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EFFECT OF NANO DAP ON NUTRIENT CONTENT, UPTAKE AND ECONOMICS OF SAFFLOWER (*CARTHAMUS TINCTORIUS* L.)

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ABSTRACT

A field experiment was conducted at ICAR- Krishi Vigyan Kendra, Hagari during *rabi*, 2024 to study the effect of nano DAP on nutrient content, uptake and economics of safflower. The experiment was laid in RCBD with nine treatments and replicated thrice. The results revealed that 100% RDF + foliar spray of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS recorded significantly higher nutrient uptake *viz*., nitrogen content, nitrogen uptake, phosphorus content, phosphorus uptake and economics *viz*., gross returns (93,781 Rs ha^{-1}), net returns (61,666 Rs ha^{-1}) and BC ratio (2.92). Further, it was found on par with 75% RDF combined foliar spray of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS. Whereas, least nutrient uptake and economic returns were noticed in the treatment foliar spray of nano DAP @ 4 ml l^{-1} at 30 DAS.
***Keywords* :** Safflower, nano DAP, Gross returns, Nutrient uptake.

Introduction

Safflower (*Carthamus tinctorius* L.) is an important oilseed crop belonging to the family Compositae (Asteraceae). The English name safflower probably evolved from saffiore to safflower. It is mentioned as kusumba in ancient scriptures. Presently, in India, it is most commonly known as karda in Marathi, kusum in Hindi, and kusube in Kannada. Among the 25 species of Carthamus, only *Carthamus tinctorius* is the cultivated type. It is widely valued for its diverse industrial uses, including the production of cosmetics, paints, varnishes, soaps, alkyd resins, waterproof leather goods, *roghans* for leather preservation and glass cement. The oilcake derived from safflower seeds serves as a nutritious livestock feed and has potential for human consumption once the bitter compounds are removed. Safflower oil is particularly rich in monounsaturated and polyunsaturated fatty acids, which contribute to cardiovascular health. Additionally, it finds broad applications in the cosmetic and pharmaceutical industries.

Safflower flowers are known to have many medicinal properties for curing several chronic diseases, hypertension, cardiovascular diseases, arthritis, spondylosis and sterility in both men and women and they are widely used in Chinese herbal preparations. All essential amino acids except tryptophan were present in safflower flowers in addition to protein, calcium, iron and potassium *etc.*

Nano fertilizers mark a revolutionary step forward in agriculture, bringing greater efficiency and sustainability to nutrient delivery. By leveraging nanotechnology, these fertilizers are engineered with particles at the nanometre scale, greatly enhancing their solubility and availability to plants. One of their key benefits is the ability to deliver nutrients precisely and release them in a controlled manner, which boosts nutrient absorption by crops while minimizing waste. As a result, nano fertilizers not only increase crop yields but also reduce the environmental footprint compared to traditional fertilizers.

On the other hand, the green revolution expanded the use of chemical fertilizers, resulting in improved output, but it also posed an environmental risk. The nutrient use efficiency of conventional fertilizers is very low. To address all the difficulties of soil-applied fertilizers like fixation, immobilization, volatilization, leaching and runoff to reduce all these losses, we should think of an alternate technology such as nanotechnology to precisely deliver the correct quantity of nutrients and other inputs required by crops in a suitable proportion that promotes productivity while ensuring environmental safety.

Nano DAP (Liquid) is a source of nitrogen and phosphorus. Along with nitrogen, phosphorus is also an important plant nutrient. Phosphorus (P) is vital for plant growth and is found in every living plant cell. It is involved in several key plant functions, including energy transfer, photosynthesis, transformation of sugars and starches, nutrient movement within the plant and transfer of genetic characteristics from one generation to the next. Nano DAP foliar spray represents a significant advancement in agricultural nutrition, offering enhanced benefits over conventional fertilizers. This innovation involves the application of nutrient particles at the nanoscale, which dramatically increases their solubility and bioavailability. The primary advantage of nano DAP foliar spray is its ability to deliver essential nutrients like nitrogen and phosphorus directly to the plant leaves. This targeted application ensures that nutrients are efficiently absorbed and utilized, leading to improved plant growth and development. Keeping these points in view, the present investigation is planned to carry out to study with an objective to study the effect of nano DAP on nutrient content, uptake and economics of safflower.

Materials and Methods

The experiment was conducted during *rabi*, 2024 at Krishi Vigyan Kendra, Hagari (UAS, Raichur) which is situated in Northern Dry Zone of Karnataka (Zone-III) at Latitude of 15° 13' North, Longitude of 77° 05' East with an Altitude of 414 meters above mean sea level. The soil sample of the experimental site was medium deep clay soil in texture.

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications and nine treatments. The treatments are T_1 : 100 % RDF + foliar spray of 2ml l^{-1} of nano DAP at 30 DAS and 45 DAS, T_2 : 75 % RDF + foliar spray of 2ml l^{-1} of nano DAP at 30 DAS and 45 DAS, T_3 : 50 % RDF + foliar spray of 2ml l^{-1} of nano DAP at 30 DAS and 45 DAS, T_4 : 100 % RDF + foliar spray of 4ml l^{-1} of nano DAP at 30 DAS, T_5 : 75 % RDF + foliar spray of 4ml l^{-1} of nano DAP at 30 DAS, T_6 : 50 % RDF + foliar spray of 4ml l^{-1} of nano DAP at 30 DAS, T_7 : 100% RDF, T_8 : 100 % RDF + 2% DAP foliar spray at 30 DAS and T_9 : Foliar spray of 4ml l^{-1} of nano DAP at 30 DAS.

The seed and stover sample collected from each plot at harvest were dried in oven at 65 °C till a constant weight. These samples were grounded in laboratory mill, passed through 40 mm mesh sieve and used for estimating of N and P contents. Total nitrogen was determined by Kjeldahl's method, Phosphorus was estimated by Vanadomolybdate method. 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).

Results and Discussion

Nitrogen content and uptake

Significantly higher nitrogen content was observed in the treatment which received 100% RDF + foliar spray of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS (3.73% in the seed and 0.59% in the stover) as compared to other treatments. However, this result was on par with treatment received 75% RDF + foliar spray of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS (3.52% in the seed and 0.56% in the stover). In contrast, notably lower nitrogen content was recorded in treatment received only foliar application of nano DAP @ 4 ml l^{-1} at 30 DAS (1.98% in the seed and 0.31% in the stover) as compared to other treatments (Table 1).

Among all the treatments, significantly lower nitrogen uptake was recorded in both seed and stover, as well as total nitrogen uptake, in the treatment which received foliar application of nano DAP @ 4 ml l^{-1} at 30 DAS (11.78, 4.91 and 16.69 kg ha^{-1}, respectively) as compared to other treatments. In contrast, significantly higher nitrogen uptake was observed in the treatment (T_1), which received 100% RDF + foliar spray of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS in seed, stover and total (62.51, 18.92 kg and 81.42 kg ha^{-1} respectively) as compared to other treatments. However, this result was found on par with 75% RDF + foliar application of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS in seed, stover and total (55.93, 17.61 and 73.54 kg ha^{-1}, respectively).

The enhanced nitrogen uptake observed in the treatment received 100% RDF with foliar application of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS can be attributed to several factors. The basal application of nitrogen to the soil, combined with the direct foliar delivery of nitrogen in its nano form, facilitated effective nutrient uptake. Nano DAP particles, due to their diminutive size, readily penetrate leaf surfaces through stomata and hydathodes, making nitrogen more readily accessible for plant assimilation and growth. This approach ensures that nitrogen is efficiently utilized by the plant. These findings align with the research conducted by Verma *et al.* (2022) and Maheta *et al.* (2023).

Phosphorus content and uptake

Significantly higher phosphorus content was noticed in the 100% RDF + foliar spray of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS in both seed and stover (0.66 and 0.31 %, respectively) as compared to other treatments. However, it was found to be on par with treatment, 75% RDF + foliar spray of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS (0.63 and 0.30 %, respectively). Significantly lower phosphorus content was recorded with treatment, foliar application of nano DAP @ 4 ml l^{-1} at 30 DAS (0.43 and 0.14 %, respectively) as compared to other treatments. (Table 2)

Among the different treatments, markedly lower phosphorus uptake by seed, stover and total uptake was observed in the treatment with only foliar application of nano DAP @ 4 ml l^{-1} at 30 DAS (2.56, 2.17 and 4.78 kg ha^{-1}, respectively) as compared to other treatments. In contrast, significantly higher phosphorus uptake was recorded in the treatment that received 100% RDF + foliar spray of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS, where uptake values for seed, stover and total phosphorus were (11.04, 9.89 and 20.93 kg ha^{-1}), respectively as compared to other treatments. This result was found on par with the treatment, 75% RDF + foliar application of nano DAP @ 2 ml l^{-1} (10.01, 9.44 and 19.45 kg ha^{-1}, respectively).

Significantly enhanced phosphorus uptake was observed with the application of 100% RDF coupled with a foliar spray of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS. This is attributed to the unique properties of nano-sized nutrients, which possess an extensive surface area and particle dimensions smaller than the pore sizes of plant leaves. These characteristics facilitated superior penetration through the leaf surfaces, thereby optimizing the uptake of phosphorus and nitrogen. The nanoparticles, owing to their diminutive size, are adept at navigating the stomatal and hydathode openings on leaves, ensuring a more efficient assimilation of these essential nutrients. Consequently, these results in augmented nutrient uptake and enhanced overall plant growth. These findings align with the observations reported by Choudhary *et al.* (2018) and Hagab *et al.* (2018).

Economic analysis (Table 3 and Figure 1)

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

The higher cost of cultivation was incurred with the treatment of 100% RDF + foliar application of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS (Rs. 32,115 ha^{-1}) followed by treatment that received 100% RDF as basal dose with foliar application of nano DAP @ 4 ml l^{-1} at 30 DAS (Rs.31,615 ha^{-1}), 75% RDF + foliar application of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS (Rs.31,323 ha^{-1}), 75% RDF as basal dose with foliar application of nano DAP @ 4 ml l^{-1} at 30 DAS (Rs.30,823 ha^{-1}). Conversely, the lower cost of cultivation was realized with the treatment that received a foliar application of nano DAP @ 4 ml l^{-1} at 30 DAS (Rs. 26,800 ha^{-1}).

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

Gross returns varied significantly among the treatments, with the higher returns recorded for the treatment which received 100% RDF + foliar spray of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS (Rs. 93,781 ha^{-1}). This was statistically on par with the treatment which received 75% RDF + foliar spray of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS (Rs. 88,984 ha^{-1}). In contrast, the lower gross returns (Rs. 33,320 ha^{-1}) were recorded in the treatment that received a foliar spray of nano DAP @ 4 ml l^{-1} at 30 DAS.

Net returns (Rs. ha^{-1})

The higher net returns were recorded for the treatment that received 100% RDF + foliar application of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS (Rs. 61,666 ha^{-1}). This was statistically on par with the treatment that received 75% RDF + foliar spray of nano DAP @ 2 ml l^{-1} at the same intervals (Rs. 57,661 ha^{-1}). In contrast, the lower net returns (Rs. 6,520 ha^{-1}) were observed in the treatment that received only a foliar application of nano DAP @ 4 ml l^{-1} at 30 DAS.

Benefit cost ratio (B:C)

The benefit-cost ratio showed significant variation among treatments as influenced by different levels of RDF and foliar application of nano DAP. The higher BC ratio (2.92) was recorded in the treatment that received 100% RDF as basal dose combined with a foliar spray of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS, which was statistically on par with the treatment that received 75% RDF + foliar application of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS (2.84). In contrast, the lower BC ratio (1.24) was observed in the treatment which received only a foliar spray of nano DAP @ 4 ml l^{-1} at 30 DAS.

The gross returns, net returns and higher BC ratio obtained with the combined application of 100% RDF and nano DAP is attributed to improved profitability per unit of investment. This integrated nutrient management approach maximized yield and quality while ensuring efficient use of inputs, resulting in higher economic returns. The enhanced nutrient uptake and utilization, facilitated by nano-scale fertilizers, contributed to better crop performance and, consequently, superior profit margins. Similar trends were reported by Sankar *et al.* (2020), Yadav *et al.* (2021), Asha Kiran (2022) and Choudhary *et al.* (2022), who noted that the integration of nano fertilizers with conventional nutrient practices significantly improved the benefit-cost ratio by enhancing yield and optimizing input efficiency.

Table 1 : Nitrogen content and uptake by safflower as influenced by the different levels of RDF and foliar application of nano DAP

Treatments	N Content (%)		N Uptake (kg ha^{-1})		
	Seed	Stover	Seed	Stover	Total
T_1	3.73	0.59	62.51	18.92	81.42
T_2	3.52	0.56	55.93	17.61	73.54
T_3	2.19	0.41	19.43	8.68	28.11
T_4	3.14	0.51	46.16	14.86	61.04
T_5	3.10	0.50	45.11	14.59	59.70
T_6	2.04	0.40	15.46	7.42	22.88
T_7	2.67	0.48	37.70	13.37	51.07
T_8	2.90	0.49	41.53	13.64	55.17
T_9	1.98	0.31	11.78	4.91	16.69
S.Em. ±	**0.09**	**0.01**	**2.30**	**0.47**	**2.64**
C.D. (P=0.05)	**0.27**	**0.04**	**6.90**	**1.40**	**7.90**

Note: RDF- Recommended doses of fertilizers (40: 40: 12.5 - N: P_2O_5: K_2O kg ha^{-1})
DAP- Di-ammonium Phosphate, DAS- Days after sowing

Table 2 : Phosphorus content and uptake by safflower as influenced by the different levels of RDF and foliar application of nano DAP

Treatments	P Content (%)		P Uptake (kg ha^{-1})		
	Seed	Stover	Seed	Stover	Total
T_1	0.66	0.31	11.04	9.89	20.93
T_2	0.63	0.30	10.01	9.44	19.45
T_3	0.49	0.19	4.35	4.02	8.37
T_4	0.57	0.27	8.38	7.88	16.26
T_5	0.55	0.25	8.00	7.25	15.25
T_6	0.46	0.18	3.49	3.34	6.83
T_7	0.51	0.21	7.20	5.85	13.05
T_8	0.53	0.22	7.59	6.10	13.69
T_9	0.43	0.14	2.56	2.22	4.78
S.Em. ±	0.02	0.01	0.43	0.22	0.50
C.D. (P=0.05)	0.05	0.02	1.30	0.65	1.50

Note: RDF- Recommended doses of fertilizers (40: 40: 12.5 - N: P_2O_5: K_2O kg ha^{-1})
DAP- Di-ammonium Phosphate, DAS- Days after sowing

Table 3 : Economics of safflower cultivation as influenced by the different levels of RDF and foliar application of nano DAP

Treatments	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C
T_1	32115	93781	61666	2.92
T_2	31323	88984	57661	2.84
T_3	30533	49672	19139	1.63
T_4	31615	82320	50705	2.60
T_5	30823	78288	47465	2.54
T_6	30033	42448	12415	1.41

T_7	27947	68768	40821	2.46
T_8	28615	71848	43233	2.51
T_9	26800	33320	6520	1.24
S.Em. ±	**-**	**2116**	**2116**	**0.07**
C.D. (P=0.05)	**-**	**6419**	**6419**	**0.22**

Note: RDF- Recommended doses of fertilizers (40: 40: 12.5 - N: P_2O_5: K_2O kg ha^{-1})
DAP- Di-ammonium Phosphate, DAS- Days after sowing

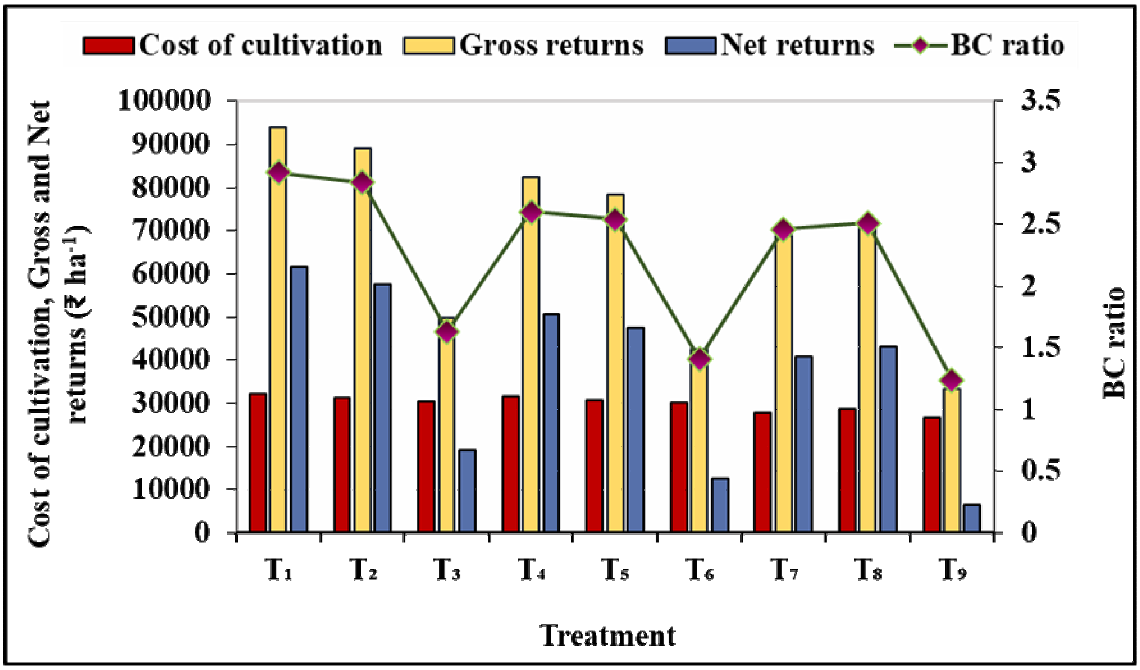

Fig. 1: Economics of safflower as influenced by different levels of RDF and foliar application of nano DAP

Conclusions

1. Application of 100% RDF + foliar spray of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS was recorded higher nitrogen, phosphorus content and uptake and maximum gross returns, net returns and B:C over rest of the treatments, which was found on par with 75% RDF + foliar spray of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS. Further, foliar spray of nano DAP at 4 ml l^{-1} at 30 DAS recorded lower nitrogen, phosphorus content and uptake and economics of safflower cultivation.
2. Soil application of 75% RDF along with foliar spray of nano DAP @ 2 ml l^{-1} at 30 and 45 DAS was found economically feasible and effectively replaces 25% of soil applied RDF thereby, helps in maintaining the soil health in a long run.

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