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EFFECT OF NANO DAP ON YIELD, NUTRIENT CONCENTRATION AND NUTRIENT UPTAKE BY FINGER MILLET

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ABSTRACT

A field experiment titled "Effect of nano DAP on yield, nutrient concentration and nutrient uptake by finger millet (*Eleusine coracana* L.)" was conducted at ARS, Dhadesugur during *Kharif*-2023, using Randomized Complete Block Design with eight treatments and replicated three times. The results indicated that treatment T_8 (100% RDF + Foliar spray of Nano DAP @ 4 ml L^{-1} at tillering and booting stages) recorded significantly higher grain yield (4117 kg ha^{-1}) and straw yield (5986 kg ha^{-1}), which were on par with T_7 (100% RDF only) grain yield (3899 kg ha^{-1}) and straw yield (5833 kg ha^{-1}) and T_6 (75% RD of N and P + 100% RDK + Foliar spray of Nano DAP @ 4 ml L^{-1}) grain yield (3773 kg ha^{-1}) and straw yield (5651 kg ha^{-1}). The lowest yields were observed in T_1 (Absolute control). Additionally, a similar trend was seen in nutrient concentration and uptake. This approach not only maximizes crop productivity but also proves economically viable by generating higher net returns for farmers. Thus, the foliar spray of Nano DAP at critical growth stages, along with RDF, effectively boosts crop yields.
Keywords**:** Nano DAP, finger millet, nutrients.

Introduction

Millet refers to a group of small-seeded grasses, primarily cultivated in dry, marginal lands. Among these, finger millet (*Eleusine coracana* L.) is especially significant for its resilience in low-rainfall regions. India is the largest producer of finger millet and Karnataka is the leading state in terms of production. Despite its nutritional benefits and adaptability, Indian agriculture faces challenges such as stagnating yields, nutrient deficiencies and improper fertilizer use, exacerbated by factors like climate change and declining soil health.

Nanotechnology offers a promising solution to these agricultural challenges by improving nutrient delivery and utilization. Conventional fertilizers often lead to nutrient losses through runoff, volatilization and poor soil absorption, resulting in poor crop growth and environmental degradation. In this context, nano fertilizers, developed by institutions like IFFCO, aim to improve nutrient uptake and reduce environmental impacts. These fertilizers, including liquid nano urea and nano DAP (di-ammonium phosphate), are designed to enhance plant health and productivity by delivering nutrients more efficiently to plant tissues through foliar spray.

A field experiment entitled "Effect of nano DAP on yield, nutrient concentration and nutrient uptake by finger millet (*Eleusine coracana* L.)" was conducted to assess the impact of nano DAP on yield and nutrient dynamics at different growth stages. The study explores how nano DAP influences the uptake of essential nutrients like nitrogen and phosphorus, critical for plant growth and resilience. By evaluating the potential of nano DAP in improving crop yield and nutrient efficiency, this research contributes to advancing sustainable agricultural practices and food security, particularly for resource-poor farmers.

Material and Methods

A field experiment was conducted at the Agricultural Research Station, Dhadesugur, University of Agricultural Sciences, Raichur, Karnataka, located in agroclimatic zone III (Northern Dry Zone). The geographical coordinates are 15° 69' N latitude and 76° 89' E longitude, with an elevation of 358 meters above sea level. The soil at the experimental site is clayey, classified under *vertisols*, with a pH of 8.33 and an electrical conductivity (EC) of 0.50 dS m^{-1}. It was low in available nitrogen (269 kg ha^{-1}), medium in phosphorus (35.7 kg ha^{-1}) and potassium (315 kg ha^{-1}). The DTPA-extractable micronutrient concentrations were as follows: zinc (0.42 mg kg^{-1}), iron (8.26 mg kg^{-1}), copper (1.22 mg kg^{-1}) and manganese (10.41 mg kg^{-1}).

The experiment was laid out in a Randomized Complete Block Design (RCBD) with eight treatments, replicated three times. The finger millet variety used was HR-13. The treatments included: T_1: Absolute control, T_2: 100% RDK only, T_3: Foliar spray of nano DAP @ 4 ml L^{-1} at tillering and booting stages, T_4: T_2 + Foliar spray of nano DAP @ 4 ml L^{-1}, T_5: 50% RD of N and P + 100% RDK + Foliar spray of nano DAP @ 4 ml L^{-1}, T_6: 75% RD of N and P + 100% RDK + Foliar spray of nano DAP @ 4 ml L^{-1}, T_7: 100% RDF only and T_8: T_7 + Foliar spray of nano DAP @ 4 ml L^{-1}. The recommended dose of fertilizer was 100:50:50 kg N: P_2O_5: K_2O ha^{-1}, with 50% of N, all of P and K applied as basal and the remaining N top-dressed at tillering.

Grain and straw yields were recorded at harvest and economic analysis was conducted based on the prevailing market prices. Soil and plant analysis were performed using standard analytical methods, with data analyzed through Fisher's method of analysis of variance as described by Panse and Sukhatme (1967).

Results and Discussion

Effect of nano DAP on grain yield

The highest grain yield (4117 kg ha^{-1}) was observed in treatment T_8 (100% RDF + foliar spray of nano DAP at 4 ml L^{-1} at tillering and booting stages), followed closely by T_7 (100% RDF only) (3899 kg ha^{-1}) and T_6 (75% RD of N and P + 100% RDK + foliar spray of nano DAP) (3773 kg ha^{-1}). The lower grain yield (1880 kg ha^{-1}) was recorded in T_1 (absolute control) (Table-1). The significant improvement in grain yield in T_8 can be attributed to the enhanced nutrient availability from nano DAP. Studies by Adhikari *et al*. (2014) demonstrated that nano-phosphorus improves phosphorus absorption and utilization, leading to higher photosynthetic efficiency and biomass production. Nano fertilizers enhance nutrient uptake efficiency, as demonstrated by Tarafdar *et al*. (2014), who showed increased wheat yields with nano fertilizers. The better assimilation of nutrients improves source-sink relationships, with more photosynthates being directed to grain filling (Taiz and Zeiger, 2006). These factors collectively contribute to the significantly higher grain yield observed in treatment T_8.

Effect of nano DAP on straw yield

Similarly, the higher straw yield (5986 kg ha^{-1}) was recorded in T_8 (100% RDF + foliar spray of nano DAP at tillering and booting stages), followed by T_7 (5833 kg ha^{-1}) and T_6 (5651 kg ha^{-1}), with the lowest straw yield (3129 kg ha^{-1}) in T_1 (absolute control) (Table-1). The increase in straw yield with the application of nano DAP is linked to improved phosphorus uptake, which plays a vital role in enhancing root development and overall plant resilience, as reported by Adhikari *et al*. (2014). Khan and Khan (2017) found that nano fertilizers, such as nano DAP, enhance nutrient transport to plant tissues, boosting growth and increasing photosynthetic efficiency. The extended grain filling period and better nutrient distribution to vegetative tissues, as noted by Ober and Sharp (2012), contribute to the higher biomass accumulation and resulted in higher straw yield. Thus, nano DAP application proved effective in maximizing both grain and straw yields in finger millet.

Table 1: Effect of nano DAP on grain and straw yield of finger millet

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1	1880	3129
T_2	2055	3294
T_3	2219	3545
T_4	2647	4220
T_5	3228	5111
T_6	3773	5651
T_7	3899	5833
T_8	4117	5986
S. Em. ±	**135**	**191**
C.D. at 5%	**409**	**578**

Effect of nano DAP on N and P content at various growth stages

The application of Nano DAP significantly enhanced nitrogen and phosphorus content in finger millet and is presented in Table-2. There was no significant difference between treatments with respect to both nitrogen and phosphorus content at tillering stage.

At the booting stage, nitrogen content was higher in treatment T_8 (100% RDF + foliar spray of nano DAP at 4 ml L^{-1} each at tillering and booting stages) with 2.40%, followed by T_6 (2.36%) and T_7 (2.31%), while the lower was in T_1 (1.49%). At harvest, T_8 also had the highest nitrogen content in grain (1.42%) and straw (0.77%). The increased nitrogen content in T_8 is attributed to the combination of 100% RDF and 8% nitrogen in nano DAP, which has high solubility and absorption efficiency (Liu and Lal, 2015), supporting photosynthesis and plant growth (Fageria, 2009).

For phosphorus, the higher content at the booting stage (0.38%) was recorded in T_8 and T_6, with T_7 closely following (0.36%). At harvest, T_8 had the highest phosphorus content in both grain (0.58%) and straw (0.35%), while T_1 had the lower content. The combined effect of 100% RDF and 16% phosphorus in nano DAP increased phosphorus availability. Foliar application of nano DAP improves phosphorus uptake by avoiding soil fixation, enhancing its utilization during critical growth stages (Adhikari *et al*., 2014; Liu and Lal, 2015). This results in higher phosphorus content and improved plant nutrition.

Table 2: Effect of nano DAP on nitrogen and phosphorus content (%) at various growth stages of finger millet

Treatment	Nitrogen content (%)				Phosphorus content (%)			
	Tillering stage	Booting stage	At harvest		Tillering stage	Booting stage	At harvest	
			Grain	Straw			Grain	Straw
T_1	1.82	1.49	1.01	0.49	0.18	0.22	0.39	0.18
T_2	1.84	1.55	1.13	0.51	0.19	0.23	0.40	0.19
T_3	1.94	1.61	1.18	0.53	0.20	0.25	0.43	0.21
T_4	1.95	1.73	1.21	0.56	0.20	0.26	0.45	0.22
T_5	2.10	1.97	1.23	0.62	0.22	0.31	0.48	0.27
T_6	2.12	2.36	1.40	0.75	0.22	0.38	0.54	0.33
T_7	2.16	2.31	1.41	0.76	0.23	0.37	0.55	0.34
T_8	2.17	2.40	1.42	0.77	0.23	0.38	0.58	0.35
S. Em. ±	**0.09**	**0.10**	**0.06**	**0.03**	**0.04**	**0.02**	**0.02**	**0.01**
C.D. at 5%	**NS**	**0.30**	**0.18**	**0.09**	**NS**	**0.05**	**0.05**	**0.04**

Effect of nano DAP on nutrient uptake at harvest

The uptake of nutrients by finger millet was significantly influenced by the application of nano DAP, as evidenced by the data (Table-3) on nitrogen, phosphorus and potassium uptake. The higher nitrogen uptake in grain (58.27 kg ha^{-1}) and straw (46.09 kg ha^{-1}) was recorded in T_8, which included 100% RDF and foliar sprays of nano DAP during critical growth stages. In contrast, the lower nitrogen uptake was observed in the absolute control treatment (T_1). The superior nitrogen uptake in T_8 can be attributed to the combined effects of comprehensive soil fertilization and targeted foliar applications, where the nano DAP provided readily available nitrogen, enhancing plant growth and development (Sahu *et al.*, 2022). For phosphorus, T_8 also showed the higher phosphorus uptake (24.01 kg ha^{-1} in grain and 21.16 kg ha^{-1} in straw). The foliar application of nano DAP, which contains 16% phosphorus, improved nutrient penetration and absorption, particularly during the critical tillering and booting phases, ensuring sufficient phosphorus for grain development (Kolay, 2000; Chen *et al*., 2017). Potassium uptake was higher in T_8 (27.10 kg ha^{-1} in grain and 80.90 kg ha^{-1} in straw). The presence of potassium in the 100% RDF treatment ensured adequate supply, while the foliar application of nano DAP improved overall nutrient absorption. The higher potassium uptake in straw reflects its role in vegetative functions, supporting enzyme activation and photosynthesis (Fageria and Baligar, 2005). Overall, the integrated nutrient management strategy in T_8 facilitated optimal nutrient uptake, enhancing finger millet growth and productivity.

Table 3: Effect of nano DAP on nutrient uptake (kg ha^{-1}) by grain and straw of finger millet at harvest

Treatment	N uptake			P uptake			K uptake		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1	18.76	15.62	34.38	7.32	5.63	12.95	7.93	29.05	36.98
T_2	23.34	16.73	40.07	8.21	6.25	14.46	10.97	36.16	47.13
T_3	26.18	18.96	45.14	9.59	7.41	17.00	12.31	42.85	55.16
T_4	31.92	23.82	55.74	12.00	9.26	21.26	15.50	51.59	67.09
T_5	39.79	31.87	71.66	15.50	13.60	29.10	17.87	62.86	80.73
T_6	53.00	42.63	95.63	20.35	18.88	39.23	24.18	74.64	98.81
T_7	55.03	44.51	99.54	21.59	19.89	41.48	25.57	77.72	103.29
T_8	58.27	46.09	104.36	24.01	21.16	45.17	27.10	80.90	108.00
S. Em. ±	**2.13**	**1.85**	**2.90**	**1.27**	**0.82**	**2.00**	**1.18**	**3.32**	**3.05**
C.D. at 5%	**6.46**	**5.63**	**8.80**	**3.86**	**2.49**	**6.07**	**3.58**	**10.08**	**9.25**

Chemical properties of soil after harvest of finger millet

The study investigated the effect of nano DAP on soil chemical properties after the harvest of finger millet and is presented in Table-4. The soil pH remained consistent among treatments, ranging from 8.15 to 8.26, indicating no significant change due to the soil's buffering capacity, as noted by Jones *et al*. (2020). Electrical conductivity showed a slight increase, with values between 0.49 and 0.53 dS m^{-1}, likely resulting from the higher levels of soluble salts introduced through fertilizer applications (Suresh, 2017). Organic carbon content varied from 3.48 to 3.76 g kg^{-1} across treatments, with no significant differences, primarily due to the consistent addition of farmyard manure (FYM), as supported by Raghavendra *et al*. (2013). While no substantial changes in organic carbon were detected, nutrient addition enhanced microbial activity and decomposition rates, contributing positively to soil quality (Santhosh, 2018).

Regarding available nutrients, Treatment T_8, which included 100% recommended dose of fertilizers (RDF) combined with a foliar spray of nano DAP, resulted in significantly higher levels of available nitrogen (250.44 kg ha^{-1}), phosphorus (27.17 kg ha^{-1}) and potassium (290.87 kg ha^{-1}). This outcome can be attributed to several factors like application of 100% RDF ensures that plants receive essential nutrients for optimal growth, significantly enhancing soil fertility. The direct application of nano DAP via foliar spray increases nutrient absorption due to the higher surface area-to-volume ratio of nano-sized particles, facilitating improved uptake during critical growth stages such as tillering and booting when nutrient demand is highest. This method reduces the dependency on soil nutrients and enhances nutrient availability, as foliar applications minimize losses from leaching, volatilization and immobilization common with soil-applied fertilizers. The combination of soil-applied fertilizers and foliar sprays creates a synergistic effect that optimizes nutrient availability and supports greater crop biomass and yield. Despite variations among treatments, a general decline in available nitrogen, phosphorus and potassium was observed, likely due to the continuous uptake by the crop as biomass increased during its growth stages.

Additionally, DTPA-extractable micronutrients, including zinc, iron, copper and manganese, showed no significant variations after harvest, although a decline was noted compared to initial levels. This reduction is linked to the uptake of micronutrients by the crop without external additions and these results are in accordance with the findings of Singh *et al*. (1995) and Yadav and Kumar (2009). Overall, Treatment T_8 significantly improved soil nutrient status and contributed to enhanced plant health.

Table 4: Effect of nano DAP on chemical properties of soil after harvest of finger millet

Treatment	pH	EC (dSm^{-1})	Organic carbon (g kg^{-1})	Available nutrients (kg ha^{-1})						
				N	P	K	Zn	Fe	Cu	Mn
T_1	8.15	0.49	3.48	188.85	21.27	235.37	0.37	7.90	0.92	9.99
T_2	8.15	0.52	3.52	198.08	21.76	242.30	0.38	7.97	0.94	10.14
T_3	8.20	0.52	3.55	206.37	22.85	243.96	0.39	8.05	0.97	10.21
T_4	8.16	0.52	3.56	210.87	23.68	247.85	0.39	8.03	0.96	10.26
T_5	8.21	0.51	3.62	226.84	24.38	257.05	0.39	8.06	0.97	10.31
T_6	8.22	0.50	3.72	243.38	26.57	282.75	0.40	8.07	0.97	10.33
T_7	8.25	0.53	3.76	248.47	26.66	285.16	0.40	8.08	0.98	10.36
T_8	8.26	0.53	3.76	250.44	27.17	290.87	0.40	8.08	0.98	10.37
S. Em. ±	**0.34**	**0.02**	**0.09**	**7.70**	**0.78**	**9.74**	**0.01**	**0.33**	**0.02**	**0.43**
C.D. at 5%	**NS**	**NS**	**NS**	**23.34**	**2.35**	**29.55**	**NS**	**NS**	**NS**	**NS**

Effect of nano DAP on economics of finger millet cultivation

The application of nano DAP (Diammonium Phosphate) in combination with the recommended dose of fertilizers (RDF) proved to be economically advantageous in finger millet cultivation. Treatment T_8, which involved 100% RDF plus foliar sprays of nano DAP at 4 ml L^{-1} at the tillering and booting stages, recorded the higher gross returns (Rs. 1,14,142 ha^{-1}), net returns (Rs. 75,629 ha^{-1}) and benefit-cost ratio (2.96) (Table 5). The superior economic performance of T_8 is attributed to the enhanced yield, nutrient uptake provided by nano DAP. The smaller particle size and increased surface area of nano DAP allow for better penetration and absorption of nitrogen and phosphorus through the leaves, resulting in improved plant growth and increased yields. This higher crop productivity, both in grain and straw, boosted gross returns, while the additional cost of nano DAP was compensated by the enhanced revenue from higher yields. Studies by Choudhary (2014) and Sharma *et al.* (2009) support these findings, showing improved financial returns due to more efficient nutrient delivery in crops like sorghum and wheat. Similarly, Ravi and Channal (2010) and Reddy *et al.* (2013) observed higher profitability in rice and soybeans due to optimized nutrient solubility and utilization. These benefits confirm the economic feasibility of integrating nano DAP with RDF in finger millet, making it a cost-effective strategy for improving both yields and net returns.

Table 5 : Effect of nano DAP on economics of finger millet cultivation

Treatment	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C
T_1	26630	52323	25693	1.96
T_2	29030	57137	28107	1.97
T_3	30030	61685	31655	2.05
T_4	32430	73570	41040	2.27
T_5	36585	89703	53118	2.45
T_6	37565	104695	67130	2.79
T_7	36613	108176	71063	2.95
T_8	38513	114142	75629	2.96
S. Em. ±	**NA**	**3662**	**3662**	**0.11**
C.D. at 5%	**NA**	**11108**	**11108**	**0.33**

NA (Not analyzed)

Conclusion

The study demonstrates the significant benefits of applying nano DAP (Diammonium Phosphate) in combination with the recommended dose of fertilizers (RDF) on finger millet growth, nutrient concentration and economic returns. Nano DAP foliar sprays, particularly in treatment T_8 (100% RDF + foliar spray of nano DAP at 4 ml L^{-1} at tillering and booting stages), resulted in enhanced nitrogen and phosphorus content in both grain and straw, due to the improved solubility and absorption efficiency of nano-sized particles. This led to better nutrient uptake, particularly at critical growth stages like tillering and booting. The increased nutrient availability not only supported higher biomass and yield but also improved overall plant health and development. Additionally, nano DAP boosted nutrient use efficiency, minimizing losses associated with conventional fertilizers. Economically, the enhanced nutrient uptake translated into higher gross and net returns, as well as an improved benefit-cost ratio, making nano DAP an effective and sustainable tool for optimizing nutrient management. The integration of nano DAP with RDF thus maximizes nutrient uptake, increases crop productivity and enhances profitability in finger millet cultivation.

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