality attributing parameters. The crop in each net plot was harvested separately as per treatment and the values were converted in to hectare basis and expressed in quintals. The samples were first dried under shade and then in electric oven at a temperature of 60 °C till constant to record dry matter of the plant. The data of all four cuts is pooled and statistically analyzed for interpretation of results.

Results and Discussion

Yield and nutrient uptake

The data pertaining to yield and nutrient uptake of pigeonpea at harvest as influenced by different levels of RDF and foliar sprays and seed treatment of nano DAP are presented in Table 1.

Among different levels of RDF, application of 100% RDF recorded significantly higher seed yield (1043 kg ha^{-1}), stalk yield (3862 kg ha^{-1}), N uptake (118.81 kg ha^{-1}), P uptake (16.97 kg ha^{-1}) and K uptake (78.17 kg ha^{-1}). But, it was found on par with 75% RDF and significantly lower yield parameters was registered in 50% RDF.

Among different levels of nano DAP, foliar spray of nano DAP @ 4 ml/litre recorded significantly higher seed yield (1051 kg ha^{-1}), stalk yield (3896 kg ha^{-1}), N uptake (116.20 kg ha^{-1}), P uptake (16.60 kg ha^{-1}) and K uptake (76.45 kg ha^{-1}) as compared to foliar spray of nano DAP @ 2 ml and 6 ml/litre of water. However, significantly lower growth parameters was registered with seed treatment of nano DAP @ 5 ml/kg of seeds at harvest.

The interaction effect between different levels of RDF and foliar sprays and seed treatment of nano DAP on yield parameters was found significant. Application of 100% RDF with foliar spray of nano @ DAP 4 ml litre^{-1} of water registered significantly higher seed yield (1167 kg ha^{-1}), stalk yield (4173 kg ha^{-1}), N uptake (121.40 kg ha^{-1}), P uptake (17.34 kg ha^{-1}) and K uptake (79.87 kg ha^{-1}). However, it was on par with 100% RDF + foliar spray of nano DAP @ 6 ml litre^{-1} of water, 75% RDF + foliar spray of nano DAP @ 4 ml litre^{-1} of water and 75% RDF + foliar application of nano DAP @ 6 ml litre^{-1} of water at harvest. The increase in nutrient uptake in 100 percent RDF with foliar spray of nano @ DAP 4 ml litre^{-1} of water was mainly because of the fact that along with the split application of nitrogen to the soil, direct supply of the nitrogen at target site (leaf) through foliar spray in nano form that could easily penetrate the leaves through the pores on the leaf surface like stomata and hydathodes which made nutrients readily available for plant growth. These results were in conformity with the findings of Pruthvi (2018) [4] and Avellan *et al*. (2021) [2].

Economics

The data pertaining to economics of pigeonpea cultivation as influenced by different levels of RDF and foliar sprays and seed treatment of nano DAP are presented in Table 2.

Among different levels of RDF, application of 100% RDF recorded numerically higher cost of cultivation (Rs. 40213 ha^{-1}), gross returns (Rs. 67802 ha^{-1}), net returns (Rs. 30590 ha^{-1}) and B:C ratio (1.82) followed by 75% RDF and numerically lower economics was registered with 50% RDF.

Among different levels of nano DAP, foliar spray of nano DAP @ 4 ml/litre recorded numerically higher cost of cultivation (Rs. 39900 ha^{-1}), gross returns (Rs. 68330 ha^{-1}), net returns (Rs. 31430 ha^{-1}) and B:C ratio (1.85) followed with foliar spray of nano DAP @ 2 ml and 6 ml/litre of water. However, numerically lower economics was registered with seed treatment of nano DAP @ 5 ml/kg of seeds at harvest.

Among interaction effect, application of 100% RDF with foliar spray of nano @ DAP 4 ml litre^{-1} of water registered numerically higher cost of cultivation (Rs. 41400 ha^{-1}), gross returns (Rs. 75843 ha^{-1}), net returns (Rs. 37444 ha^{-1}) and B:C ratio (1.98) followed with 100% RDF + foliar spray of nano DAP @ 6 ml litre^{-1} of water, 75% RDF + foliar spray of nano DAP @ 4 ml litre^{-1} of water and 75% RDF + foliar application of nano DAP @ 6 ml litre^{-1} of water at harvest.

Lower cost of cultivation was observed in absolute control due to absence of cost on fertilizers. The higher cost of cultivation, gross returns, net returns and B:C ratio recorded in 100% RDF + foliar application of nano DAP @ 4 ml litre^{-1} of water was mainly due to higher cost of fertilizer and also due to higher seed yield and profit. The results are in accordance with the findings of Rajesh (2021) [5] and Mallikarjuna (2021) [6].

Table 1: Yield and nutrient uptake of pigeonpea as influenced by different levels of RDF and foliar sprays and seed treatment of nano DAP

Treatments	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})
Main plot: RDF levels (M)					
M_1: 50%	837	3444	102.75	14.68	67.60
M_2: 75%	1002	3778	114.10	16.30	75.07
M_3: 100%	1043	3862	118.81	16.97	78.17
S.Em±	26.53	79	2.27	0.57	1.56
CD @ 5%	79.60	312	6.83	1.72	4.69
Sub plot: Nano DAP levels (S)					
S_1: 2 ml	931	3651	110.17	15.74	72.48
S_2: 4 ml	1051	3896	116.20	16.60	76.45
S_3: 6 ml	975	3687	113.78	16.25	74.86
S_4: Seed treatment	885	3543	107.40	15.34	70.66
S.Em±	29.44	80	1.05	0.26	0.90
CD @ 5%	88.34	238	3.19	0.78	2.75
Interaction effect (M X S)					
M_1 x S_1	817	3392	99.90	14.27	65.72
M_1 x S_2	898	3604	107.60	15.37	70.79
M_1 x S_3	830	3427	105.80	15.11	69.61
M_1 x S_4	802	3354	97.70	13.96	64.28
M_2 x S_1	973	3755	112.20	16.03	73.82
M_2 x S_2	1057	3843	118.25	16.90	78.08
M_2 x S_3	1037	3791	116.30	16.61	76.51
M_2 x S_4	909	3653	108.30	15.47	71.25
M_3 x S_1	1004	3807	118.40	16.91	77.89
M_3 x S_2	1167	4173	121.40	17.34	79.87
M_3 x S_3	1089	3913	119.60	17.04	78.45
M_3 x S_4	945	3623	116.20	16.60	76.45
S.Em±	48.53	131.50	2.11	0.28	1.46
CD @ 5%	145.60	394.50	6.35	0.85	4.37
CV (%)	12.91	13.92	12.23	13.10	12.85

Table 2: Economics of sunflower cultivation as influenced by different levels of RDF and Nano DAP

Treatments	Total Cost of Cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net Returns (Rs. ha^{-1})	B:C ratio
Main plot: RDF levels (M)				
M_1: 50%	37213	54379	20166	1.59
M_2: 75%	38713	65130	29418	1.82
M_3: 100%	40213	67802	30590	1.82
S.Em±	-	1945	1240	0.03
CD @ 5%	-	7640	4880	0.11
Sub plot: Nano DAP levels (S)				
S_1: 2 ml	38300	60512	25212	1.71
S_2: 4 ml	39900	68330	31430	1.85
S_3: 6 ml	39100	63359	27260	1.75
S_4: Seed treatment	37550	57547	22997	1.66
S.Em±	-	2340	1199	0.03
CD @ 5%	-	6950	3560	0.10
Interaction effect (M X S)				
M_1 x S_1	36800	53052	19252	1.57
M_1 x S_2	38400	58363	22963	1.65
M_1 x S_3	37600	53943	19343	1.56
M_1 x S_4	36050	52158	19108	1.58
M_2 x S_1	38300	63223	27923	1.79
M_2 x S_2	39900	70785	33885	1.92
M_2 x S_3	39100	67429	31329	1.87
M_2 x S_4	37550	59083	24533	1.71
M_3 x S_1	39800	65260	28461	1.77
M_3 x S_2	41400	75843	37444	1.98
M_3 x S_3	40600	68705	31105	1.83
M_3 x S_4	39050	61400	25350	1.70
S.Em±	-	4055	2070	0.05
CD @ 5%	-	12020	6170	0.17
CV (%)	-	12.26	12.51	12.17

Conclusion

Application of 100 percent RDF with foliar spray of nano DAP @ 4 ml litre^{-1} of water recorded significantly higher growth, yield and quality of pigeonpea.

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