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Effect of Nano DAP on Growth and Yield of Fenugreek (*Trigonella foenum-graecum* L.)

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Abstract
A field experiment entitled "Effect of Nano DAP on Growth and Yield of Fenugreek (*Trigonella foenum-graecum* L.)" was conducted during *rabi*, 2024-25 at Instructional Farm, School of Agricultural Sciences, Dabok, Udaipur to find out the effect of nano DAP on growth, yield and quality of fenugreek, to explore whether application of nano DAP can fulfil the recommended dose of fertilizers and to work out an economically viable treatment. The experiment consisted of 12 treatment combinations including RDF (50, 75 and 100%), nano DAP 6 ml l^{-1} (one and two spray) in combination or alone and control which were evaluated under randomized block design with 3 replications. The findings showed that the highest values for growth attributes *viz.*, plant height at 30, 60, 90 DAS and harvest, dry matter accumulation at and number of branches per plant as well as yield attributes and yield *viz.*, number of pods per plant, pod length, number of seeds per pod, test weight, seed and biological yield (1829 and 6616 kg ha^{-1}) were recorded with the application of treatment T_{12} [100% RDF + Nano DAP (6 ml l^{-1}) two spray] which was statistically at par with T_{11} [100% RDF + Nano DAP (6 ml l^{-1}) one spray]. Fenugreek crop recorded highest chlorophyll content with the application of treatment T_{12} [100% RDF + Nano DAP (6 ml l^{-1}) two spray]. The aforesaid treatment also fetched highest net return (₹105741 ha^{-1}) contrary highest B-C ratio (3.79) was recorded under treatment T_{10} (100% RDF). Therefore, application of 100% RDF + Nano DAP (6 ml l^{-1}) two spray may be recommended for fenugreek to obtain higher yield and net returns.

Keywords: Fenugreek, Nano DAP, Growth, Yield, Quality and Economics

1. Introduction
Fenugreek (*Trigonella foenum-graecum* L.), an essential autogamous seed spice, belongs to the Fabaceae family and the Papilionaceae subfamily. It is a diploid species with chromosomal number 2n=16. It is popularly grown as annual *rabi* crop in north India and generally known as 'methi'. The name fenugreek is derived from the species name "*foenum-graecum*" which translates to "Greek hay" (Flammang *et al*., 2004) [9]. It is thought to be indigenous to an area stretching from Iran to Northern India (Marzougui *et al*., 2007) [16]. The seed contain an alkaloid trigonellin (0.12-0.38%) is thought to reduce glycosuria in diabetes. The important steroid "Diosgenin" is used in synthesis of sex hormone and makes ovule contraceptive. The sapogenin, is an estrogen precursor and helps in managing menopause. The concentration of diosgenin varies from 0.86 to 2.2% in seed (Bochalia *et al*., 2011) [3]. Fenugreek is reported to have anti-diabetic, anti-fertility, anticancer, anti-microbial, anti-parasitic and hypocholesterolaemic effects (Al-Habori and Raman, 2002) [1]. Fenugreek seed contains carbohydrates (48%), followed by proteins (25.5%), mucilaginous matter (20%), fats (7.9%) and saponins (4.8%) (Rao and Sharma, 1987). Fenugreek is India's third most important seed spice, after coriander and cumin. Total area under cultivation of fenugreek in India is 1.56 lakh hectares with an annual production of 2.41 lakh tons during 2020-21. Fenugreek occupies prime place amongst the seed spices grown in northern India particularly in Rajasthan. Rajasthan is considered as "Fenugreek Bowl" of the country (Latye *et al*., 2016) [12]. Rajasthan is the major producer of fenugreek followed by Madhya Pradesh, Gujarat, West Bengal, Uttaranchal, Haryana (Spice Board of India, 2020-21). The average productivity of fenugreek in India is low (1215 kg ha^{-1}) which is required to be increased (Malav *et al*., 2018) [14].
Nano DAP is a nanotechnology based revolutionary input and a sustainable option for

farmers towards smart agriculture. Nano DAP is an efficient source of available nitrogen and phosphorous for all crops and helps in correcting their deficiencies in standing crops. Nano DAP formulation contains 8.0 per cent N (w/v) and 16 per cent P_2O_5 (w/v). Application of nano DAP leads to higher seed vigour, more chlorophyll, photosynthetic efficiency, better quality and increase in crop yield. Nano DAP fulfils the nutritional demand of crops without harming the environment. Nano-fertilizers outperform traditional fertilizers because they can triple nutrient efficacy, minimize the need for chemical fertilizers, make crops drought and disease resistant and are less harmful to the environment. It takes less time, produces more and decreases the amount of conventional fertilizer needed by at least 50% (Panda *et al.*, 2020) [19]. The term "nano" derives from the Greek word for "dwarf" which refers to one billionth of a metre, or 10^{-9}. Particles with at least one dimension smaller than 100 nm are termed as "nanoparticles" (Thakkar *et al.*, 2010) [27]. Nano-fertilizers offer large surface area sorption capacity, and controlled-release kinetics to specified areas, they have been termed as smart delivery method (Rameshaiah *et al.*, 2015; Solanki *et al.*, 2015) [22, 25].

Materials and Methods

In the *rabi* of 2024-25, the field experiment was carried out at the School of Agricultural Sciences, Instructional Farm in Dabok, Udaipur. There was 6.4 mm of rain overall throughout the crop growing season. Clay loam soil with a slightly alkaline response (pH 7.3), low organic carbon (0.58%), low nitrogen (254.4 kg ha^{-1}) and medium accessible phosphorus (21.5 kg ha^{-1}), but high potassium (353.2 kg ha^{-1}) was the soil type used in the experiment. Ten treatment combinations including four with 100% RDF along with vermicompost, FYM and PSB in combination or alone, five with 50% RDF along with vermicompost, FYM and PSB in combination or alone and control which were evaluated under randomized block design with 3 replications. On November 16, 2024, fenugreek crop was planted. To maximize plant stands, 25 kg ha^{-1} of seeds were utilized, with 30 cm between rows. The fertilizer dosage that was advised was maintained at 40:20:0 (N:P:K). During the whole growth season, two irrigations were given. In accordance with treatments, fertilizers were administered.

Results and Discussion

Effect of treatments

Growth attributes

The results (Table 4.1, 4.2 and 4.3) revealed that significant effect of nano DAP was recorded on different growth parameter as *viz.*, plant height, dry matter accumulation and number of leaves per plant over control which indicated that varying doses of treatments were effective in increasing the growth parameter of fenugreek. The highest plant height at 30, 60, 90 DAS and harvest (20.45, 46.31, 60.56 and 71.72 cm, respectively), dry matter accumulation at 60, 90 DAS and harvest (4.89, 12.07 and 17.48 g $plant^{-1}$, respectively) and number of branches per plant (7.13) were recorded superior with the application of T_{12} [100% RDF + Nano DAP (6 ml l^{-1}) two spray] which was statistically at par with T_{11} [100% RDF + Nano DAP (6 ml l^{-1}) one spray]. Liu and Lal (2014) observed similar results on soybean crops, stating that the use of nanoparticles boosted growth characteristics such as plant height and raised soybean growth rate by 32.6 per cent when compared to soybean provided with standard phosphatic fertilizer. Results published by Vaghar *et al.* (2020) [28] in soybean indicated that foliar application of iron, zinc and manganese nano-chelate, particularly in combination, might improve plant development, height, number of branches and yield contributing traits.

Yield attributes and yield

The results (Table 4.4 and 4.5) revealed that the application of nano DAP in fenugreek significantly influenced the yield attributes. Maximum number of pods per plant (29.28), pod length (12.25 cm), number of seeds per pod (16.18) and test weight (12.07) were recorded with the application of 100% RDF + Nano DAP (6 ml l^{-1}) two spray as compared to other treatments except 100% RDF + Nano DAP (6 ml l^{-1}) one spray. Seed and biological yield (1829 and 6616 kg ha^{-1}) were significantly higher with application of T_{12} [100% RDF + Nano DAP (6 ml l^{-1}) two spray] which was statistically at par with T_{11} [100% RDF + Nano DAP (6 ml l^{-1}) one spray]. The foliar application of NPK nano-fertilizers was shown to enhance chickpea yield attributes by increasing growth hormone activity and enhancing metabolic processes, which in turn prompted flowering, the number of pods and grain formation (Drostkar *et al.*, 2016) [8]. Thus, foliar application of nano DAP improves yield contributing characteristics along with yield. Similar results were reported by Kailas *et al.* (2017) [10] in pegionpea, Choudhary *et al.* (2018) [6], Mallikarjuna (2021) [15] in maize and Rajput *et al.* (2022) [21] in millet.

Quality parameters

It was observed (Table 4.6) that application of nano DAP had a significant effect on chlorophyll content of fenugreek. Maximum chlorophyll content (3.04 mg g^{-1}) was recorded with the application of treatment T_{12} [100% RDF + Nano DAP (6 ml l^{-1}) two spray] which was statistically at par with T_{11} [100% RDF + Nano DAP (6 ml l^{-1}) one spray]. The minimum values for chlorophyll content was recorded with treatment T_1 (Control). This might be due to the fact that use of inorganic fertilizers in combination with nano DAP may serve as an adequate nutrition that is prerequisite in protein biosynthesis which might have improved the nutrient uptake, ultimately resulted to more chlorophyll content and dry matter accumulation in fenugreek. Nano fertilizers, with their small particle size, which ensure efficient nutrient uptake and utilization, providing essential elements for metabolic processes. Maske *et al.* (2025) [17] noted that balanced application in nano form improves nutrient availability, leading to increased TSS content in chili fruits. Similar inferences were also concluded by Mishra *et al.* (2020) [18], Chauhan and Deepanshu (2023) [5] in chilli, Bolashetti *et al.* (2023) [4] in Onion and Khule *et al.* (2023) [11] in Linseed.

Economics

The results (Table 4.7) revealed that the application of nano DAP in fenugreek significantly influenced net return and B-C ratio. The maximum net return (₹105741 ha^{-1}) was recorded under T_{12} [100% RDF + Nano DAP (6 ml l^{-1}) two spray] which was statistically at par with T_9 [75% RDF + Nano DAP (6 ml l^{-1}) two spray], T_{10} (100% RDF) and T_{11} [100% RDF + Nano DAP (6 ml l^{-1}) one spray] whereas, maximum B-C ratio (3.79) was recorded under T_{10} (100%

RDF). The increased net return could be explained on the basis of increased yield under T_{12} [100% RDF + Nano DAP (6 ml l^{-1}) two spray] which was higher than rest of the treatments. The present results are consistent with the findings of Attri *et al*. (2023) [2] in rice, Singh *et al*. (2023) [24] in wheat, Dobriya *et al.* (2025) [7] in pearl millet and Rajpurohit *et al.* (2024) [20] and Yewale *et al*. (2025) [29] in chickpea.

Conclusion

On the basis of results procured from present investigation it may be concluded that under prevailing agro-climatic zone IVa of Rajasthan, a significant increase in growth, yield attributes, yield, quality, as well as net returns of fenugreek were found under application of T_{12} [100% RDF + Nano DAP (6 ml l^{-1}) two spray]. The maximum yield (1829 kg ha^{-1}) and net return (₹105741 ha^{-1}) were obtained with T_{12} [100% RDF + Nano DAP (6 ml l^{-1}) two spray]. Therefore, application of 100% RDF + Nano DAP (6 ml l^{-1}) two spray may be recommended for fenugreek to obtain higher yield and net returns. However, these are one-year results and need further experimentation for final recommendation.

Table 1: Effect of treatments on plant height and dry matter accumulation of fenugreek at successive growth stages

Treatments	Plant height (cm)				Dry mater accumulation (g $plant^{-1}$)			
	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest
Control	15.51	31.13	45.38	56.54	1.67	3.56	8.10	12.99
Nano DAP (6 ml l^{-1}) one spray	16.25	37.12	51.37	62.54	1.77	3.99	10.76	15.65
Nano DAP (6 ml l^{-1}) two spray	16.50	37.37	51.62	62.78	1.83	4.14	10.91	15.80
50% RDF	16.39	37.26	51.51	62.68	1.82	4.12	10.83	15.72
50% RDF + Nano DAP (6 ml l^{-1}) one spray	16.49	38.03	52.28	62.78	1.89	4.49	11.04	15.93
50% RDF + Nano DAP (6 ml l^{-1}) two spray	17.03	40.79	55.04	66.21	1.91	4.57	11.12	16.01
75% RDF	18.51	39.38	53.63	64.79	1.82	4.52	11.08	15.97
75% RDF + Nano DAP (6 ml l^{-1}) one spray	19.12	40.27	54.52	65.69	1.93	4.59	11.14	16.03
75% RDF + Nano DAP (6 ml l^{-1}) two spray	19.30	42.40	56.65	67.82	1.90	4.68	11.23	16.12
100% RDF	19.58	40.79	55.37	66.20	1.85	4.76	11.32	16.21
100% RDF + Nano DAP (6 ml l^{-1}) one spray	19.80	44.65	58.90	70.07	1.88	4.77	11.33	16.88
100% RDF + Nano DAP (6 ml l^{-1}) two spray	20.45	46.31	60.56	71.72	1.90	4.89	12.07	17.48
S.Em. ±	0.67	0.77	0.75	0.71	0.08	0.13	0.29	0.39
C.D. (P=0.05)	1.97	2.25	2.20	2.09	NS	0.37	0.86	1.14

Table 2: Effect of treatments on number of branches per plant, number of pods per plant, pod length, number of seeds per pod and test weight in fenugreek

Treatments	Number of branches per plant	Number of pods per plant	Pod length (cm)	Number of seeds per pod	Test weight (g)
Control	4.18	16.18	8.49	10.85	8.76
Nano DAP (6 ml l^{-1}) one spray	5.35	20.58	10.94	11.78	10.93
Nano DAP (6 ml l^{-1}) two spray	5.91	21.85	11.09	12.46	10.91
50% RDF	5.41	22.45	11.01	13.59	10.83
50% RDF + Nano DAP (6 ml l^{-1}) one spray	6.04	22.83	11.22	13.65	11.13
50% RDF + Nano DAP (6 ml l^{-1}) two spray	6.19	23.36	11.30	14.18	11.23
75% RDF	6.33	23.62	11.25	14.76	11.08
75% RDF + Nano DAP (6 ml l^{-1}) one spray	6.47	23.69	11.32	15.83	11.30
75% RDF + Nano DAP (6 ml l^{-1}) two spray	6.73	26.37	11.41	15.92	11.33
100% RDF	6.58	25.25	11.49	16.01	11.32
100% RDF + Nano DAP (6 ml l^{-1}) one spray	6.63	27.02	11.50	16.11	11.47
100% RDF + Nano DAP (6 ml l^{-1}) two spray	7.13	29.28	12.25	16.18	12.07
S.Em. ±	0.26	1.57	0.21	0.54	0.27
C.D. (P=0.05)	0.76	4.61	0.60	1.58	0.79

Table 3: Effect of treatments on yield, harvest index, chlorophyll content, net return and B-C

Treatments	Yield (kg ha^{-1})			Harvest index (%)	Chlorophyll content at 60 DAS (mg g^{-1})	Net return (₹ ha^{-1})	B-C ratio
	Seed	Haulm	Biological				
Control	1181	4027	5243	22.68	2.28	68215	2.78
Nano DAP (6 ml l^{-1}) one spray	1318	4112	5430	24.29	2.49	74050	2.60
Nano DAP (6 ml l^{-1}) two spray	1430	4127	5557	25.75	2.50	77909	2.40
50% RDF	1434	4210	5643	25.44	2.41	85507	3.37
50% RDF + Nano DAP (6 ml l^{-1}) one spray	1530	4329	5859	26.10	2.60	88589	3.02
50% RDF + Nano DAP (6 ml l^{-1}) two spray	1625	4340	5964	27.24	2.61	91198	2.73
75% RDF	1567	4477	6044	25.92	2.51	95080	3.69
75% RDF + Nano DAP (6 ml l^{-1}) one spray	1607	4426	6033	26.80	2.67	93756	3.15
75% RDF + Nano DAP (6 ml l^{-1}) two spray	1691	4754	6446	26.26	2.69	96484	2.85
100% RDF	1629	4636	6264	26.01	2.63	99359	3.79
100% RDF + Nano DAP (6 ml l^{-1}) one spray	1732	4523	6255	27.71	2.91	102300	3.38
100% RDF + Nano DAP (6 ml l^{-1}) two spray	1829	4787	6616	27.70	3.04	105741	3.09
S.Em. ±	44.70	168.28	181.44	0.81	0.06	3269	0.11
C.D. (P=0.05)	131.10	NS	532.16	NS	0.17	9587	0.33

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