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Impact of nano fertilizers on yield and economics of cauliflower

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Abstract
Cauliflower (*Brassica oleracea* var. *botrytis*) is a nutrient-rich crop with high nitrogen demand, often leading to excessive synthetic fertilizer use, environmental degradation, and increased production costs. This study evaluated the impact of nano fertilizers—Nano DAP and Nano Urea Plus—on curd yield and economic returns under varied fertilizer regimes. A factorial design was adopted with two factors: four levels of recommended doses of fertilizer (RDF) and six nano fertilizer treatments, resulting in 24 treatment combinations. Significant differences in curd yield were observed among treatments. The highest yield, net returns and B: C ratio was recorded in C_2T_2 (75% RDF coupled with nano DAP seedling dip + foliar spray of nano DAP at 15 DAT), which was statistically comparable to other nano treatments under 75% or 100% RDF and seedling dip with nano DAP followed by one or two foliar spray of either nano DAP or nano urea plus (C_2T_3, C_1T_3, C_2T_5, C_2T_4, and C_1T_2).

Keywords: Nano fertilizers, nano DAP, nano urea plus, curd yield, economic returns, sustainable agriculture, B:C ratio

Introduction

Cauliflower (*Brassica oleracea* var. *botrytis*) is a nutrient-rich, economically significant crop of the Brassicaceae family, widely cultivated in temperate and subtropical regions. Its Latin name, *caulis* (stem) and *floris* (flower) reflects its structure, with the edible curd formed by compact, immature inflorescences harvested before blooming. Though suitable for year-round cultivation, its growth stages vegetative, curd formation, and reproductive are highly temperature-sensitive, especially during curding.

In addition to being gluten-free and low in calories, cauliflower is a staple in functional and therapeutic diets. It is also rich in proteins, carbohydrates, calcium, phosphorus, iron, and vitamin C. China is the leading global producer, supplying more than 70% of the world's supply. Andhra Pradesh has great potential due to its diverse agro-ecological zones, temperate climate, and fertile red and alluvial soils, though West Bengal leads in acreage in India. Pest pressure, microbiological decline, and soil salinization result from the overuse of synthetic fertilizers driven by the crop's high nitrogen needs (Sherif & El-Naggar, 2005; Badawy *et al*. 2007) [4, 5]. Besides increasing production costs, these practices harm the environment. To reduce these issues, sustainable nutrient management is essential.

Nanotechnology offers a promising alternative. Nano-fertilizers, with high solubility and controlled-release properties, improve nutrient uptake and reduce input volumes (Saleh, 2015; Monreal *et al*. 2016) [2, 1]. Foliar application of Nano Urea Plus and Nano DAP enhances nitrogen and phosphorus efficiency, boosting yields while minimizing ecological risks (Jyothi & Hebsur, 2017) [3]. This study evaluates their role in optimizing economics in cauliflower cultivation and promoting sustainable agriculture.

By adopting a smart and targeted application approach, both Nano Urea Plus and Nano DAP can significantly reduce dependence on conventional fertilizers without compromising crop yields. Nano Urea Plus, applied as a foliar spray, can replace up to 25% of traditional urea by enhancing nitrogen use efficiency and minimizing nutrient loss. Likewise, using Nano DAP alongside 75% of standard phosphorus inputs has proven effective in sustaining or even boosting crop performance. With their ultra-fine particles, nano fertilizers offer improved nutrient absorption and precision delivery at key growth stages, making them a more efficient and sustainable option for modern farming.

This study explores how nano fertilizers can reduce reliance on conventional inorganic inputs for higher yield and profitability.

Materials and Methods

The investigation was conducted at Dr. YSRHU-College of Horticulture, Anantharajupeta (13.98° N, 79.40° E), located in the Southern Agro-Climatic Zone of Andhra Pradesh.

The experiment was structured using a factorial approach involving two main factors: conventional chemical fertilizer levels and nano-fertilizer treatments. The first factor comprised four levels of recommended doses of fertilizers (RDF): C_1-100% RDF (60-80:80:100 kg ha^{-1} of N:P_2O_5:K_2O), C_2-75% RDF (45-60:60:75 kg ha^{-1}), C_3-50% RDF (30-40:40:50 kg ha^{-1}), and C_4-a control with no fertilizer application. The second factor included six nano-fertilizer treatments: T_1-seedling dip with Nano DAP @ 4 ml L^{-1}, T_2-T_1 + foliar spray of Nano DAP at 15 days after transplanting (DAT) @ 4 ml L^{-1}, T_3-T_1 + foliar sprays of Nano DAP at both 15 and 30 DAT @ 4 ml L^{-1}, T_4-T_1 + foliar application of Nano Urea Plus at 15 DAT @ 4 ml L^{-1}, T_5-T_1 with Nano Urea Plus foliar sprays at 15 and 30 DAT @ 4 ml L^{-1}, and T_6-water spray as control. Each treatment combination was replicated twice, and uniform agronomic practices were maintained throughout the crop cycle to ensure consistency and accuracy in the results. Cauliflower seeds were sown in protrays containing sterilized coco peat approximately one month before transplanting. To prevent fungal infections, seeds were treated with carbendazim prior to sowing. Germination occurred within 2-3 days, and seedlings were irrigated regularly to maintain optimal moisture Integrated pest and disease management practices were followed throughout the nursery phase. After 25-30 days, twenty uniform seedlings per treatment were selected. Protrays were irrigated a day before transplanting to ease uprooting, and seedlings were carefully removed to minimize root damage. Transplanting was performed in the evening to utilize cooler temperatures and reduce transplant stress

Nitrogen and potassium were applied in three split doses using urea and muriate of potash, with half the quantity incorporated as a basal dose and the remaining applied as top dressings at 25 and 45 days after transplanting (DAT). Phosphorus was applied entirely as a basal dose using single super phosphate, in accordance with the respective treatment levels. Nano fertilizers (nano DAP and urea plus) were used at 4 ml^{-1} for seedling dip and foliar spray, as per the specified treatment protocols. The present study investigated the curd yield and economics of cauliflower, where in curd yield was determined by averaging the total curd weight from two replications per treatment during harvest, and subsequently extrapolated to kilograms per hectare (kg/ha). The cost of cultivation, expressed in rupees per hectare, was calculated based on prevailing input prices and labour costs at the time of utilization. Statistical analysis was performed using the analysis of variance (ANOVA) method as outlined by Panse and Sukhatme (1985) [6], with the F-test employed to assess treatment significance at the 5% probability level. For traits exhibiting significant differences, the critical difference (CD) at the 0.05 level was computed to facilitate mean comparisons.

Results and Discussion

Curd yield of cauliflower was significantly varied by different graded levels of conventional chemical fertilizers and nano fertilizers and their interactions. (Table 1)

Among chemical fertilizers, 75% RDF (C_2) produced the highest yield (19,381 kg ha^{-1}), which is statistically on par with 100% RDF (C_1: 18,807 kg ha^{-1}), while the lowest was recorded under C_4 (11,512.7 kg ha^{-1}).

In nano fertilizer treatments, T_2 (seedling dip with nano DAP + foliar spray with nano DAP at 15 DAT) resulted in maximum curd yield (17,892 kg ha^{-1}), which is comparable to that of T_3 (17,724 kg ha^{-1}), T_5 (17,295 kg ha^{-1}), and T_4 (17,156 kg ha^{-1}). The lowest curd yield was was observed in T_6 (13,450.75 kg ha^{-1}).

With respect to interaction effects of conventional chemical fertilizers and nano fertilizers the maximum curd yield (21,420 kg ha^{-1}) was achieved in C_2T_2 (75% RDF + nano DAP dip + foliar spray of nano DAP), which is statistically similar to that of treatment under 75% RDF or 100% RDF coupled with seedling dip with nano DAP and followed by one or two foliar spray of either nano DAP or nano urea plus(C_2T_3-20,906 kg ha^{-1}, C_1T_3-20,855 kg ha^{-1}, C_2T_5-20,704 kg ha^{-1}), C_2T_4-20,630 kg ha^{-1}, and C_1T_2-20,208 kg ha^{-1}) . The lowest yield was in treatment combination C_4T_6 (13,450.75 kg ha^{-1}). Increases in curd diameter, curd weight, curd volume, length, biomass, and increased photosynthetic activity likely prompted by strong vegetative growth and improved glucose assimilation, might be responsible for the higher curd yield seen in these treatments. These physiological functions were greatly aided by adequate nitrogen supplementation, which is essential for the production of chlorophyll and protein biosynthesis. Additionally, effective nutrient absorption and mobilization were facilitated by the combined application of nano fertilizers and RDF, increasing production per unit area. These results are in line with previous research on cauliflower by Chaudhary *et al*. (2015) [7] and Tekasangla *et al*. (2015) [8], and cabbage by Merentola *et al*. (2012) [9].

Cost of cultivation

The cost of cauliflower cultivation excluding treatmental cost amounted to ₹1,20,341 per hectare, covering essential agronomic operations such as land preparation, nursery management, transplanting, weeding, irrigation, FYM application, plant protection, mulching, harvesting etc., is furnished in table 3 .

Economic analysis of cauliflower cultivation under varied bulk blended chemical and nano fertilizer regimes showed significant profitability differences. Total costs ranged from ₹1,20,341 to ₹1,47,225/ha, influenced by fertilizer type and dose. Treatments combining nano fertilizers with 75% RDF notably improved yield and returns. C_2T_2 (75% RDF coupled with nano DAP seedling dip and subjected to foliar spray nano DAP at 15 DAT) achieved the highest curd yield (21,421 kg/ha), net returns (₹3,97,540/ha), and B:C ratio of 3.88. Other nano-integrated treatments like C_2T_4 and C_2T_3 also performed well. In contrast, control treatment C_4T_6 yielded the lowest output and returns, highlighting the economic advantage of nano fertilizer integration with 75% RDF for enhanced nutrient efficiency and profitability. The data presented in Table 3

Table 1: Effect of conventional chemical and nano fertilisers on curd yield (kg ha^{-1}) of cauliflower.

		Nano fertilizers						
Conventional chemical fertilizers		T_1	T_2	T_3	T_4	T_5	T_6	Mean (C)
	C_1	14,427	20,704	20,614	19,322	18,818	16,808	18,449
	C_2	17,612	21,421	20,833	20,690	20,826	15,383	19,461
	C_3	12,500	17,846	16,987	17,706	17,109	12,464	15,769
	C_4	11,246	12,094	10,876	11,530	12,433	9,417	11,266
	Mean	C		T			C xT	
	SEm	196.094		240.166			579.313	
	CD at 5%	777.232		706.962			1413.93	

Table 2: Cost of cultivation of cauliflower (₹ ha^{-1}) excluding the variation in cost due to treatments

S. No.	Particulars	Cost
1.	Land preparation (Cultivator, Rotavator)	8,500
2.	Nursery raising and management	19,535
3.	Transplanting and gap filling	4,850
4.	Weeding	13,500
5.	Irrigation	8,740
6.	FYM	28,511
7.	Plant protection	8,740
8.	Mulching	20,274
9.	Harvesting	8000
	Total	1,20,341

Table 3: Cost-benefit evaluation of nano fertilizers in cauliflower production

Treatments	Total cost of cultivation	Curd yield (kg/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio
C_1T_1	1,41,811	14520	3,62,988	2,21,178	2.56
C_1T_2	1,44,518	20890	5,05,212	3,60,694	3.50
C_1T_3	1,47,225	20855	5,21,384	3,74,159	3.54
C_1T_4	1,42,826	20614	4,92,775	3,49,949	3.45
C_1T_5	1,43,841	19711	5,15,339	3,71,498	3.58
C_1T_6	1,40,547	16937	4,23,432	2,82,885	3.01
C_2T_1	1,35,272	17612	4,40,303	3,05,031	3.25
C_2T_2	1,37,979	21421	5,35,519	3,97,540	3.88
C_2T_3	1,40,686	20752	5,22,670	3,81,983	3.72
C_2T_4	1,36,287	20208	5,15,758	3,79,471	3.78
C_2T_5	1,37,302	20907	5,17,610	3,80,307	3.77
C_2T_6	1,34,008	15013	3,75,322	2,41,314	2.80
C_3T_1	1,31,708	12500	3,12,501	1,80,793	2.37
C_3T_2	1,34,415	17846	4,46,150	3,11,734	3.32
C_3T_3	1,37,122	16979	4,24,481	2,87,359	3.10
C_3T_4	1,32,723	16987	4,35,244	3,02,521	3.28
C_3T_5	1,33,738	17410	4,24,683	2,90,945	3.18
C_3T_6	1,30,444	12464	3,11,589	1,81,145	2.39
C_4T_1	1,21,605	11530	2,88,243	1,66,638	2.37
C_4T_2	1,24,312	12094	3,02,355	1,78,043	2.43
C_4T_3	1,27,019	12155	3,03,875	1,76,856	2.39
C_4T_4	1,22,620	12040	2,71,903	1,49,282	2.22
C_4T_5	1,23,635	10876	2,71,903	1,48,267	2.20
C_4T_6	1,20,341	9417	2,35,414	1,15,073	1.96

Table 4: Cost of cultivation of cauliflower (₹ ha^{-1}) excluding the variation in cost due to treatments

S. No.	Particulars	Cost
1.	Land preparation (Cultivator, Rotavator)	8,500
2.	Nursery raising and management	19,535
3.	Transplanting and gap filling	4,850
4.	Weeding	13,500
5.	Irrigation	8,740
6.	FYM	28,511
7.	Plant protection	8,740
8.	Mulching	20,274
9.	Harvesting	8000
	Total	1,20,341

Conclusion

It can be concluded that application of 75% RDF along with nano DAP seedling dip and foliar application of nano DAP at 15 DAT, resulted in the highest yield, net returns, and benefit-cost (B:C) ratio, which is closely followed by other nano-based treatments, either with 75% or 100% RDF, combined with a nano DAP seedling dip followed by one or two foliar sprays of nano DAP or nano urea plus (C_2T_3, C_1T_3, C_2T_5, C_2T_4, and C_1T_2). These findings suggest that integrating nano fertilizers allows for a 25% reduction in conventional fertilizer use, offering a highly remunerative and environmentally friendly alternative.

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