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Optimising Growth and Nutrient Uptake in Cabbage through Combined Application of Nano-DAP, Nano-Zn and Conventional Fertilisers

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Abstract

Maximising productivity with reduced conventional fertiliser usage by integration of nano-fertilisers offers a sustainable approach to enhance productivity vis-à-vis reducing environmental pollution. To explore this, an experiment consisting of thirteen treatments was conducted during the rabi season 2023-24, replicated thrice to study the effect of conventional fertilisers in combination with nano DAP and nano Zn on growth and nutrient uptake in cabbage. Better performance of growth attributes was obtained at 100% application of NP + seedling dip and foliar spray of nano DAP + nano Zn foliar spray (T_8) along with early harvest. N, P, K and Zn content increased significantly with the use of conventional fertilisers in conjunction with nano fertiliser DAP and nano zinc, with maximum N and P at 100% NP + nano DAP as seedling dip and spray + nano zinc spray. Overall, the study highlights that partial substitution of conventional fertilisers with nano-fertilisers can maintain productivity.

Keywords: Cabbage, Growth, Nano DAP, Nano Zn, Uptake

Cabbage (*Brassica oleracea* var. *capitata*) plant of the Brassicaceae family, is a highly nutritious vegetable, rich in vitamins C, K, and fibre (Sharma *et al.* 2006), which contribute to immune health, digestion, and strong bones. In India, it is grown over 423,000 hectares with an average yield of 23.1 metric tonnes per hectare (Anonymous 2021-22). In Himachal Pradesh, it is cultivated as both a primary and off-season crop, covering 4,660 hectares, producing 146,660 tonnes with a productivity rate of 31.47 metric tonnes per hectare (Anonymous 2021-22). Because of its higher biomass production, cabbage requires significant nutrients and water. The ongoing use of conventional chemical fertilisers with low efficiency has led to environmental damage and rising costs.

Nutrients are vital elements of nucleotides, proteins, chlorophyll, and enzymes, and hence facilitate numerous metabolic developments in plants, resulting in improved output (Chandel *et al.* 2022; Chandel *et al.* 2023). Suitable plant nutrient supply holds the crucial role for enhancing the yield and maintaining soil health (Sharma & Sharma 2016). In the current scenario, awareness has been created in sustainable agricultural practices to curtail adverse impacts due to the indiscriminate use of chemical fertilisers (Sharma *et al.* 2016). Nanotechnology is transforming fertilisers by improving nutrient delivery and increasing efficiency, gaining momentum across agriculture. Nitrogen and phosphorus fertilisers, which have low efficiency, pose environmental risks. Nanotechnology, including nano-DAP, is widely adopted in various crops to manage these nutrients better. Nano-fertilisers, made of tiny particles containing macro and micronutrients, release nutrients slowly and efficiently, minimising waste and maximising plant uptake (Jubouri *et al.* 2023).

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By raising productivity, improving food quality and assisting in the maintenance of the nutritional balance of agricultural land, this new technology is anticipated to increase farm income profitably.

MATERIALS AND METHODS

The present investigation, entitled "Effect of nano DAP and nano Zn along with conventional fertilisers on growth and development attributes in cabbage (*Brassica oleracea* var. *capitata*) was conducted at Irrigation and Farm Management Research Farm of the Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, during *rabi* 2023-24. The area lies at 32° 06`05`` N latitude and 76° 33` 02" longitude at an elevation of 1284 meters above mean sea level. The seedlings were produced at the Experimental Farm. Royal ball variety was used for sowing of cabbage in a nursery on September 1st 2023, and transplanted in the main field on October 4th 2023. The plants were transplanted at a spacing of 45 cm within rows and 45 cm between plants. About 1500 plants are transplanted in a 285 m^2 area, or 36 plants per plot. N, P and K were applied in the form of urea, Single super phosphate and Muriate of potash. The nano DAP as a seedling dip and foliar spray was applied at 5ml/l and 4ml/l, while nano Zn was used at @2ml/l. The foliar sprays of nano DAO and Zn were done at 30 and 60 days after transplanting.

Experimental Details

The experiment comprised thirteen treatments, each replicated three times and arranged in a completely randomised block design. The treatments were T_1:.Control, T_2:100% NP, T_3:75% NP, T_4:100% NP + seedling dip of nano DAP, T_5:100% NP + foliar spray nano DAP, T_6:100% NP + foliar spray of nano Zn, T_7:100%NP + seedling dip of nano DAP + foliar spray of nano DAP, T_8:100% NP + seedling dip of nano DAP + foliar spray of nano DAP + foliar spray of nano Zn, T_9:75% NP + seedling dip of nano DAP, T_{10}:75% NP + foliar spray of nano DAP, T_{11}:75% NP + foliar spray of nano Zn, T_{12}:75% NP +seedling dip of nano DAP+ foliar spray of nano DAP, T_{13}:75% NP + seedling dip of nano DAP + foliar spray of nano DAP + foliar spray of nano Zn.

RESULTS AND DISCUSSION

Growth Parameters

A perusal of data revealed that treatments combination of 100% NP alone or its combination with nano fertilisers DAP and Zn resulted in comparatively maximum growth compared to treatments of 75% NP and their combination with nano fertilisers (Table 1). The maximum plant height was observed with treatment where 100 % NP, nano DAP seedling dip plus foliar spray, and nano Zn spray (T_8) were applied. The notable increase in plant height may be due to the high surface area-to-volume ratio of nano fertilisers, which enhances nutrient uptake and use efficiency, stimulating root growth and vegetative development. Reddy *et al.* (2022) and Thakur *et al.* (2024) similarly reported that plants treated with both conventional and nano fertilisers showed greater height than those treated with either fertiliser alone.

The number of loose leaves also followed the same trend as that of plant height, where the maximum number of loose leaves was observed with the application of nano DAP as a seedling dip and foliar spray combined with nano zinc spray alongside 100% NP (T_8), while the minimum was found in the control (Sharma *et al.* 2023). However, the number of leaves observed with the combined application of nano DAP or Zn with 75% NP (T_{13}) and with 100% NP, including seedling dip and foliar spray of nano DAP (T_7), was also comparable to T_8. Similar findings were reported by Chamuah *et al.* (2023), who attributed the increased non-wrapper leaf count in cabbage to the consistent nutrient release and efficiency of combined fertiliser applications.

The data on the effect of conventional and nano fertilisers on the fresh weight of loose leaves shows no significant increase in weight with the additional application of nano DAP as a seedling dip, foliar spray, Zn foliar spray or a combination of nano DAP seedling dip and foliar spray compared to the use of 100% NP or 75% conventional fertiliser alone. However, a significant increase in fresh leaf weight was observed when DAP was applied both as a seedling dip and foliar spray, along with a nano Zn spray, in both the 100% NP (T_8) and 75% NP (T_{13}) treatments (Saqib *et al.* 2025). The increased leaf weight can be attributed to enhanced biomass production, made possible by the

Table 1. Effect of different fertiliser treatments on the growth of cabbage

Treatments	Plant height (cm)	No. of loose leaves	Fresh weight of loose leaves (g)	Stem diameter (cm)	Stem length (cm)
T_1: Control	16.49	7.48	358	1.83	5.98
T_2:100%NP	18.32	10.04	429	2.43	6.37
T_3:75%NP	17.64	8.24	415	1.98	6.30
T_4:100%NP+ seedling dip of nano DAP	19.32	10.54	456	2.51	6.48
T_5:100%NP+ foliar spray of nano DAP	19.56	10.74	437	2.53	6.49
T_6:100%NP+foliar spray of nano Zn	19.26	10.47	447	2.52	6.45
T_7:100%NP+ seedling dip of nano DAP + foliar spray of nano DAP	20.77	12.12	469	2.63	6.57
T_8:100%NP+ seedling dip of nano DAP + foliar spray of nano DAP + foliar spray of nano Zn	21.16	12.35	510	2.65	6.59
T_9:75%NP+ seedling dip of nano DAP	18.28	9.93	435	2.30	6.30
T_{10}:75%NP+ foliar spray of nano DAP	19.11	10.04	448	2.39	6.35
T_{11}:75%NP+ foliar spray nano Zn	18.29	9.92	439	2.32	6.31
T_{12}:75%N+seedling dip of nano DAP+ foliar spray of nano DAP	19.88	11.95	460	2.62	6.56
T_{13}:75%NP +seedling dip of nano DAP +foliar spray of nano DAP + foliar spray of nano Zn	20.97	12.21	497	2.64	6.58
SEm+	0.16	0.09	18.66	0.02	0.05
CD (P= 0.05)	0.47	0.27	54.47	0.06	0.15

combined application of foliar spray and conventional fertilisers, which met the plant's nutrient demands more effectively. Similar findings were reported by Venkatesh *et al.* (2022), who observed greater leaf weight in cabbage with the use of nano Zn in combination with conventional fertilisers.

The data on stem diameter influenced by conventional and nano fertilisers alone or in combination. It also followed the same trend as above by applying a combination of DAP as a seedling dip and foliar spray (T_7), or both DAP and nano Zn as seedling dip and foliar sprays (T_8) with 100% NP fertiliser, led to a significant improvement in stem diameter compared to conventional NP application alone (Baghla and Sharma 2023). The nano DAP likely enhanced photosynthesis, root growth, and nutrient uptake, promoting cell expansion, while the addition of nano Zn, known for its role in protein synthesis and enzymatic activity, further supported these processes. Similarly, Abdulrehman *et al.* (2023) reported that a balanced nano-fertiliser blend (N_2O: P_2O: K_2O at 3 g/l) significantly increased curd diameter in cauliflower. Treatments with 100% NP and 75% NP applications resulted in similar stem lengths. Additional nano DAP as seedling dip or spray, and nano Zn sprays did not enhance stem length beyond conventional 100% or 75% NP applications alone. However, the combination treatments nano DAP seedling dip + foliar spray or seedling dip + foliar spray + nano Zn with 100% NP (T_7 and T_8) significantly increased stem length compared to the 100% NP application alone (T_3). Enhanced stem length under nano-fertiliser treatments may result from improved nutrient absorption, photosynthesis, and cell expansion, along with findings by Jat *et al.* (2021).

Phenological Attributes

The response to phenological attributes under various conventional and nano-fertiliser treatments (Table 2) revealed that the control treatment (T_1) showed the longest time to reach the first and 50% harvest, whereas treatments with combined nano DAP seedling dip, foliar spray, and nano Zn spray (T_8) applied to 100% NP significantly reduced the time to harvest. This aligns with (Prasad *et al.* 2017), who found that nano zinc

Table 2. Effect of different fertiliser treatments on phonological studies of cabbage

Treatments	Days taken for the first harvest	Days taken to 50% harvest	Days taken to complete harvest
T_1: Control	106	120	132
T_2:100%NP	99	120	130
T_3:75%NP	101	122	132
T_4:100%NP+ seedling dip of nano DAP	98	120	131
T_5:100%NP+ foliar spray of nano DAP	98	119	129
T_6:100%NP+foliar spray of nano Zn	99	120	130
T_7:100%NP+ seedling dip of nano DAP + foliar spray of nano DAP	98	119	129
T_8:100%NP+ seedling dip of nano DAP + foliar spray of nano DAP + foliar spray of nano Zn	96	117	127
T_9:75%NP+ seedling dip of nano DAP	101	121	129
T_{10}:75%NP+ foliar spray of nano DAP	100	120	130
T_{11}:75%NP+ foliar spray nano Zn	101	121	129
T_{12}:75%N+seedling dip of nano DAP+ foliar spray of nano DAP	99	120	130
T_{13}:75%NP +seedling dip of nano DAP +foliar spray of nano DAP + foliar spray of nano Zn	97	118	128
SEm+	1.94	2.45	3.75
CD (P= 0.05)	5.66	7.15	NS

oxide application delayed maturity in Chinese cabbage. Days to complete harvest were not significantly different among treatments, but generally, fertiliser applications led to earlier harvesting compared to the control, which required more time to mature.

Nutrient Uptake

The data presented in Table 3 on nutrient content and uptake in cabbage as affected by treatments revealed that the N, P, K and Zn content increased significantly when nano fertiliser DAP and nano zinc were used in conjunction with conventional fertiliser doses of 75% and 100% NP. The maximum nitrogen content was recorded when, along with 100% NP conventional fertiliser nano DAP was applied both as a seedling dip and spray and also the nano zinc spray was used (T_8). The nitrogen uptake is the function of nitrogen content and yield. The uptake followed a similar trend of nitrogen content observed for cabbage in the experiment. The nitrogen uptake decreased significantly when the conventional dose of NP was decreased from 100% to 75%. The lowest uptake was observed under control conditions as compared to 100% conventional fertiliser alone application. The increase in N uptake with supplementation of nano DAP and Zn over conventional fertiliser may be attributed to high nitrogen uptake through enhanced availability by basal application and nano N applied as DAP at critical stages (Rani *et al.* 2019; Hasaneen *et al.* 2016).

The phosphorus uptake in all conventional and nano fertiliser combinations of 100% and 75% NP were statistically at par with 100% NP alone application (T_2). It increased the same as in N content and their uptake. The high phosphorus content is attributed to the addition of nano P as the foliar spray of DAP, with more absorption and uptake, whereas when P is supplied through soil, it gets fixed, resulting in low availability. Nano DAP has improved the phosphorus efficiency and uptake of all the nutrients. Similar results were reported by Dhansil *et al.* (2018), who concluded that different levels of nano and chemical phosphatic fertilisers produced a significant effect on phosphorus content and its uptake in pearl millet.

The increase in K and Zn content under treatment, where conventional and nano fertilisers were combined, may be attributed to increased uptake triggered by efficient absorption of nano P as nano DAP at critical stages, which enhanced the physiological response in terms of better root proliferation and hence uptake. Silva *et al.* (2021) and Bhunia *et al.* (2005) also observed higher K uptake due to the combined effect of fertilisers.

However, the zinc uptake in treatment T_{12} and treatment $T_{13,}$ where only 75% NP was applied but supplemented with nano DAP alone or nano DAP + nano Zn spray the uptake was statistically similar to T_8. Treatment T_7 also recorded Zn uptake at par with $T_{8,}$ where only nano DAP as seedling dip and foliar spray was applied with 100% NP (Meena *et al.* 2021).

Table 3. Effect of different fertiliser treatments on nutrient content and uptake

Treatments	N content (%)	N uptake (kg/ha)	P content (%)	P uptake (kg/ha)	K content (%)	K uptake (kg/ha)	Zn content (mg/kg)	Zn uptake (g/ha)
T_1:Control	1.97	80.93	0.266	10.92	1.83	75.59	28.21	98.91
T_2:100% NP	2.19	115.28	0.273	15.04	1.87	104.15	33.10	126.82
T_3:75% NP	2.15	99.27	0.270	13.53	1.85	93.72	31.21	122.23
T_4:100% NP + seedling dip of nano DAP	2.22	121.56	0.275	15.19	1.89	105.54	34.82	131.86
T_5:100% NP + foliar spray of nano DAP	2.24	124.65	0.277	15.75	1.90	109.22	35.27	135.21
T_6:100% NP + foliar spray of nano Zn	2.23	119.22	0.273	15.13	1.88	105.36	37.14	132.15
T_7:100% NP + seedling dip of nano DAP + foliar spray of nano DAP	2.25	130.01	0.280	16.38	1.91	113.52	35.52	138. 87
T_8:100% NP + seedling dip of nano DAP + foliar spray of nano DAP + foliar spray of nano Zn	2.27	135.33	0.283	16.93	1.93	117.30	37.98	143.25
T_9:75%NP + seedling dip of nano DAP	2.21	104.31	0.274	13.65	1.87	94.17	32.82	126.36
T_{10}:75%NP + foliar spray of nano DAP	2.22	120.59	0.275	15.20	1.89	105.36	33.89	129.14
T_{11}:75%NP + foliar spray nano Zn	2.21	114.04	0.273	14.57	1.87	100.35	37.06	128.16
T_{12}:75%N + seedling dip of nano DAP + foliar spray of nano DAP	2.23	126.54	0.276	15.70	1.90	109.03	33.14	138.36
T_{13}:75%NP +seedling dip of nano DAP + foliar spray of nano DAP + foliar spray of nano Zn	2.26	131.10	0.280	16.40	1.92	113.62	37.78	141.26
SEm+	0.01	3.13	0.001	0.63	0.01	2.38	0.32	2.63
CD (P= 0.05)	0.03	9.15	0.003	1.84	0.03	6.94	0.93	7.68

CONCLUSION

The present study clearly articulated that the application of nano DAP and nano Zn in combination with the conventional recommended 100% NP or 75% NP significantly increased the growth attributes and uptake, and helps us to decrease the time for head maturity over conventional fertiliser application alone. For higher net returns, benefit cost and saving of 25 per cent conventional fertilisers, the cabbage crop for higher productivity and quality should be fertilised with 75% NP + nano DAP seedling dip + two sprays of nano DAP (4.0ml L^{-1}) + two sprays of nano Zn (2.0ml L^{-1}) at 30 and 60 days after transplanting.

Conflict of Interest: Authors declared that they do not have any conflict of interest.

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