Environment and Ecology 44 (2) 261—267, April—June 2026
Article DOI: https://doi.org/10.60151/envec/TNAL5284
ISSN: 0970-0420 (Print), ISSN: 3049-3625 (Online)

Influence of Exogenous Application of Nano-Calcium and Humic Acid on Different Horticultural Traits of Cabbage (*Brassica oleracea* var. *capitata* L.) under Valley Conditions of Garhwal Region

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Received 17 September 2025, Accepted 8 April 2026, Published on 27 April 2026

ABSTRACT

The experiment was conducted to investigate the influence of exogenous application of nano-calcium and humic acid on different horticultural traits of cabbage (*Brassica olerace*a var. *capitata* L.) under subtropical condition of Srinagar Garhwal at Horticultural Research Centre, Department of Horticulture, Chauras Campus, H.N.B. Garhwal University, Srinagar (Garhwal), Uttarakhand during *rabi* season, 2023-24. The experiment was laid out in randomized Block Design with three replications having 9 treatments viz., T_0 (Control), T_1 (Humic acid @ 2.5g/l), T_2 (Humic acid @ 4g/l), T_3 (Nano-calcium @ 2.5ml/l), T_4 (Nano-calcium @ 4ml/l), T_5 (Nano-calcium @ 2.5ml/l + Humic acid @ 2.5g/l), T_6 (Nano-calcium @ 2.5 ml/l + Humic acid @ 4g/l), T_7 (Nano-calcium @ 4ml/l + Humic acid @ 2.5g/l) and T_8 (Nano-calcium @ 4ml/l + Humic acid @ 4g/l). The means of the ANOVA test were compared at 0.05 level of probability. The result of present investigation showed that, the treatment T_7 (Nano-calcium @ 4ml/l + Humic acid @ 2.5g/l) gave the best outcome for growth parameters *i.e.*, plant height, plant spread and number of unwrapped leaves, and yield parameters *i.e.*, plant weight, head weight, head diameter, polar diameter and core diameter. For quality parameters, *i.e.,* total soluble solid, ascorbic acid and dry weight, and core length, the treatment T_6 (Nano-calcium @ 2.5 ml/l + Humic acid @ 4g/l) gave the superior result, while yield per plot, yield per hectare, head compactness and total soluble solid were found best under the treatment T_8 (Nano-calcium @ 4ml/l + Humic acid @ 4g/l). However, equatorial diameter was found to be highest in treatment T_4 (Nano-calcium @ 4ml/l). Therefore, it is possible to propose that combined treatments, such as 4 ml/l of nano-calcium and 2.5 g/l of humic acid, could be used to increase the production of cabbage cv. Golden Acre in the valley condition of Garhwal region.

Keywords Cabbage, Calcium, Exogenous, Humic, Nano.

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INTRODUCTION

Horticulture, being a subset of agriculture as a whole, contributes significantly to agricultural output and economic activity in India. Adoption of plant-based diets instead of meat and other animal products could help in reducing carbon footprints and mitigate climate change, while human health also gets improved, according to the UN Intergovernmental Panel on Climate Change's report "Climate Change 2022: Mitigation of Climate Change." As a trend shifts towards a vegan diet, the demand for vegetables will likely be increased. Vegetables are edible portions of herbaceous plants including roots, stems, leaves, fruits or seeds and are important source of vitamins, minerals, dietary fibers and antioxidants (Asaduzzaman and Asao 2018).

Cabbage (*Brassica oleracea* var. *capitata* L.) is one of the most important vegetable crops grown in India. It is a herbaceous plant with a short stem upon which is crown with a mass of leaves called head, usually green in color but red or purplish in some varieties (Sajib *et al*. 2015). According to FAO, 2020, world produces about 71.80 million tons of cabbage from a total area of 2 million hectares. After China, India is the world's second-largest producer of cabbage. It is the excellent source of vitamin C, folate and potassium and contains an anticancer agent, Indole-3-Carbinol, a hydrolysis product of glucosinolate glucobrassicin. On an addition to this, it also contains antioxidant, anti-inflammatory, gastroprotective and anti-obesity activity (Samec and Salopek-Sondi 2019). With the increasing demand for high-quality produce, there is a growing interest in exploring innovative agricultural practices and inputs to enhance crop yield and quality. Two of these developments that show promise for enhancing plant growth and development are nano-calcium and humic acid.

In agriculture, nanoparticles (NPs) are commonly utilized to increase crop yields through improved photosynthesis, seed germination, seedling growth, and other processes. Underutilized at current levels, NPs have been proven to be a novel, potent, and promising strategy for improving plant photosynthesis that has the potential to change agriculture in the future. (Gao *et al*. 2023). As a component of plant cell walls and membranes, calcium maintains cell wall structure stability and normal physiological functions, enabling plants to withstand abiotic stresses (Zhu 2016). Due to the smaller particle size of nano-particles and increased adhesion, nano-scale calcium is more readily absorbed by plants than traditional calcium carbonate particles. Cabbage absorbs calcium only through the root tips, so the limited absorption area requires a high calcium concentration in the nutrient solution. Cabbage's high calcium requirement and restricted absorption mechanism increase its susceptibility to calcium deficiency (Lee *et al.* 2013).

It is possible to infer that the increased concentration of carotenoids and chlorophyll in leaves is probably caused by nano-calcium and humic acid applications, which increase nutrient uptake and improve a variety of biochemical processes, including photosynthesis in leaves, which produces sugars that are quickly transported and released into the rhizosphere (Rachid *et al.* 2020). Therefore, keeping in view from these above-mentioned facts, the present investigation was conducted to assess the effect of nano-calcium and humic acid on growth, yield and quality of cabbage and to find out the best treatment among the different concentrations of nano-calcium and humic acid with respect to quality yield.

MATERIALS AND METHODS

The field experiment was conducted at Horticultural Research Centre, Department of Horticulture, Chauras Campus, H.N.B. Garhwal University, Srinagar (Garhwal), Uttarakhand, India during winter season, 2023-24. The experimental field is geographically situated in the Alaknanda Valley at 30°13'9"N latitude and 78°47'30"E longitude at an elevation of 540 m above sea level in the Lesser Himalayan region. The climatic condition is sub-tropical and humid with dry summers and harsh winters and it has a sandy loam soil with neutral pH. The experiment comprises of 3 replications and 9 treatments viz., T_0 (Control), T_1 (Humic acid @ 2.5g/l), T_2 (Humic acid @ 4g/l), T_3 (Nano-calcium @ 2.5ml/l), T_4 (Nano-calcium @ 4ml/l), T_5 (Nano-calcium @ 2.5ml/l + Humic acid @ 2.5g/l), T_6 (Nano-calcium @ 2.5 ml/l + Humic acid @ 4g/l), T_7 (Nano-calcium @ 4ml/l + Humic acid @ 2.5g/l), T_8 (Nano-calcium @ 4ml/l + Humic acid @ 4g/l). The experiment was laid out in Randomized Block Design with three replications. For the experiment, Golden Acre was the variety chosen. The treated cabbage seeds with Bavistin fungicide were sown in lines 5 cm apart across the prepared nursery beds of 2m ×1m size. 30 days old uniform and healthy cabbage seedlings were transplanted in the evening time. Row to row and plant to plant spacing was maintained at 60 × 45 cm respectively. An incorporation of well rotten farm yard manure (FYM) @ 20 t/ha before 15 days of transplanting. By using urea, single super phosphate, and muriate of potash at a rate of 120:60:60 kg/ha, the recommended dosage of N_2, P_2O_5, and K_2O was applied. Just before to transplanting, the entire dose of P_2O_5, K_2O, and half of the dose of N_2 were applied as a basal dose. The remaining half of the N_2 dose was top dressed in two split doses at 30 and 45 days later. The product from www.lobachemie.com, i.e., Humic Acid and nano-calcium, commercially labelled "Classic Ca-11%", which is composed of 11% of water-soluble calcium was used for the experiment. The solution was prepared on the basis of above-mentioned treatment details. The foliar application was done thrice at 20, 40 and 60 days after transplanting. On the basis of growth, yield and quality attributes, the treatments were assessed. The quality parameters were estimated according to the methods given by Ranganna (2014). The head compactness was measured by the formula given by Pearson (1931). The ascorbic acid content in cabbage was estimated by visual titration method as suggested by Ranganna (2014). Five healthy plants from each treatment per replication were tagged randomly for recording the data. The collected data was statistically analysed using the standard procedure described by Panse and Sukhatme (1985). The analysis of variance was performed using a simple randomized block design (RBD) with values calculated at the 5% level of significance. The critical difference at 5% level of probability was estimated to compare treatment means whenever 'F' test was significant.

RESULTS AND DISCUSSION

Growth parameters

Based on the data regarding the effect of nano-calcium, humic acid and their combination on the growth parameters presented in Table 1, at 30 DAT the maximum plant height (27.13 cm), plant spread (2173.40 cm^2) and number of unwrapped leaves (11.17) were recorded by treatment T_7 (Nano-calcium @ 4ml/l + Humic acid @ 2.5g/l), which were found significv antly superior over the rest of the treatments. At 45 DAT, maximum plant height (30.82 cm), plant spread (2657.73 cm^2) and number of unwrapped leaves (10.60) were observed from the treatment T_7 (Nano-calcium @ 4ml/l + Humic acid @ 2.5g/l) and T_8 (Nano-calcium @ 4ml/l + Humic acid @ 4g/l) respectively. At harvest, maximum plant height (31.2 cm), plant spread (2769.67 cm^2) and number of unwrapped leaves (10.33) in treatment T_7 and T_5 respectively were found significantly superior over the other treatments. Plant height at 30 DAT and at harvest shows significant growth among the applied treatments. This might be due to the synergistic effect of combined application in which nano-calcium enhances the nutrient uptake and promotes cell elongation, cell division and cell wall strength (Heidaria *et al.* 2022) and humic acid has a direct relation with plant growth hormones such as auxin that contributes to increase the plant height (Rubio *et al.* 2009). This is consistent to the findings of Rachid *et al.* (2020) in

Table 1. The effect of nano-calcium, humic acid and their combination on growth parameters of cabbage.

Treatments	Plant height (cm)			Plant spread (cm^2)			No. of unwrapped leaves		
	at 30 DAT	at 45 DAT	at harvest	at 30 DAT	at 45 DAT	at harvest	at 30 DAT	at 45 DAT	at harvest
T_0	22.34	28.48	29.53	1,927.47	2,475.93	2,481.73	10.40	9.20	8.73
T_1	22.57	26.23	27.40	1,328.70	2,037.13	2,476.87	10.33	10.47	9.20
T_2	25.25	27.07	27.70	1,839.47	1,802.80	2,031.73	10.53	9.53	9.40
T_3	24.50	27.23	28.76	1,882.93	2,292.93	2,581.80	10.20	9.73	9.47
T_4	24.70	27.53	30.13	1,882.60	2,289.87	2,383.60	10.43	9.73	9.47
T_5	23.37	25.59	26.66	1,467.53	1,888.40	2,217.00	10.33	9.67	10.33
T_6	23.37	27.53	29.46	1,368.67	1,774.60	2,155.33	10.70	10.27	9.73
T_7	27.13	30.82	31.20	2,173.40	2,657.73	2,769.67	11.17	10.53	8.60
T_8	26.87	27.67	28.40	2,145.93	2,311.80	2,388.13	11.10	10.60	9.40
CD at 5%	1.747	2.362	1.79	182.732	156.936	98.411	0.236	0.296	0.307
SE m±	0.578	0.781	0.592	60.431	51.9	32.545	0.078	0.098	0.102

Table 2. The effect of nano-calcium, humic acid and their combination on yield parameters of cabbage.

Treatments	Plant weight (g)	Head weight (g)	Head diameter (cm)	Polar diameter (cm)	Equatorial diameter (cm)	Core length (cm)	Core diameter (cm)	Yield/plot (kg)	Yield per hectare (q)
T_0	1,451.33	1,016.67	16.67	15.51	16.12	7.01	3.43	14.46	334.68
T_1	1,682.67	1,333.67	15.64	15.80	15.33	6.73	3.35	15.76	364.76
T_2	1,699.00	1,250.13	15.54	15.57	16.24	6.89	3.45	16.23	375.56
T_3	1,705.00	1,192.33	16.50	15.45	15.55	6.03	3.40	11.92	275.86
T_4	1,974.33	1,327.00	17.26	15.80	17.27	6.67	3.47	12.04	278.59
T_5	1,904.00	1,365.33	16.67	15.10	15.53	6.11	3.51	10.86	251.33
T_6	1,714.33	1,190.00	16.46	15.46	15.70	7.35	3.34	15.34	354.96
T_7	2,126.67	1,494.67	17.35	16.45	16.48	7.20	3.53	16.91	391.39
T_8	1,960.00	1,375.33	15.46	15.69	16.32	6.75	3.42	17.26	401.78
CD at 5%	207.539	182.318	0.399	0.580	0.358	0.656	0.103	1.054	24.869
SEm±	68.635	60.294	0.132	0.192	0.118	0.217	0.034	0.348	8.224

cauliflower and Mirzaee-Esgandian *et al*. (2020) in gerbera. Increased plant spread may result from the development of larger primordium cells as well as a gradual rise in cell size during meristem initiate and subsequent expansion. Similar findings are also supported by Ananda kumar *et al.* (2024) in bok-choy and red leaf lettuce and Farhan *et al.* (2023) in broccoli. However, no significant increase in unwrapped leaves number was observed till the overall concentration of combined nano-calcium and humic acid reached 6 ml l^{-1} and beyond this concentration, the maximum increase was 25%, which was supported by Rachid *et al.* (2020) in cauliflower.

Yield parameters

On the basis of data representing the effect of nano-calcium, humic acid and their combination on the yield parameters in Table 2, the treatment T_7 (Nano-calcium @ 4ml/l + Humic acid @ 2.5g/l) was found to be significantly superior over the rest of the treatments and recorded maximum plant weight (2126.67 g), head weight (1494.67 g), head diameter (17.35 cm), polar diameter (16.45 cm), core diameter (3.53 cm), while the minimum plant weight and head weight was observed in T_0 (Control). Total plant weight might be connected with the combinational effect of nano-calcium and humic acid on increasing the leaf size, plant spread, number of unwrapped leaves and total plant biomass via cell division, cell elongation and cell expansion which could have resulted in increased plant weight (Muromtsev *et al.* 1990). Accordingly, similar results are also obtained by Rachid *et al.* (2020) in cauliflower and Kazemi (2014) in tomato. An average weight of head is significantly correlated with head compactness, head size and head diameter (Kibar *et al.* 2014). On the other hand, nano-calcium enhances cell wall strength and overall plant structure therefore, increases average head weight of cabbage. Similar finding was also supported by Gladis *et al.* (2020) in cabbage and Cimrin and Yilmaz (2005) in lettuce. Head diameter might be governed by the combined effect of vegetative growth by nano-calcium and humic acid enhancing the photosynthetic rate and chlorophyll content on head weight and head size ultimately, head circumference will increase so the head diameter will automatically be increased. Similar finding was also reported by Abdel-Razzak (2010), as the foliar application of humic acid helps in enhancing the head diameter in cabbage indirectly.

Maximum yield per plot (26.93 kg) and yield per hectare (401.78 q) were observed in treatment T_8 (Nano-calcium @ 4ml/l + Humic acid @ 4g/l) which was statistically at par with treatment T_7 (Nano-calcium @ 4ml/l + Humic acid @ 2.5g/l) while the minimum yield per plot and yield per hectare was observed in treatment T_5 (Nano-calcium @ 2.5ml/l + Humic acid @ 2.5g/l). This may increase due to the cumulated efforts of result due to several factors, such as total plant weight, average weight of head, head diameter, leaf area, and core diameter, influences yield per plot directly and indirectly (Meena *et al.* 2017). The results are in conformity with the findings of Muromtsev *et al.* (1990) in tomato, Husein *et al.* (2015) in tomato

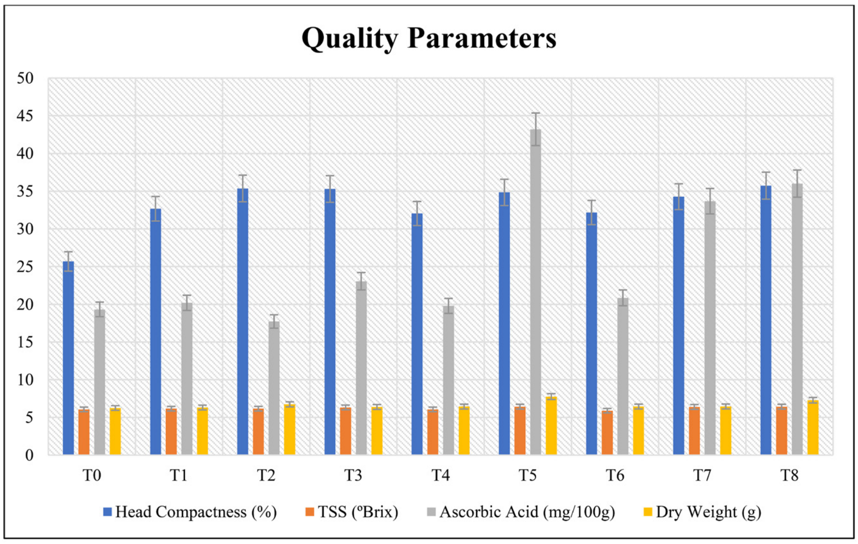

Fig. 1. Effect of nano-calcium, humic acid and their combination on quality parameters of cabbage.

and Rachid *et al.* (2020) in cauliflower.

Maximum core length (7.35 cm) was recorded in treatment T_6 (Nano-calcium @ 2.5 ml/l + Humic acid @ 4g/l) while minimum was recorded in treatment T_3 (Nano-calcium @ 2.5ml/l) and maximum equatorial diameter (17.27 cm) in treatment T_4 (Nano-calcium @ 4ml/l) whereas minimum was observed in treatment T_1 (Humic acid @ 2.5g/l). However, polar diameter, core length and core diameter were not found significant among the treatment, therefore, no effect of applied treatments was shown on those parameters.

Quality parameters

The quality parameters as influenced by nano-calcium, humic acid and their combination which are depicted in Fig.1 revealed that, the maximum head compactness (35.73%) was reported in treatment T_8 (Nano-calcium @ 4ml/l + Humic acid @ 4g/l) whereas minimum was recorded in T_0 (Control). This might be due to better nutrient absorption and structure integrity leads to enhance fresh head weight and overall plant biomass, which may correlate with improved head compactness in cabbage. Together, nano-calcium and humic acid can create a synergistic effect that promotes photosynthesis and improves accumulation of carbohydrates that promotes more compact cabbage heads. Similarly, the maximum ascorbic acid (43.20 mg/100g) and dry weight (7.76 g) was observed in treatment T_6 (Nano-calcium @ 2.5 ml/l + Humic acid @ 4g/l) whereas the minimum ascorbic acid was recorded in T_2 (Humic acid @ 4g/l) and minimum dry weight was recorded in T_0 (Control). The production of ascorbic acid could be enhanced by indirect influence of the metabolic pathways and enzymatic activities by the foliar application of nano-calcium and humic acid (Abou-El-Hassan and El-Shinawy 2015). Similar finding was also reported by Kazemi (2014) in tomato and Abou-El-Hassan and El-Shinawy (2015) in red cabbage. Nano-calcium, due to its small particle size, can be more efficiently absorbed by the plant leaves. This enhances calcium uptake, which is crucial for cell wall strength and overall plant structure, leading to improve growth and potentially increase dry head weight. Also, humic acid helps in better nutrient uptake, better root development, enhance photosynthetic rate and activation of enzymes. This is consistent to the findings of Husein *et al.* (2015) in tomato Rachid *et al.* (2020) in cauliflower. However, total soluble solid (TSS) was found non-significant enhancement, the maximum TSS (6.43 ºBrix) was noticed in treatment T_6 (Nano-calcium @ 2.5 ml/l + Humic acid @ 4g/l) and T_8 (Nano-calcium @ 4ml/l + Humic acid @ 4g/l) while the minimum was observed in treatment

T_4 (Nano-calcium @ 4ml/l).

CONCLUSION

Based on the findings of this investigation, it may be determined that the application of treatment (T_7) i.e., Nano-calcium @ 4 ml/l + Humic acid @ 2.5 g/l generated the highest plant height, spread, number of unwrapped leaves, total plant weight, average head weight, and polar diameter. Therefore, it is possible to suggest that, in the valley condition of Garhwal, combined treatments, such as 4 ml/l of nano-calcium and 2.5 g/l of humic acid might be used to increase the production of cabbage cv. Golden Acre.

ACKNOWLEDGMENT

The authors express their sincere gratitude to Department of Horticulture, Hemvati Nandan Bahuguna Garhwal University (A Central University) for providing the research facilities needed to conduct the study at the Horticultural Research Center, HNBGU, Srinagar, Garhwal, Uttarakhand.

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