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IMPACT OF NANO AND CHEMICAL FERTILIZERS ON YIELD AND QUALITY OF CABBAGE (*BRASSICA OLERACEA* L. VAR. *CAPITATA*)

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ABSTRACT

The study on the impact of nano and chemical fertilizers on cabbage was conducted at Dr. YSRHU - Citrus Research Station, Tirupati during *Rabi* season (2023-24). The research investigated how different rates of NPK chemical fertilizers, along with nano-urea and nano DAP applied *via.*, foliar sprays and seedling dips, affect cabbage yield and quality. Key findings include, nano fertilizers significantly improved various aspects such as head circumference, volume, fresh weight, dry matter, yield and ascorbic acid content after harvest. The best results for dry matter yield, head weight and overall yield were achieved with a combination of nano and chemical fertilizers (N_6C_3). Among chemical fertilizers, 75% RDF (C_3) resulted in the best head circumference, volume, weight, dry matter, yield and ascorbic acid content. Nano nitrogen foliar spray at 20 and 40 days after transplanting (N_2) produced the largest head circumference, volume, fresh weight, dry matter, yield and ascorbic acid content. Overall, combining nano fertilizers with chemical fertilizers can significantly increase cabbage yield and enhance head quality. This approach offers a valuable method for optimizing vegetable production.

***Key words*:** Nano fertilizers, balanced nutrient supply, improve nutrient efficiency.

Introduction

The cruciferous plants known as cole crops are members of the Brassicaceae family and are descended from a common progenitor *Brassica oleracea* L. *var. sylvestris* (wild cabbage, cliff cabbage, or colewort). Cabbage, a staple in India used in salads, curries, and processed forms, also has a long history in traditional medicine. It has been used to treat gastric ulcers, gout, cancer, migraines and diarrhea. Its anticancer properties, especially against bowel cancer, are due to compounds like indole-3-carbinol.

Cabbage, being an exhaustive crop, requires substantial nutrients especially nitrogen, phosphorus and potassium, for optimal growth. To achieve sustainable agriculture, nanotechnology offers a promising solution, particularly through nano fertilizers. These improve nutrient efficiency by enhancing absorption and reducing waste. Nano Urea provides a steady nitrogen release, addressing issues of volatilization and leaching. Similarly, nano phosphorus fertilizers overcome the problems of high fixation and low availability in soil, boosting plant growth, biomass and yield.

Material and Methods

The study was conducted at Dr. YSRHU - Citrus Research Station, Tirupati, Andhra Pradesh during *Rabi* 2023-24. Using a factorial randomized block design with two replications, 28 nutrient management treatments were tested. Well-decomposed farm yard manure was applied as a basal dose. We investigated the impact of various nano fertilizer treatments and chemical fertilizer application rates on cabbage yield and quality. For Factor 1, we explored seven nano fertilizer treatments: N_1 involved a nano nitrogen foliar spray applied at 20 days after transplanting (DAT); N_2 included nano nitrogen foliar sprays at both 20 and 40 DAT; N_3 combined a nano nitrogen seedling dip at transplanting with a foliar spray

Table 1: Yield parameters as influenced by nano and chemical fertilizers (At harvest).

Nano fertilizers (N)	HEAD CIRCUMFERENCE (cm)					HEAD VOLUME (cc)					HEAD COMPACTNESS				
	Chemical fertilizers (C)					Chemical fertilizers (C)					Chemical fertilizers (C)				
	C1	C2	C3	C4	Mean	C1	C2	C3	C4	Mean	C1	C2	C3	C4	Mean
N1	39.45	42.00	42.80	40.85	41.28	722.00	797.20	891.50	826.00	809.18	0.86	0.76	0.68	0.74	0.76
N2	42.74	42.51	44.13	42.76	43.04	743.50	916.00	1058.00	767.00	871.13	0.77	0.87	0.75	0.71	0.77
N3	39.83	41.43	41.46	41.42	41.04	570.00	847.00	1039.00	682.00	784.50	0.64	0.73	0.85	0.63	0.71
N4	39.44	40.85	43.14	40.16	40.90	680.50	753.50	687.50	707.00	707.13	0.83	0.70	0.72	0.83	0.77
N5	39.33	40.90	42.57	41.19	41.00	610.00	750.00	715.50	710.50	696.50	0.83	0.64	0.67	0.73	0.72
N6	40.89	41.38	42.47	41.20	41.49	557.50	831.50	1148.50	746.00	820.88	0.66	0.68	0.78	0.88	0.75
N7	40.36	41.07	40.59	40.25	40.57	542.00	676.95	692.18	692.00	650.78	0.76	0.64	0.70	0.81	0.72
Mean	40.29	41.45	42.45	41.12		632.21	796.02	890.31	732.93		0.76	0.72	0.73	0.76	
Factors	N		C		N × C	N		C		N × C	N		C		N × C
SE.(m) ±	0.31		0.23		0.62	13.99		10.58		27.98	0.03		0.02		0.07
CD @ 5%	0.90		0.68		NS	40.82		30.85		81.63	NS		NS		NS

at 20 DAT; N_4 used a nano phosphorus foliar spray at 20 DAT; N_5 applied nano phosphorus foliar sprays at both 20 and 40 DAT; N_6 incorporated a nano phosphorus seedling dip at transplanting along with a foliar spray at 20 DAT and N_7 served as the control with a water spray. For Factor 2, we varied the fertilizer application rates of NPK as follows: C_1 was the control with no additional fertilizer; C_2 applied 100% of recommended dose of NPK (79:98:98kg/ha); C_3 utilized 75% of recommended dose of NPK (59:74:74 kg/ha)and C_4 used 50% of recommended dose of NPK (40:49:49 kg/ha). Nitrogen and potassium were applied in three stages using urea and muriate of potash, with half as a basal dose and the rest in top dressings at 25 and 45 days after transplanting (DAT). Phosphorus was applied as a full basal dose with single super phosphateas per the treatments. Nano urea was used at the rate of 4ml per litre of water for foliar application and seedling dip. Nano DAP was used at the rate of 4ml for foliar spray and 5ml for seedling dip per litre of water as per the treatments. Seedlings were dipped for 30mins. Observations on various traits, including head circumference, volume, compactness, fresh weight, dry matter production, yield, total soluble solids (TSS) and ascorbic acid content, were recorded and analysed from five randomly selected plants per replication after harvest. The data was analysed as per the method of variance outlined by Panse and Sukhatme (1985). Statistical significance was tested by F value at 5% level of significance. Critical difference at 0.05 levels was worked out for the effects which were significant.

Result and Discussion

Yield parameters

As illustrated in Table 1, the biggest head circumference of cabbage after harvest was seen with the application of Nano nitrogen spray at 20 and 40 DAT, measuring 43.04 cm. The second-largest head circumference came from using 75% RDF, which was 42.45 cm. The smallest head circumference was in control (C_1), with 40.29 cm and among nano fertilizers N_7 with 40.57 cm.

Nitrogen is key for cabbage head circumference. Nano fertilizers may have enhanced head size by improving nitrogen availability and efficiency (Suppan, 2013). Chemical fertilizers, by supplying balanced NPK, likely boosted root development and nutrient uptake, leading to larger and denser cabbage heads.

The data from Table 1 show that the largest cabbage head volume was achieved with the combination of a nano phosphorus seedling dip, a foliar spray at 20 days after transplanting (DAT) and 75% of the recommended dose of fertilizer (N_6C_3), reaching 1148.50 cc. The highest volume among nano fertilizer was from the nano nitrogen foliar spray at 20 and 40 DAT (N_2), with 871.13 cc, followed by (chemical fertilizer) 75% RDF (C_3) with 890.31 cc. The smallest volumes were observed in treatments N_7C_1 (542.00 cc), N_7 (650.78 cc)and C_1 (632.21 cc). The increase in cabbage head volume would be likely due to the larger circumference of the cabbages in these treatments.

As shown in Table 1, the cabbage head compactness after harvest was not significantly affected by the use of nano and chemical fertilizers or a combination of both.

As reported in Table 2, the heaviest cabbage heads were achieved with the combination of nano and chemical fertilizers. Treatment N_6C_3, which used both nano and chemical fertilizers, produced the largest heads with 1.48 kg. Among nano and chemical fertilizers alone, nano nitrogen foliar spray at 20 and 40 DAT (N_2) and 75% RDF (C_3) resulted in the highest head weight with N_2-1.14 kg and C_3-1.21 kg. The lowest head weight was observed in N_7C_1 (0.71 kg), C_1 (0.84 kg) and N_7 (0.92 kg).

Combining nano fertilizers with conventional chemical

Table 2: Yield parameters as influenced by nano and chemical fertilizers (At harvest).

Nano fertilizers (N)	FRESH WEIGHT (kg)					DRY MATTER PRODUCTION (kg/ha)					YIELD (kg/ha)				
	Chemical fertilizers (C)					Chemical fertilizers (C)					Chemical fertilizers (C)				
	C1	C2	C3	C4	Mean	C1	C2	C3	C4	Mean	C1	C2	C3	C4	Mean
N1	0.84	1.05	1.32	1.12	1.08	3572.40	4955.67	6055.96	5322.43	4976.61	41204.10	51675.40	64562.40	54757.50	53049.85
N2	0.97	1.06	1.42	1.11	1.14	4605.13	5116.20	6398.11	5199.09	5329.63	47672.10	51993.90	69393.80	54497.80	55889.40
N3	0.89	1.15	1.22	1.09	1.09	4117.05	6507.88	5336.99	4698.24	5165.04	43659.00	56541.10	59966.20	53571.70	53434.50
N4	0.87	1.09	0.97	0.85	0.95	3978.43	5177.25	5305.22	3865.96	4581.71	42732.90	53209.10	47623.10	41703.90	46317.25
N5	0.75	1.16	1.08	0.98	0.99	3617.83	5289.06	6225.55	4505.59	4909.51	36803.90	57055.60	52714.20	47931.80	48626.38
N6	0.86	1.23	1.48	0.89	1.12	4151.97	6011.68	6616.71	4061.92	5210.57	41939.10	60176.90	72711.10	43629.60	54614.18
N7	0.71	1.07	0.99	0.89	0.92	3175.06	4590.94	4516.41	3358.92	3910.33	35025.20	52229.10	48720.70	43365.00	44835.00
Mean	0.84	1.12	1.21	0.99		3888.26	5378.38	5779.28	4430.31		41290.90	54697.30	59384.50	48493.90	
Factors	N		C		N × C	N		C		N × C	N		C		N × C
SE.(m) ±	0.03		0.03		0.07	152.52		115.30		305.05	1671.04		1263.18		3342.07
CD @ 5%	0.10		0.08		0.20	444.94		336.35		889.89	4848.89		3665.41		9697.77

fertilizers likely enhanced nutrient uptake and efficiency, resulting in heavier cabbage heads, as seen in treatment N_6C_3. Chemical fertilizers provided balanced nitrogen for leafy growth, phosphorus for root development and potassium for overall plant health, leading to larger cabbage heads in treatment C_3. Nano fertilizers may have further boosted head weight by improving nutrient absorption in N_2. These findings match research by Jaysawal *et al.*, (2023) in ridge gourd, Biswas *et al.*, (2023) in bottle gourd and Pooja *et al.*, (2022) in broccoli.

Data recorded in Table 2 indicate that the highest dry matter yield after harvesting of cabbage heads was achieved with the combination of nano and chemical fertilizers, specifically N_6C_3, which produced 6616.71 kg/ha. For individual treatments, 75% RDF (C_3) resulted in the highest dry matter of 5779.28 kg/ha. Among nano fertilizers, N_2, which involved a nano nitrogen foliar spray at 20 and 40 DAT, produced 5329.63kg/ha. The lowest dry matter yield was observed with the N_7C_1(3175.06 kg/ha). Among nano and chemical fertilizers alone, the lowest dry matter yields were from N_7 at 3910.33 kg/ha and C_1 at 3888.26 kg/ha.

Combining nano and chemical fertilizers, as in treatments N_6C_3, likely improved nutrient absorption and chlorophyll synthesis. This enhanced photosynthesis and dry matter production. In treatment C_3, higher chlorophyll boosted sunlight absorption and photosynthesis, while treatment N_2 also experienced increased dry matter from improved photosynthesis.

As indicated in Table 2, the highest cabbage head yield was achieved in treatment combination N_6C_3, which involved a nano phosphorus seedling dip at transplanting, foliar spray at 20DAT and 75% RDF (72711.10 kg/ha). Among chemical fertilizers alone, the highest head yield was from 75% RDF (C_3) with 59384.50 kg/ha. For nano fertilizers alone, the highest head yield was achieved with N_2, producing 55889.40 kg/ha, while the lowest was 44835 kg/ha with N_7.

Table 3 : Quality parameters as influenced by nano and chemical fertilizers (At harvest).

Nano fertilizers (N)	TSS (°Brix)					ASCORBIC ACID (mg/100)				
	Chemical fertilizers (C)					Chemical fertilizers (C)				
	C1	C2	C3	C4	Mean	C1	C2	C3	C4	Mean
N1	6.80	6.87	7.05	6.97	6.92	34.17	34.69	35.48	32.91	34.31
N2	6.73	7.10	7.06	7.17	7.02	45.49	44.86	46.44	45.07	45.46
N3	6.87	6.93	6.90	6.58	6.82	43.18	43.68	44.84	44.55	44.06
N4	7.11	6.68	6.98	6.74	6.88	31.62	31.49	35.60	31.72	32.60
N5	6.88	7.32	6.91	6.61	6.93	38.14	36.94	39.88	38.18	38.28
N6	6.47	6.97	6.89	7.12	6.86	40.37	41.41	43.64	39.86	41.32
N7	6.53	6.81	6.64	6.93	6.73	30.91	29.53	35.42	33.80	32.41
Mean	6.77	6.95	6.92	6.87		37.70	37.51	40.18	38.01	
Factors	N		C		N × C	N		C		N × C
SE.(m) ±	0.09		0.07		0.19	0.46		0.35		0.93
CD @ 5%	NS		NS		NS	1.35		1.02		NS

The higher cabbage yield with nano fertilizers, especially in treatment N_6C_3 and N_2, is likely due to improved nutrient efficiency and reduced losses, leading to greater productivity and head weight. This matches findings by Sulaiman and Rasheed (2024) for lettuce, Al-Baghdadi and Shammari (2024) for kohlrabi and Lekshmi *et al.*, (2022) for okra. In treatment C_3, enhanced vegetative growth likely increased carbohydrate production in the cabbage head, boosting yield. This supports previous research by Chandel *et al.*, (2021) in cabbage, Kumar *et al.*, (2019) in cabbage and Singh *et al.*, (2018) in cabbage, Preeti *et al.*, (2024) in rat-tail radish.

Data recorded in Table 3 clearly show

that Total Soluble Solids (TSS) in cabbage heads after harvest were not significantly affected by the use of nano and chemical fertilizers or a combination of both.

As shown in Table 3, nano nitrogen foliar spray at 20 and 40 DAT (N_2) resulted in the highest ascorbic acid content in cabbage heads after harvest, with 45.46 mg/100g. This was followed by N_3(44.06 mg/100g). The lowest ascorbic acid content was found in N_7(32.41 mg/100g). Among different levels of RDF, the highest ascorbic acid content was observed with 75% RDF(C_3), yielding 40.18 mg/100g followed by 50% RDF (C_4) with 38.01 mg/100g and lowest in C_2 (37.51 mg/100g).

Nitrogen is key for synthesizing vitamins and enzymes (Tisdale and Nelson, 1966). In treatments N_2 and N_3, nano fertilizers improved nitrogen supply, boosting ascorbic acid levels, aligning with Juthery and Maamouri (2020) for potatoes, Shams (2019) for kohlrabi and Juthery *et al*., (2018) for potato. High nitrogen at 100% RDF may cause nutrient imbalances and excessive growth, reducing ascorbic acid, which explains lower levels in treatment C_2. Conversely, 75% RDF (C_3) offered a more balanced nutrient supply, enhancing ascorbic acid content.

Conclusion

The study demonstrates that the combination of nano and chemical fertilizers, especially nano phosphorus seedling dip and foliar spray along with 75% RDF, led to the highest headvolume, weight, dry matter yield and head yield. Nano fertilizers particularly nano nitrogen two foliar sprays have improved nitrogen efficiency, which enhanced various aspects of cabbage yield and quality, including head circumference, volume,weight, yield, dry matter production and ascorbic acid content.

In contrast, while chemical fertilizers alone also contributed to better growth outcomes compared to controls, their effects were generally less pronounced than those achieved with the combination of nano and chemical fertilizers. The increased efficiency in nutrient uptake and utilization provided by nano fertilizers likely contributed to the superior performance observed.

Overall, integrating nano fertilizers with conventional chemical fertilizers appears to be an effective strategy for optimizing cabbage production, resulting in larger, denser heads, higher yields.

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