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Effect of various nano formulations of nutrients on soil attributes pre transplanting and post harvesting the crop of cabbage (*Brassica oleracea* var. *capitata*) cv. Pride of India

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Abstract
A field study was conducted at the Horticultural Research Farm of Horticulture Department, Institute of Agriculture, Nain, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj (U.P.) during the academic years 2021-22 and 2022-23. In this study, we used a randomized block design with 09 treatments (including variations of micro- and macronutrients, biofertilizers and fertilizer Nano formulations) and 3 replications. "The main objective of this study was to evaluate the growth, yield and quality of cabbage grown with different concentrations of different Nano nutrients. The experimental results indicate that, treatment T_2 displayed the highest notable Available Nitrogen (kg/ha) of soil measurements i.e., [173.64 (2021-22), 169.87 (2022-23) and 171.76 (Pooled)] kg/ha, displayed the highest notable Available Phosphorus (kg/ha) of soil measurements i.e., [17.36 (2021-22), 15.42 (2022-23) and 16.39 (Pooled)] kg/ha when compared to the remaining treatments across both years of investigation and in the pooled analysis. treatment T_2 displayed the highest notable Available Potassium (kg/ha) of soil measurements i.e., [219.48 (2021-22), 216.91 (2022-23) and 218.20 (Pooled)] kg/ha when compared to the remaining treatments across both years of investigation and in the pooled analysis. T_2 displayed the lowest notable Organic carbon (%) of soil measurements i.e., [0.22 (2021-22), 0.21 (2022-23) and 0.22 (Pooled)] %. T_2 displayed the lowest notable Soil pH measurements i.e., [6.98 (2021-22), 6.97 (2022-23) and 6.97 (Pooled)]. when compared to the remaining treatments across both years of investigation and in the pooled analysis found were determined in both years and associated with T1 (treatment number 1) with various nano formulations of nutrients with different combinations of micro and micronutrients at the nanoscale. On the other hand, T_4 (treatment number 4 changed the mix of micronutrients and micronutrients in Nano preparations) recorded the lowest value for this crop cabbage.

Keywords: Cabbage, micro, macro, nutrients, nanocomposites, growth, yield and quality

Introduction

According to the Cruciferae family, cabbage (*Brassica oleracea* var. *capitata* L.) is one of the most prominent and commonly cultivated cool-season green vegetables in India. It was also an essential food for the ancient Greeks and Romans. Cabbage probably originated in Western Europe and was the first collard crop ever cultivated. Cabbage was mostly used as medicine before it was grown and eaten.

In addition to the fresh produce market, cabbage is currently processed into kale, cabbage rolls and egg rolls. Specialty markets may also develop for other types of cabbage, such as red cabbage, savoy cabbage and baby cabbage. Cabbage contains a modest amount of protein and various essential vitamins and minerals. With 36.6 mg, it is an excellent source of vitamin C. In addition to the vitamin B content, cabbage adds dietary minerals such as potassium (170 mg), calcium (40 mg), phosphorus (26 mg) and magnesium (12 mg). mg) per 100 grams (USDA Nutrient Database, 2016).

Nanotechnology proved its place in agriculture and related applications (Abdel-Aziz *et al*., 2019). The interaction of nano materials and fertilizer, due to high reactivity of nano materials, results in an increased and effective absorption of nutritional elements and essential compounds for plants. Important applications of nano materials in agriculture include nano bio-farming, nano pesticides, nano herbicides, nano bio-sensore and nano fertilizers.

In India, 9.049 million tons were produced on 0.399 million hectares of land (Anon., 2016-17) [3]. Various aspects of this production technology have been studied in different parts of the world, but little research has been done on the sources of the various organic nutrients. Nutrient availability is one of the many factors affecting cabbage productions, and it affects the amount of cabbage produced. The most important cabbage in the world is cabbage. Russia is the largest consumer of cabbage in the world, India, China and Russia are the three largest vegetable producers in the world. India is the second largest supplier of cabbage in the world after China (FAOSTAT, 2019) [4] With an average yield of 27.7 tons per hectare and a production of 59.55 million tons, it is grown on more than 21, 5 million hectares worldwide.

Due to their high reactivity, fertilizers and nanomaterials together effectively fix and absorb plant nutrient components and important chemicals. According to Jyoth and Hebsur (2017) [114], important applications of nanomaterials in agriculture are Nano bio-agriculture, Nano pesticides, Nano herbicides, Nano biosensors, and Nano fertilizers. And quit Hidden hunger and malnutrition, also known as micronutrient deficiencies, is a major problem in developing countries, especially in Southeast Asia and sub-Saharan Africa. "Micronutrient deficiencies negatively affect human health, which can include stunting, dementia, perinatal complications and increased mortality.

According to the test data, cabbage reacts strongly to nitrogen supply and somewhat to phosphorus. The authors studied in detail the effect of organic and inorganic fertilizers on the yield and nutritional value of cabbage. Soil management techniques have changed significantly in recent years due to the increased use of artificial fertilizers and pesticides to increase yields.

Cabbage is a very nutritious food that is rich in digestible protein and has biological value. In addition, it is moderately deficient in vitamin B6 and folate and rich in minerals, vitamins A, B1, B2, C and K. potassium (114 mg), phosphorus (44 mg), calcium (40 mg), magnesium (10 mg), sodium (14.1 mg), ascorbic acid (30-65 mg), protein (1.5 g), iron (0.5 mg), fat (0.2 g), water (93 ml) and essential amino acids - especially those containing sulfur - are found in cabbage. 100 g of green cabbage leaves contain 103 KJ of energy. Low or high temperatures can cause premature budding (flowering). In India, cabbage is often produced as a rabi crop. However, the development of hybrid varieties extended the growing season to the spring months. There are a number of varieties available that can cause stress in warmer seasons.

Materials and Methods

The current study on Kharif Cabbage cv. Pride of India planted at 60 cm×45 cm was carried out in the years 2021-22 and 2022-23. The experimental field is located about 8 kilometres from Allahabad city, on the left side of the Allahabad-Rewa Road, close to the Yamuna River, at the Horticulture Research Farm, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj (U.P.). Randomized block design was used to set up the experiment, with 3 replications for each of the seventeen treatment combinations. Details and various nano formulations of nutrients in which the best combination Treatment T_2 was suggested in Table 1. Each treatment received a unique combination of various formulations of nutrients (micro and macro nutrients in nano form). Growth attributes like Plant height (cm), number of leaves per plant & plant spread (cm) and Yield attributes like diameter of head (cm), weight of trimmed head (g), total weight of plant without roots, Head yield per plot (Kg) & Head yield per hectare (t/ha) were all successfully measured to determine the best treatment combination for cabbage cultivation.

Tabel 1: The best Treatment combination details

	Stage of growth		
	1	2	3
Nutrients	**Before heading**	**Young mature leaf formation**	**After head formation**
Nano N	87.5 ppm	65.6 ppm	80 ppm
Nano P	61.25 ppm	61.25 ppm	61.25 ppm
Nano K	40 ppm	40 ppm	40 ppm
Ca	70 ppm	88.75 ppm	117.5 ppm
Mg	32 ppm	32 ppm	32 ppm
S	40 ppm	40 ppm	40 ppm
Nano Fe	3.125 ppm	3.125 ppm	3.125 ppm
Nano Cu	0.375 ppm	0.375 ppm	0.375 ppm
Mn	1.625 ppm	1.625 ppm	1.625 ppm
Nano Zn	0.375 ppm	0.375 ppm	0.375 ppm
B	1.625 ppm	1.625 ppm	1.625 ppm
Mo	0.075 ppm	0.075 ppm	0.075 ppm
Nano Ag	0.50 ppm	0.50 ppm	0.50 ppm
Nano Ti Anatase	0.25 ppm	0.25 ppm	0.25 pm

Effect of nano formulations of nutrients on soil attributes of Cabbage

Available Nitrogen (kg/ha)

The experimental results indicate that, treatment T_2 displayed the highest notable Available Nitrogen (kg/ha) of soil measurements i.e., [173.64 (2021-22), 169.87 (2022-23) and 171.76 (Pooled)] kg/ha when compared to the remaining treatments across both years of investigation and in the pooled analysis. Treatment T_1 demonstrated the second most effective outcome, as evidenced by the Available Nitrogen (kg/ha) of soil measurements of [172.94 (2021-22), 169.19 (2022-23) and 171.06 (Pooled)] kg/ha. During the temporal interval encompassing both the years of study as well as pooled data, empirical evidence indicated that treatment T_1 was found to be statistically at par to that of treatment T_2. The analysis of the Available Nitrogen (kg/ha) of soil data reveals that T_5 consistently displayed the most diminutive measurements throughout both years of observation and pooled analysis data. Specifically, the measurements for T_5 were recorded as [165.22 (2021-22), 161.63 (2022-23) and 163.43 (Pooled)] kg/ha. According to both the years of study and pooled data, it was found that effect of treatment T_4 was found to be at par with treatment T_5.

Available Phosphorus (kg/ha)

According to the data, treatment T_2 displayed the highest notable Available Phosphorus (kg/ha) of soil measurements i.e., [17.36 (2021-22), 15.42 (2022-23) and 16.39 (Pooled)] kg/ha when compared to the remaining treatments across both years of investigation and in the pooled analysis. Treatment T_1 demonstrated the second most effective outcome, as evidenced by the Available Phosphorus (kg/ha) of soil measurements of [17.05 (2021-22), 15.15 (2022-23) and 16.10 (Pooled)] kg/ha. During the temporal interval encompassing both the years of study and pooled data, empirical evidence indicated that treatment T_1 was found to be statistically at par to that of treatment T_2. The analysis of the Available Phosphorus (kg/ha) of soil data reveals that T_5 consistently displayed the most diminutive measurements throughout both years of observation and pooled analysis data. Specifically, the measurements for T_5 were recorded as [13.98 (2021-22), 12.42 (2022-23) and 13.20 (Pooled)] kg/ha. According to both the years of study as well as pooled data, it was found that effect of treatment T_4 was found to be at par with treatment T_5.

Available Potassium (kg/ha)

According to the data, treatment T_2 displayed the highest notable Available Potassium (kg/ha) of soil measurements i.e., [219.48 (2021-22), 216.91 (2022-23) and 218.20 (Pooled)] kg/ha when compared to the remaining treatments across both years of investigation and in the pooled analysis. Treatment T_1 demonstrated the second most effective outcome, as evidenced by the Available Potassium (kg/ha) of soil measurements of [218.84 (2021-22), 216.28 (2022-23) and 217.56 (Pooled)] kg/ha. During the temporal interval encompassing 2021-22 and 2022-23 and pooled data, empirical evidence indicated that treatment T_1 was found to be statistically at par to that of treatment T_2. The analysis of the Available Potassium (kg/ha) of soil data reveals that T_5 consistently displayed the least measurements throughout both years of observation and pooled analysis data. Specifically, the measurements for T_5 were recorded as [211.28 (2021-22), 208.81 (2022-23) and 210.04 (Pooled)] kg/ha. According to both the years of study as well as pooled data, it was found that effect of treatment T_4 was found to be at par with treatment T_5.

Organic carbon (%)

However, according to the data, treatment T_2 displayed the lowest notable Organic carbon (%) of soil measurements i.e., [0.22 (2021-22), 0.21 (2022-23) and 0.22 (Pooled)] % during both years of investigation and in the pooled analysis. Where-as analysis of the Organic carbon (%) of soil data reveals that T_5 and T_4 consistently displayed the highest measurements throughout both years of observation and pooled analysis data. Specifically, the measurements for T_5 and T_4 were recorded as [0.26 (2021-22), 0.25 (2022-23) and 0.26 (Pooled)] %.

Soil pH

However, according to the data, treatment T_2 displayed the lowest notable Soil pH measurements i.e., [6.98 (2021-22), 6.97 (2022-23) and 6.97 (Pooled)] during both years of investigation and in the pooled analysis. Where-as analysis of the Soil pH data reveals that T_5 and T_4 consistently displayed the highest measurements throughout both years of observation and pooled analysis data. Specifically, the measurements for T_5 and T_4 were recorded as [7.03 (2021-22), 7.02 (2022-23) and 7.02 (Pooled)].

Table 2: Shows the pooled data of both the years 2022- 2023 of cabbage on the effect of various nano formulations of nutrients soil attributes pre transplanting and post transplanting of Cabbage (*Brassica oleracea* var. *capitata*) cv. Pride of India

Treatment Symbol	Number of leaves per plant	Plant spread (cm)	Diameter of head (cm)	Weight of trimmed head (g)	Total weight of Plant without roots (g)	Head yield per plot (kg)	Head yield per hectare (t)	Head compactness (%)	TSS (°Brix)	Ascorbic acid (mg/100 g of edible portion)	Vitamin A (µg/100 g)
T_0	19.63	46.41	16.14	1040.14	1135.59	9.36	38.52	24.75	5.65	42.01	123.53
T_1	19.91	46.79	16.22	1068.28	1166.32	9.61	39.57	25.02	5.66	42.57	124.96
T_2	18.24	44.84	15.69	913.04	996.82	8.22	33.82	23.64	5.54	38.62	115.37
T_3	17.50	43.93	15.40	843.73	921.14	7.59	31.25	23.11	5.47	36.72	110.75
T_4	16.91	43.39	15.32	815.57	890.40	7.34	30.21	22.69	5.46	36.18	107.39
T_5	18.93	45.59	15.92	976.36	1065.95	8.79	36.16	24.19	5.60	40.19	119.17
T_6	18.53	45.21	15.78	941.19	1027.55	8.47	34.86	23.97	5.56	39.29	116.82
T_7	19.22	45.97	16.01	1004.47	1096.65	9.04	37.20	24.49	5.61	40.86	120.99
T_8	17.89	44.39	15.56	878.38	958.98	7.91	32.53	23.34	5.51	37.67	112.86
F-test	S	S	S	S	S	S	S	S	S	S	S
S.E. (m) (±)	0.12	0.15	0.04	10.68	11.96	0.10	0.40	0.11	0.01	0.26	0.69
C.D. @ 5%	0.35	0.44	0.11	32.02	35.85	0.29	1.19	0.32	0.03	0.78	2.06

Summer and Conclusion

Soil attributes

Effect of Treatment T_2 displayed most notable Available Nitrogen of before transplanting (kg/ha) measurements i.e., [173.64 (2021-22), 169.87 (2022-23) and 171.76 (Pooled)] kg/ha where-as the measurements for T_5 were recorded as [165.22 (2021-22), 161.63 (2022-23) and 163.43 (Pooled)] kg/ha which were found lowest.

Effect of Treatment T_2 displayed most notable Available Phosphorus of before transplanting (kg/ha) measurements i.e., [17.36 (2021-22), 15.42 (2022-23) and 16.39 (Pooled)] kg/ha where-as the measurements for T_5 were recorded as [13.98 (2021-22), 12.42 (2022-23) and 13.20 (Pooled)] kg/ha which were found lowest.

Effect of Treatment T_2 displayed most notable Available Potassium of before transplanting (kg/ha) measurements i.e., [219.48 (2021-22), 216.91 (2022-23) and 218.20 (Pooled)] kg/ha where-as the measurements for T_5 were recorded as [211.28 (2021-22), 208.81 (2022-23) and 210.04 (Pooled)] kg/ha which were found lowest.

Effect of Treatment T_2 displayed least Organic carbon (%) of before transplanting measurements i.e., [0.22 (2021-22), 0.21 (2022-23) and 0.22 (Pooled)] % where-as the measurements for T_5 and T_4 were recorded as [0.26 (2021-22), 0.25 (2022-23) and 0.26 (Pooled)] % which were found lowest.

Effect of Treatment T_2 displayed least Soil pH of before transplanting measurements i.e., [6.98 (2021-22), 6.97 (2022-23) and 6.97 (Pooled)] where-as the measurements for T_5 and T_4 were recorded as [7.03 (2021-22), 7.02 (2022-23) and 7.02 (Pooled)] % which were found lowest.

Effect of Treatment T_2 displayed most notable Available Nitrogen after the harvest (kg/ha) measurements i.e., [173.64 (2021-22), 169.87 (2022-23) and 171.76 (Pooled)] kg/ha where-as the measurements for T_5 were recorded as [163.22 (2021-22), 160.63 (2022-23) and 161.63 (Pooled)] kg/ha which were found lowest.

Effect of Treatment T_2 displayed most notable Available Phosphorus after the harvest (kg/ha) measurements i.e., [18.36 (2021-22), 14.42 (2022-23) and 17.39 (Pooled)] kg/ha where-as the measurements for T_5 were recorded as [12.98 (2021-22), 11.42 (2022-23) and 12.20 (Pooled)] kg/ha which were found lowest.

Effect of Treatment T_2 displayed most notable Available Potassium after the harvest (kg/ha) measurements i.e., [220.48 (2021-22), 217.91 (2022-23) and 201.20 (Pooled)] kg/ha where-as the measurements for T_5 were recorded as [218.22 (2021-22), 215.91 (2022-23) and 200.00 (Pooled)] kg/ha which were found lowest.

Effect of Treatment T_2 displayed least Organic carbon after the harvest (%) measurements i.e., [0.21 (2021-22), 0.20 (2022-23) and .0.20 (Pooled)] % where-as the measurements for T_5 and T_4 were recorded as [0.21 (2021-22), 0.22 (2022-23) and 0.22 (Pooled)] % which were found lowest.

Effect of Treatment T_2 displayed least Soil pH after the harvet measurements i.e., [6.91 (2021-22), 6.95 (2022-23) and 6.93 (Pooled)] where-as the measurements for T_5 and T_4 were recorded as [7.01 (2021-22), 7.01 (2022-23) and 7.00 (Pooled)] % which were found lowest.

References

1. Abdullah HM, Rasheed SMS. Effect of sowing date, bio and nano fertilizers on vegetative growth and nutrient contents of cauliflower (*Brassica oleracea* var. botrytis l.) Under plastic house conditions. Journal of Duhok University. 2023;26(1):190-200.
2. Ali S, Javed HU, Rehman URN, Sabir IA, Naeem MS, Siddiqui MZ, *et al*. Foliar application of some macro and micronutrients improves tomato growth, flowering and yield. International Journal of Biosciences. 2013;3(10):280-287.
3. Alireza J, Alireza LM, Elham D. Response of growth and yield of cucumber plants (*Cucumis sativus* L.) to different foliar applications of nano-iron and -zinc. International Research Journal of Applied and Basic Sciences. 2015;9(2):1477-8.
4. Alloway BJ. Fundamental aspects of zinc in soils and plants. Zinc Soils Crop Nutr. 2008;2:30-52.
5. Amiri AB, Baninasab C, Ghobadi A. Zinc soil application enhances photosynthetic capacity and antioxidant enzyme activities in almond seedlings affected by salinity stress. Photosynthetic. 2016;54(2):267-274.
6. Asad A, Blamey EPC, Edward DG. Effects of boron foliar applications on vegetative and reproductive growth of sunflower. Ann Bot. 2003;92:565-570.
7. Astaneh N, Bazrafshan F, Zare M, Amiri B, Bahrani A. Nano-fertilizer prevents environmental pollution and improves physiological traits of wheat grown under drought stress conditions. 2021;12:005.
8. Aswathy M. Response of tomato to calcium and boron in the onattukara tract of Alappuzha district. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, Kerala, India. 2017;106p.
9. Avila-Quezada GD, Ingle AP, Golińska P, Rai M. Strategic applications of nano-fertilizers for sustainable agriculture: Benefits and bottlenecks. Nanotechnology-reviews. 2022;0126.
10. Ayyub CM, Muhammad AP, Muhammad RS, Muhammad IA. Assessment of various growth and yield attributes of tomato in response to pre-harvest applications of calcium chloride. Pakistan Journal of Life and Social Science. 2012;10(2):102-105.
11. Beig B, Niazi MBK, Sher F, Jahan Z, Malik US, Khan MD, *et al*. Nanotechnology-based controlled release of sustainable fertilizers: A review. Environmental Chemistry Letters. 2022;20:2709-2726.
12. Benzon HRL, Rubenecia MRU, Ultra VU Jr, Lee SC. Nano-fertilizer affects the growth, development and chemical properties of rice. International Journal of Agronomy and Agricultural Research. 2015;7(1):105-117.
13. Brand JJ, Becker DW. Evidence for direct roles of calcium in photosynthesis. J Bioenerg Biomembr. 1984;16:239-249.
14. Budak Z, Erdal I. Effect of foliar calcium application on yield and mineral nutrition of tomato cultivars under greenhouse conditions. Journal of Soil Science and Plant Nutrition. 2016;4(1):1-10.
15. C AM, Aziz I, Kaleri AR, Hasnain M, Haider G, Ma J, *et al*. Nano-fertilizers: A sustainable technology for improving crop nutrition and food security. NanoImpact. 2022;27:100411.
16. Chatterjee R, Jana JC, Paul PK. Enhancement of head yield and quality of cabbage (*Brassica oleracea*) by combining different sources of nutrients. Indian Journal of Agricultural Sciences. 2012;82(4):324-8.
17. Chaudhary I, Singh V. Titanium Dioxide Nanoparticles and its Impact on Growth, Biomass and Yield of Agricultural Crops under Environmental Stress: A Review. Research Journal of Nanoscience and Nanotechnology. 2020;10(1):1-8.
18. Das A, Prasad M, Gautam RC, Shivay YS. Productivity of cotton (*Gossypium hirsutum*) as influenced by organic and inorganic sources of nitrogen. Indian J Agric Sci. 2006;76:354-357.
19. Davis DR, Epp MD, Rioden HD. Changes in USDA food composition. Data for 43 Garden Crops from 1950-1999. J American College of Nutrition. 2004;23(1-2):1-2.

20. DeRosa MR, Monreal C, Schnitzer M, Walsh R, Sultan Y. Nanotechnology in fertilizers. National Nanotechnology Journal. 2010;5:91.
21. Devi HJ, Maity TK, Paria NC. Effect of different sources of nitrogen on yield and economics of cabbage. Environment and Ecology. 2001;21(4):878-880.
22. Ding CK, Chachin Y, Hamauzu Y, Imahori Y. Effects of storage temperatures on physiology and quality of loquat fruit. Postharvest Biology and Technology. 1998;14(3):309-315.
23. Dou Z, Li YY, Guo HL, Chen LR, Jiang JL, Zhou YC, *et al*. Effects of mechanically transplanting methods and planting densities on yield and quality of Nanjing 2728 under rice-crayfish continuous production system. Agronomy. 2021;11:488.
24. Eichert T, Goldbach HE. Equivalent pore radii of hydrophilic foliar uptake routes in stomatous and astomatous leaf surfaces-further evidence for a stomatal pathway. Physiologia Plantarum. 2008;132:491-502.
25. El Hadidi EM, El Dissoky RA, Amal AH, Abd El Hafez. Foliar calcium and magnesium application effect on potato crop grown in clay loam soils. Journal of Soil Science and Agricultural and Engineering Mansoura University. 2017;8(1):1-8.
26. El Sagan MA, Khater MS. Effect of Nano Titanium spraying on Growth and Productivity of Onion (*Allium cepa* L.). J Plant Production, Mansoura. 2015;6(11):1803-1810.
27. Elatafi E, Fang J. Effect of Silver Nitrate (AgNO3) and Nano-Silver (Ag-NPs) on Physiological Characteristics of Grapes and Quality during Storage Period. Horticulturae. 2022;8:419.
28. El-Azizy F, Habib A, Abd-El Baset A. Effect of Nano Phosphorus and Potassium Fertilizers on Productivity and Mineral Content of Broad Bean in North Sinai. J Soil Sci Agric Eng. 2021;12:239-246.
29. El-Sagan MAE, Shokry AM. Impact of bio-fertilizer and TiO2 nanoparticles spray on growth, productivity and pickle quality of turnip crop (*Brassica rapa*). Egyptian J Desert Res. 2019;69(1):101-121.
30. Farooq M, Bakhtiar M, Ahmed S, Ilyas N, Khan I, Saboor A, *et al*. Influence of sulfur and boron on the growth and yield of broccoli. Int J Environ Agri Res. 2018;2454-1850.
31. Farooq M, Bakhtiar M, Ahmed S, Ilyas N, Khan I, Saboor A, *et al*. Influence of sulfur and boron on the growth and yield of broccoli. Int J Environ Agri Res. 2018;2454-1850.
32. Fernández V, Eichert T. Uptake of hydrophilic solutes through plant leaves: current state of knowledge and perspectives of foliar fertilization. Critical Reviews in Plant Sciences. 2009;28(1-2):36-68.
33. Francis DV, Sood N, Gokhale T. Biogenic CuO and ZnO Nanoparticles as Nanofertilizers for Sustainable Growth of Amaranthus hybridus. Plants (Basel). 2022;11(20):2776.
34. Ghosh DK, Roy, Malic SC. Effect of fertilizers and spacing on yield and other characters of black cumin (*Nigella sativa* L.). Indian Agric. 1981;25:191-197.
35. Gladis R, Parvathy PJ, Biju J, Aparna B. Soil and Foliar Nutrition of Calcium, Magnesium and Boron influences Yield and Quality of Cabbage (*Brassica oleracea* L. var. *capitata*). Ind J Pure App Biosci. 2020;8(2):438-447.
36. Gobara AA. Response of 'Le-Conte' pear trees to foliar applications of some nutrients. Egypt J Hort. 1998;25(1):55-70.
37. Havlin JL, Beaton JD, Tisdale SL, Nelson WL. Soil Fertility and Fertilizers - An Introduction to Nutrient Management (7th Ed.). Prentice Hall of India Private Ltd., New Delhi. 2006;515 p.
38. Heansch R, Mendel RR. Physiological functions of mineral micronutrients (Cu, Zn, Mn, Fe, Ni, Mo,B, Cl). Current Opinion in Plant Biology. 2009;12(3):259-66.
39. Helper. Effect of calcium and boron nutrients on yield of tomato. Plant Soil. 2005;2(8):145-156.
40. Hochmuth G. Iron (Fe) nutrition of plants. SL353, Department of Soil and Water Sciences, UF/IFAS Extension. Available at: https://edis.ifas.ufl.edu/pdffiles/SS/SS55500.pdf. Accessed March 2024.
41. Huang Y, Dong Y, Ding X, Ning Z, Shen J, Chen H, *et al*. Effect of Nano-TiO_2 Composite on the Fertilization and Fruit-Setting of Litchi. Nanomaterials. 2022;12(23):4287.
42. Jahan SL, Niaz M, Ghulam H, Laghari AH, Khalid H, Tofique A, *et al*. Role of Nitrogen in Plant Growth and Development: a review of advances in *en-viro* Mental Biology. 2016;10(9):209-218.
43. Jakhar RK, Singh SP, Ola AL, Jat HR, Netwal M. Effect of NAA and boron levels on growth and quality of sprouting broccoli [*Brassica oleracea* (L.) var. italica Plenck]. Journal of Pharmacognosy and Phytochemistry. 2018;7(5):3402-3405.
44. Janet C, Cole MW, Smith CJ, Penn BS, Cheary K, Conaghan J. Nitrogen, phosphorus, calcium and magnesium applied individually or as a slow release or controlled release fertilizer increase growth and yield and affect macronutrient and micronutrient concentration and content of field-grown tomato plants. Scientia Horticulturae. 2016;211:420-430.
45. Jassim RA. Effect of levels and times of foliar application of Nano fertilizer Super micro plus on concentration of some micronutrients in dry matter and yield of Rice (*Oryza sativa* L.). Karbala Journal of Agricultural Sciences. The third agricultural scientific conference. College of Agriculture - University of Karbala; c2018. p. 255-264.
46. Kareem I, Akinrinde EA, Oladosu Y, Eifediyi EK, Abdulmaliq SY, Alasinrin SY, Kareem SA. Influence of Organic, Inorganic and Organo-Mineral Fertilizers on Yield and Quality of Sweet Potato (Ipomoea batatas). J Appl Sci Environ Manage. 2020;24(1):111-118.
47. Kasinath BL, Ganeshamurthy AN, Nagegowda NS. Effect of Magnesium on plant growth, dry matter and yield in tomato (L*ycopersicon esculantum* L.). Journal of Horticulture Science. 2015;10:190-193.
48. Kasinath BL, Ganeshmurthy AN, Sadashiva AT. Interaction effect of applied calcium and magnesium on alfisols of Karnataka and its influence on uptake and yield levels of tomato (*Solanum lycopersium* L.). Journal of Horticulture Science. 2014;9(2):179-184.
49. Khan FN, Rahman MM, Karim AJ, Hossain KM. Effects of nitrogen and potassium on growth and yield of gladiolus corms, Bangladesh Journal of Agriculture Research. 2012;37(4):607-616.

51. Kleiber T. Effect of manganese on nutrient content in tomato (*Lycopersicon esculentum* Mill.) leaves. Journal of Elementology. 2015;20(1):115-126.
52. Kobraee S. Effect of foliar fertilization with zinc and manganese sulfate on yield, dry matter accumulation, and zinc and manganese contents in leaf and seed of chickpea (*Cicer arietinum*). J App Biol Biotech. 2019;7(3):20-28.
53. Kumar A, Sharma N, Sharma CL, Singh G. Studies on nutrient management in apple cv. Oregon Spur-II under the cold desert region of Himachal Pradesh in India. Indian Journal of Agricultural Research. 2017, 51(2).
54. Kumar A, Yadav KK, Singh V. Effect of Integrated Nutrient Management on Soil Fertility and Soil Microbial Population after Cropping to Wheat Crop in Western Uttar Pradesh. International Journal of Plant & Soil Science. 2022;34(19):117-125.
55. Kumar J, Phookan DB, Lal N, Kumar H, Sinha K, Hazarika M. Effect of organic manures and biofertilizers on nutritional quality of cabbage. Journal of Eco-friendly Agriculture. 2015;10(2):114-119.
56. Kumar P, Sharma SK. Integrated nutrient management for sustainable cabbage - tomato cropping sequence under mid hill conditions of Himachal Pradesh. Indian Journal of Horticulture. 2002;61(4):331-334.
57. Kumar P, Kumar R, Singh SK, Kumar A. Effect of fertility on growth yield and yield attributes of pearl millet (*Pennisetum glaucum* L.) under rainfed condition. Agriways. 2014;2(2):89-93.
58. Kumar S, Shukla HS. Farm Science Journal. 2005;15:136-8.
59. Lal R. Soils and India’s food security. Journal of the Indian Society of Soil Science. 2008;56:129-138.
60. Lee SK, Kader AA. Preharvest and postharvest factors influencing vitamin C content of horticultural crops. Postharvest Biol. and Techn. 2000;20:207-220.
61. Li J, Wee C, Sohn B. Effect of ammonium- and potassium-loaded zeolite on Kale (*Brassica alboglabra*) growth and soil property. American Journal of Plant Sciences. 2013;4:1976-1982.
62. Liu R, Lal R. Potentials of engineered nanoparticles as fertilizers for increasing agronomic productions. Sci Total Environ. 2015;514:131-139.
63. Liu X, Wazne M, Han Y, Christodoulatos C, Jasinkiewicz KL. Effects of natural organic matter on aggregation kinetics of boron nanoparticles in monovalent and divalent electrolytes. J Colloid Interface Sci. 2010;348(1):101-107.
64. M Rahman SM, Kibria MG. Effect of boron and nitrogen on yield and hollow stem of broccoli. J Sci. Nature. 2007;1(3):24-29.
65. Mahil EIT, Kumar BNA. Foliar application of nanofertilizers in agricultural crops - A review. J Farm Sci. 2019;32(3):239-249.
66. Marschner H. Mineral nutrition of higher plants. Academic press, London. 4th printing; c1995. p. 889.
67. Masclaux-Daubresse C, Daniel-Vedele F, Dechorgnat J, Chardon F, Gaufichon L, Suzuki A. Nitrogen uptake, assimilation and remobilization in plants: challenges for sustainable and productive agriculture. Annals of botany. 2010;105(7):1141-1157.
68. Masuda T. Recent overview of the Mg branch of the tetrapyrrole biosynthesis leading to chlorophylls. Photosynth. Res. 2008;96:121-143.
69. McCarty LB. Best golf course management practices. 2nd Edition, Prentice, Hall Inc. Upper Saddle River, New Jersey, USA; c2005. p. 896.
70. McKenzie R. Wheat nutrition and fertilizer requirements: nitrogen, agriculture, food and Rural development, Canada Grains Council's complete guide to wheat management; c2001.
71. Meena SL, Aravindakshan K, Arya CK, Meena KK, Meena MK. Effect of bioregulators and boron on growth attributes of cabbage (*Brassica oleracea* var. *capitata* L.) cv. golden acre. International Journal of Chemical Studies. 2019;7(3):1540-1543.
72. Mehraj H, Taufique T, Mandal MSH, Sikder RK, Jamal Uddin AFM. Foliar Feeding of Micronutrient Mixtures on Growth and Yield of Okra (*Abelmoschus esculentus*). American-Eurasian Journal of Agricultural & Environmental Sciences. 2015;15(11):2124-2129.
73. Gad MAM, Zagzog O. Improving the yield and fruiting characteristics of Ewais mango cultivar by spraying with nano-chitosan and nano-potassium silicate. Scientific J. Agri. Sci. 2021;3(2):68-77.
74. Moklikar MS, Waskar DP, Maind MM, Bahiram VK. Studies on Effect of Micronutrients on Growth and Yield of Cauli-Flower (*Brassica oleracea* var. botrotis) cv. Sungro-Anandi. Int. J. Curr. Microbiol. App. Sci. 2018;6:2351-2358.
75. Moncada A, Miceli A, Sabatino L, Iapichino G, D’Anna F, Vetrano F. Effect of Molybdenum Rate on Yield and Quality of Lettuce, Escarole, and Curly Endive Grown in a Floating System. Agronomy. 2018;8(9):171.
76. Mukesh K, Chattappadhyay TK, Das DK, Kumar M. Effect of foliar application of zinc, copper and iron on the yield and quality of Gladiolus cv. Mirela. Journal of Interacademicia. 2001;5:300-303.
77. Nadeem AA, Lubna Z, Aziz HK, Abdul AQ. Effects of naphthalene acetic acid and calcium chloride application on nutrient uptake, growth, yield and post-harvest performance of tomato fruit. Pakistan Journal of Botany. 2013;45(5):1581-1587.
78. Nair SH, Nair BG, Maekawa T, Yoshida Y, Kumar DS. Nanoparticulate material delivery to plants. Plant Science. 2010;179:154-163.
79. Neuhaus C, Geilfus CM, Muhling KH. Increasing root and leaf growth and yield in Mg deficient faba beans (Vicia faba) by $MgSO_4$ foliar fertilization. J Plant nutr. Soil Sci. 2014;177(5):741-747.
80. Nibin PM, Ushakumari K, Ishrath PK. Organic nano NPK formulations on soil microbial and enzymatic activities on post-harvest soil of Bhindi. International Journal of Current Microbiology and Applied Sciences. 2019;8:1819-1814.
81. Nofal AS, Ashmawi AE, Mohammed AA, El-Abd MT, Helaly AA. Effect of soil application of nano NPK fertilizers on growth, productivity and quality of Lettuce (*Lactuca sativa*). Al-Azhar Journal of Agricultural Research. 2021;46(1):91-100.
82. Nongbet A, Mishra AK, Mohanta YK, Mahanta S, Ray MK, Khan M, *et al*. Nanofertilizers: A Smart and Sustainable Attribute to Modern Agriculture. Plants (Basel). 2022;11(19):2587.
83. Pankaj P, Rana BS, Kumar B, Saravanan S. Influence of different micronutrients on vegetative growth of broccoli (*Brassica oleracea* var. *italica*) cv. green

magic. The Pharma Innovation Journal. 2018;7(7):615-620.
84. Patil AS, Patel HK, Chauhan NP. Yield, quality and monetary returns of summer pearl millet (*Pennisetum glaucum* L.) as influenced by integrated nitrogen management and sowing methods. Crop Research. 2014;47(1, 2 & 3):24-28.
85. Patil RB. Role of potassium humate on growth and yield of soybean and black gram. Int. Jour. of Pharma and Bio sciences. 2011;2(1):242-246.
86. Pérez-Velasco EA, Valdez-Aguilar LA, Betancourt-Galindo R, González-Fuentes JA, Baylón-Palomino A. Covered Rutile-TiO_2 Nanoparticles Enhance Tomato Yield and Growth by Modulating Gas Exchange and Nutrient Status. Plants. 2023;12(17):3099.
87. Ping Z, Haixin C, Zhijuan Z, Rugang Z. Effects of Nano-TiO_2 Photosemiconductor on Photosynthesis of Cucumber Plants. Journal of Northeast Forestry University; c2008-08.
88. Priyadarshini A, Khambalkar, Tomar PS, Verma SK. Long-term effects of integrated nutrient management on productivity and soil fertility in pearl millet (*Pennisetum glaucum*) - mustard (*Brassica juncea*) cropping sequence. Indian Journal of Agronomy. 2012;57(3):222-228.
89. Rai V, Acharaya S, Dey N. Implications of Nanobiosensors in Agriculture. J Biomater Nanobiotechnol. 2012;3:315-324.
90. Rai-Kalal P, Jajoo A. Priming with zinc oxide nanoparticles improve germination and photosynthetic performance in wheat. Plant Physiology and Biochemistry. 2021;160:341-351.
91. Rajonee AA, Nigar F, Ahmed S, Imamul HSM. Synthesis of nitrogen nano fertilizer and its efficacy. Canadian Journal of Pure and Applied Sciences. 2016;10:3913-3919.
92. Rani B, Nirali B, Bahu D. Effect of chemical and nano nitrogenous fertilizers on availability of major nutrients (N, P, K) in soil after harvest of the sorghum crop. Int J Chem Stu. 2019;7(4):2940-2942.
93. Ranjan S, Misra S, Sengupta S, Parween S, Kumari U. Influence of micronutrients on growth and yield of cauliflower. Journal of Pharmacognosy and Phytochemistry. 2020;9(1):238-240.
94. Rashmi CM, Prakash SS. Effect of Nano Phosphorus Fertilizers on Growth and Yield of Maize (*Zea mays* L.) in Central Dry Zone of Karnataka. Mysore J Agric Sci. 2023;57(2):286-293.
95. Roshdy KHA, Refaai MM. Effect of nanotechnology fertilization on growth and fruiting of zaghloul date palms. J Plant Production. 2016;7(1):93-98.
96. Ruban JS, Gayathri B, Jeyaraj C. Bioefficacy of Nano Nutrients (N, Zn & Cu) on Yield of Capsicum. Plant Archives. 2021;21(2):386-390.
97. Saad TMA, Issa FH, Agaab RH. Effect of different organic fertilizer on N,P,K for tomato hybrid (Waaed and Alyste). Al-Muthanna Journal of Agriculture Sciences. 2014;2(2):119-123.
98. Sadak MS. Impact of silver nanoparticles on plant growth, some biochemical aspects, and yield of fenugreek plant (*Trigonella foenum-graecum*). Bulletin of the National Research Centre. 2019;43:38.
99. Saha P, Chatterjee R, Das NR, Mukhopadhyay D. Response of sprouting broccoli to foliar application of boron and molybdenum under Terai region of West Bengal. Indian Journal of Horticulture. 2010;67:214-217.
100. Saleh SAAA, Galala AA, Ezzo MI, Ghoname AA. An attempt for reducing mineral fertilization in lettuce production by using bio-organic farming system. Acta Hort. 2010;852:311-318.
101. Sarkar MMU. Effect of Boron and Molybdenum On growth And Yield of Cauliflower. A Thesis Submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka; c2020.
102. Shams AS. Effects of nano-anatase TiO_2 on growth and nitrate accumulation of lettuce. J. Plant Production, Mansoura Univ. 2014;5(5):765-771.
103. Sharma RK, Dashora LK, Mohammed S. Effect of time of planting and nitrogen on growth and flower yield of tuberose (*Polianthes tuberosa* L.) cv. Double. Orissa J. Hort. 2007;35(2):108-113
104. Sultana J, Siddique MA, Rashid MHA. Effects of cowdung and potassium on growth and yield of kohlrabi. J Bangladesh Agril. Univ. 2012;10(1):27-32.
105. Sun L, Wang Y, Wang R, Zhang P, Ju Q, Xu J. Physiological, Transcriptomic and Metabolomic Analyses Reveal Zinc Oxide Nanoparticles Modulate Plant Growth in Tomato. Environ Sci Nano. 2020;7:3587-3604.
106. Taiz L, Zeiger E. Plant physiology. 2nd ed. Sunderland, MA: Sinauer Associates, Inc., Publishers; c1998. p. 792.
107. Talukdar MC, Sangita M. Response of graded levels of N, P and K on yield and quality of tuberose (*Polianthes tuberosa* L.) cv. Single. J Ornamental Hort. 2003;6(4):335-340.
108. Thapliyal A, Uniyal SP, Bhatt L, Bhusan B. Effect of organic nitrogen sources along with urea and bioagents on growth, yield and quality of cabbage (*Brassica oleracea* var. *capitata* L.). Progressive Agriculture. 2008;8(2):173-176.
109. Thirunavukkarasu M, Subramanian KS. Synthesis and characterization of surface modified nano-zeolite fortified with sulphate and its sulfate sorption and desorption pattern. J Sci Ind Res. 2015;74(12):671-675.
110. Tränkner M, Tavakolb E, Jákli B. Functioning of potassium and magnesium in photosynthesis, photosynthate translocation and photoprotection. Physiol. Plant. 2018;163(3):414-431.
111. Umami N, Abdiyansah A, Agus A. Effects of different doses of NPK fertilization on growth and productivity of *Cichorium intybus*. In IOP Conference Series: Earth and Environmental Science. 2019;387(1):012097.
112. Wang H, Wang X, Ma J, Xia P, Zhao J. Removal of cadmium (II) from aqueous solution: A comparative study of raw attapulgite clay and a reusable waste-struvite/attapulgite obtained from nutrient-rich wastewater. J Hazard. Mater. 2017;329:66-76.
113. Yadav A, Yadav K, Abd-Elsalam KA. Nanofertilizers: Types, Delivery and Advantages in Agricultural Sustainability; Agrochemicals. 2023;2(2):296-336.
114. Jyothi TV, Hebsur NS. Effect of nanofertilizers on growth and yield of selected cereals: A review. Agricultural reviews. 2017;38(2):112-120.