

IMPACT OF NANO-DAP ON GROWTH AND DEVELOPMENT OF CABBAGE

ABSTRACT

Comment [eN1]: This abstract does not include: The research background and research aims.

The current study, "Impact of nano-DAP on growth and development of cabbage," was carried out in 2021–2022 at the Department of Horticulture's Experimental Farm at A.A.U., Jorhat. The treatments followed were T₁ (Untreated control), T₂ (100% RDF of N & K), T₃ (100% RDF of 130:80:80 kg/ha), T₄ (T₂ + ST with nano-DAP @ 5 ml/ltr), T₅ (T₂ + ST @ 10 ml/ltr), T₆ (T₂ + 1 FS of nano-DAP @ 6 ml/ltr at 25-30 DAT), T₇ (50 % P, 100% N & K + FS nano-DAP @ 2 ml/ltr at 25-30 DAT), T₈ (25% P, 100% N & K + FS nano-DAP @ 4 ml/ltr), T₉ (T₂ + ST @ 5 ml/ ltr + FS nano-DAP @ 6 ml/ltr), T₁₀ (25% P, 100% N & K + ST @ 5 ml/ ltr + FS nano-DAP @ 4 ml/ltr), T₁₁ (50% P, 100% N & K + ST @ 5 ml/ ltr + FS nano-DAP @ 2 ml/ltr), T₁₂ (25% P, 50% N & 100% K + ST @ 5 ml/ ltr + FS nano-DAP @ 4 ml/ltr) and T₁₃ (50% P, 50% N & 100% K + ST @ 5 ml/ ltr + FS nano-DAP @ 2 ml/ltr).

The results revealed that the maximum plant spread and number of non-wrapper leaves was observed in T₃ (17.12 cm) and (7.67) at 30 DAT whereas in T₃ (34.77 cm) and (16.83) at 60 DAT. The highest leaf area was recorded in T₃ (107.56 sqcm) at 30 DAT and at 60 DAT (226.54 sqcm), although at 30 DAT, the maximum leaf fresh weight was recorded in T₇ (4.40 g) although in T₃ (12.46 g) at 60 DAT. The maximum number of days (88.30 days) to harvest was taken by T₅. Thus, the investigation suggests that nano-DAP can reduce the amount of inorganic fertiliser applied while maintaining the potency of the crop.

Keywords: Impact, growth, potency and nano-DAP.

1. INTRODUCTION

India represents the second-largest supplier of veggies worldwide after China, comprising an area and annual output of specifically 27.23 million tonnes and 329.86 million tonnes (DAC & FW, 2020-2021). The cruciferous crops, usually referred to as cole crops, are members of the Brassicaceae family and have an ancestral relationship with *Brassica oleracea* L. var. *sylvestris* known as wild cabbage, cliff cabbage as well as colewort. The word "cole" is originated from the Latin term "caulis," that implies "stem." The plant has become one of the nation's principal veggies and usually grows in almost every region. Assam produces the most cabbage amongst the North Eastern regions, at roughly 640.13 tonnes, which is approximately 7.80% of the primary producing regions (85%).

Cabbage is a nutrient-rich food, comprising 400 I.U. of vitamin A, 27 mg of vitamin B1, 100 mg of vitamin C, 0.73% of calcium, 0.38% of phosphorus, 2.71% of potassium, 15 ppm of copper, 1.4% of protein, 5.3% of total carbohydrate, 0.2% of fat, and 92.4% of water per 100 g of palatable section (Brown and

Hutchison, 1949), however it contains significantly fewer amount of fat. In ancient times, cabbage was employed for its numerous medical benefits fighting ailments like gout, diarrhoea, gastrointestinal issues, and celiac disease. Because this plant contains indole-3-carbinol, it exhibits a cancer prevention action that protects towards cancer of the bowel. The extract of cabbage was additionally employed as a remedy for toxic mushrooms as well as a throat rinse for a sore throat. When salt is added pursuant to pressure to shredded cabbage leaves, a product that is fermented known as "sauerkraut" is created, and the resulting liquid is used to treat the scurvy condition.

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Because of the rapid increase in world populations, we have to boost agricultural output on the same quantity of arable land. This shows that we must produce crops of superior quality if we want to increase availability while preserving the current resources. Since cabbage needs a lot of mineral compounds to grow and produce more, especially the three elements phosphorus, nitrogen, and potassium. Thereby, producers frequently apply these fertilisers indiscriminately in order to enhance output, which has an impact on both the cost of cultivation and the condition of the agricultural land. Several methods and approaches are being developed to decrease the overuse of fertilisers and boost the effectiveness of nutrient effectiveness. In this present instance, nanotechnology has demonstrated the ability to support sustainable agriculture through the manufacturing of fertiliser that is both effective and advantageous. By raising productivity, improving the nutritional value of food as well as preserving the nutrition equilibrium of the farmland. It is projected that this cutting-edge technology will increase the revenue generated by farms.

As an outcome of nanotechnology, nano fertilisers are distinct from conventional fertilisers in a number of aspects. According to Calabi-Floddyet al. (2018), smart fertilisers, sometimes referred to as nanofertilizers, are made using tiny particles that act as both nutrient transporters and carriers for controlled distribution. According to Rameshaiah et al. (2015) and Solanki et al. (2015), nano-fertilizers possess a bigger surface area, a higher capacity for incorporation, as well as regulated discharge in targeted locations. Nanoparticles are moved between cells in the roots by means of plasmodesmata. The delayed and purposeful delivery of components by the nano-fertilizer formulations keeps plants from inadvertently depleting essential elements through their uptake. As a result, the efficiency with which elements are utilised increases as the dietary surplus decreases. Nano-formulations necessitates less application than conventional fertilisers, which reduces run-off from the surface, leaching, or the and emissions of gases into the environment. Using nanofertilizers as an agent to promote more intelligent and environmental conscious agriculture is a tempting option due to its several essential qualities, such as their broad surface area, increased capacity for adsorption, more penetration potential, as well as appropriate controllable kinetics for providing nourishment at the envisioned regions alongside minimal loss (Janmohammadi et al. 2016). The most widely used phosphatic fertiliser is diammonium phosphate (DAP) due to its beneficial physical attributes as well as its elevated composition with N (18%) and P₂O₅ (46% of the overall constitution) so, it is generally favoured. Thus, applying this fertiliser in nano form is

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going to be quite advantageous. The Ministry of Chemicals and Fertilisers has therefore commanded the factories that produce fertiliser to speed up the development of nano-DAP while setting a goal to make the fertiliser accessible with the aim to lessen the reliance on imports in our nation in a year. Considering every one of these factors, investigations were done to evaluate the advantage of employing nano-DAP by evaluating the efficacy of nano-DAP on crop growth attributes at graded levels of fertilizer application.

2. MATERIALS AND METHODS

A field study entitled "Impact of nano-DAP on growth and development of cabbage" was conducted in the agro-climatic condition of Jorhat (Assam) at the Experimental Farm, Department of Horticulture, Assam Agricultural University during the year 2021-2022. The soil used for the experiment was clay loam. The crop "cabbage" was selected for this study. The seedlings were produced at the Experimental Farm. The cabbage cultivar "Angad" (Enza zaden) was taken for this study. Seeds were collected from the authorized dealer. The 13 therapies of nutrient administration that made up the experiment were arranged in a simple randomised manner. N, P and K were applied in the form of Urea, Single super phosphate (SSP), nano-DAP and Muriate of potash (MOP). The treatment combinations of the experiment were T₁ (Control (No Fertilizer), T₂ (100% RD of N & K (130:0:80 kg/ha)), T₃ (100 % RD of NPK (130:80:80 kg/ha)), T₄ (T₂ + Seedling root-dip treatment of n-DAP @ 5 ml/ltr), T₅ (T₂ + Seedling root-dip treatment of n-DAP @ 10 ml/ltr), T₆ (T₂ + 1 FS of n-DAP @ 6 ml/ltr at 25-30 DAT), T₇ (50% P, 100% N & K + FS of n-DAP @ 2 ml/ltr at 25-30 DAT), T₈ (25% P, 100% N & K + FS of n-DAP @ 4 ml/ltr at 25-30 DAT), T₉ (T₂ + ST @ 5 ml/ ltr + FS of n-DAP @ 6 ml/ltr at 25-30 DAT), T₁₀ (25% P, 100% N & K + ST @ 5 ml/ ltr + FS of n-DAP @ 4 ml/ltr at 25-30 DAT), T₁₁ (50% P, 100% N & K + ST @ 5ml/ ltr + FS of n-DAP @ 2 ml/ltr at 25-30 DAT), T₁₂ (25% P, 50% N & 100% K + ST @ 5 ml/ ltr + FS of n-DAP @ 4 ml/ltr at 25-30 DAT) and T₁₃ (50% P, 50 % N & 100% K + ST @ 5 ml/ ltr + FS of n-DAP @ 2 ml/ltr at 25-30 DAT). Studies were made between the findings made during the nano-DAP applications and the recommended dose of fertiliser. The observations for the plant growth parameters were taken as follows:

2.1 Plant Spread (cm)

Plant spread of the randomly chosen five plants was measured at 30 and 60 days after transplanting with the help of a measuring tape. The maximum distance in between the two opposite outer leaflets were surveyed crosswise in centimetres, and the mean was determined.

2.2. Number of non-wrapper leaves

At 30 and 60 days after transplanting five randomly selected plants were counted for the number of non-wrapper leaves, and a mean was calculated for each treatment.

2.3. Leaf area (sqcm)

After transplantation, the leaf area of each plant was measured at 30 and 60 days by placing the leaves in a leaf area meter. The readings were taken and averaged to get the leaf area.

2.4. Leaf fresh weight (g)

For measuring the leaf weight, fresh leaves of the randomly sampled five plants were collected. Fresh weight of the leaf samples were measured in an electric balance and then readings were taken and averaged to get the fresh leaf weight.

2.5. Leaf dry weight (g)

After being dried in hot air oven to get the weight of the dry leaves. Readings were taken and averaged to get the dry leaf weight.

2.6. Root fresh weight (g)

Fresh roots were collected from five random plants at 30 and 60 days, washed to remove the soil and were weighed in electronic balance. The root weights were averaged to get the fresh root weight.

2.7. Root dry weight (g)

The fresh roots which were collected earlier to get the fresh root weight were then dried in hot air oven until fully dried. The readings of the dry root were taken in electronic balance and averaged to get the dry root weight.

2.8. Days to harvest

The period of days from the transplantation date to the harvest date was calculated.

3. RESULTS AND DISCUSSION

3.1. Plant spread (cm)

Significant response in plant spread by the treatments is presented in Table No. 1. The results revealed that the maximum plant spread was observed in T₃ (17.12 cm) at 30 DAT and the minimum was observed in T₁ (8.60 cm). The maximum plant spread was observed in T₃ (34.77 cm) at 60 DAT and the minimum in T₁ (19.26 cm). Treatments T₅, T₇, T₈, T₉, T₁₀ and T₁₁ were found to be statistically at par with T₃ at 30 DAT and T₇ & T₈ were statistically at par with T₃ at 60 DAT. Of the plants that were treated with nano-DAP, the highest plant spread was recorded in T₅ (16.47 cm) and T₇ (34.45 cm) at 30 & 60 DAT and the minimum plant spread was recorded in T₁₂ (14.61 cm) and T₄ (25.56 cm) at 30 & 60 DAT. It is possible that the leaf application of nano-DAP aided in the crops' immediate uptake of N and P, leading to increased tissue differentiation, proliferation of cells, and elongation of cells. Analyses on cabbage conducted by Nath (2000) confirm this conclusion.

3.2. Number of non-wrapper leaves

The data on number of non-wrapper leaves presented in Table No. 1 showed significant differences among the treatments. At 30 & 60 DAT the maximum number of non-wrapper leaves (7.67 & 16.83) was recorded in T₃. The minimum number of non-wrapper leaves was recorded in T₂ (6.03) and T₁ (10.50) at 30 & 60 DAT, respectively. Treatment T₇ was found to be statistically at par with T₃ at 30 DAT while T₇, T₁₁, T₁₂ and T₁₃ were at par with T₃ at 60 DAT. Of the plants administered nano-DAP, the greatest no. of non-wrapper leaves was recorded in T₇ (7.60) at 30 DAT and the minimum was recorded in T₆ (5.23) at 30 DAT. At 60 DAT the maximum no. of non-wrapper leaves was recorded in T₁₂ (17.43) and the minimum was recorded in T₆ (11.50). Treatments T₈ and T₁₁ were found to be statistically at par with T₇ and treatments T₇ & T₁₃ were found to be statistically at par with T₁₂ at 30 & 60 DAT. The variations in the number of non-wrapper leaves might be due to the certainty that nutrient release efficiency supplied by different doses of fertilizers were not in a similar magnitude. Nath (2000), Devi and Singh (2012) also recorded similar observations in cabbage.

3.3. Leaf area (sqcm)

The results of the leaf area were significantly impacted by the treatments and are furnished in Table 1. The highest leaf area was recorded in T₃ (107.56 sqcm) at 30 DAT and at 60 DAT (226.54 sqcm) and the lowest was recorded in T₁ (17.27 sqcm) at 30 DAT and at 60 DAT T₁ (37.70sqcm). Amongst the crops that were treated with nano-DAP at 30 & 60 DAT the highest leaf area was recorded in T₇ (88.33 and 183.70 sqcm). The lowest leaf area was recorded in T₄ (27.40 sqcm) at 30 DAT and in T₄ (54.69 sq cm) at 60 DAT. The disparity among the leaf areas of different treatments might be due to the synergistic outcomes of discrete doses of fertilizers applied. Nitrogen has a significant influence on the morphological development of plants, favouring the growth of plants with larger leaf areas that are more effectively used in the production of heads. With higher nitrogen rates, the vegetative characteristics improved (Chaudhury *et al.*, 2015).

3.4. Leaf fresh weight (g)

The data on leaf fresh weight presented in Table 1 showed a significant difference among the treatments. At 30 DAT, the maximum leaf fresh weight was recorded in T₇ (4.40 g), however, did not differ significantly from T₃, T₈, T₉ and T₁₁. At 60 DAT the leaf fresh weight was recorded maximum in T₃ (12.46 g) while the minimum leaf fresh weight was in T₁ (0.91 g) at 30 DAT and at 60 DAT (5.25 g). Amongst the nano-DAP treatments, the maximum leaf fresh weight at 30 & 60 DAT was recorded in T₇ (4.40 g) and T₁₁ (10.61 g), respectively and the minimum weight at 30 & 60 DAT were recorded in T₄ (1.39 g) and (9.27 g). At 30 DAT T₈, T₉ and T₁₁ were found to be statistically at par with T₇. At 60 DAT treatments T₆, T₇, T₈ and T₉ were found to be statistically at par with T₁₁. The agronomic qualities of the produce were enhanced by higher levels of nitrogen (Chaudhury *et al.*, 2015).

TABLE No. 1 Measurement of Plant Spread, Number of non-wrapper leaves, Leaf Area, and Leaf fresh weight

Treatments	Plant spread (cm)		Number of non-wrapper leaves		Leaf area (sqcm)		Leaf fresh weight (g)	
	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT
T ₁	8.60	19.26	6.40	10.50	17.27	37.70	0.91	5.25
T ₂	13.11	21.85	6.03	11.50	18.97	44.03	1.16	7.81
T ₃	17.12	34.77	7.67	16.83	107.56	226.54	4.13	12.46
T ₄	15.04	25.56	6.43	12.40	27.40	54.69	1.39	9.27
T ₅	16.47	28.45	5.70	14.97	27.88	58.41	1.41	9.41
T ₆	15.41	26.20	5.23	11.50	37.94	63.41	1.77	9.93
T ₇	16.36	34.45	7.60	16.77	88.33	183.70	4.40	10.50
T ₈	16.20	32.46	7.37	15.27	78.95	158.81	4.07	10.17
T ₉	15.60	26.59	6.50	14.60	63.70	127.81	3.88	9.84
T ₁₀	15.35	29.42	6.23	15.03	55.68	111.07	2.98	9.72
T ₁₁	16.39	32.01	7.33	15.80	65.83	130.57	4.03	10.61
T ₁₂	14.61	30.16	6.40	17.43	57.96	113.56	3.28	9.61
T ₁₃	14.70	32.00	6.63	16.97	62.95	115.03	3.44	9.64
SEd (±)	0.68	0.99	0.14	0.64	4.28	10.59	0.28	0.40
CD (5%)	1.40	2.05	0.28	1.32	8.85	21.86	0.57	0.82

ST: Seedling root-dip treatment FS: Foliar spray

3.5. Leaf dry weight (g)

A significant difference was found in leaf dry weight (Table No. 2). At 30 DAT, the maximum leaf dry weight was obtained in T₃ (1.29 g) while the minimum was observed in T₂ (0.02 g). Application of 100% NPK 130:80:80 kg/ha (T₃) proved to be superior in leaf dry weight (4.98 g) among all the treatments at 60 DAT the minimum being in T₁ (0.91 g). Among the nano-DAP treated plants, the maximum leaf dry weight at 30 DAT was recorded in T₇ (0.95 g) and the minimum was in T₄ (0.06 g) while at 60 DAT the maximum leaf dry weight (4.11 g) was observed in T₉ (N & K 130:80 kg/ha + seedling root-dip @ 5 ml/ ltr + foliar spray of n-DAP @ 6 ml/ltr at 25-30 DAT) and the minimum (2.86 g) was observed in T₅ and T₁₀. At 30 DAT, treatments T₈, T₉, T₁₁ and T₁₃ were found to be statistically at par with T₇ and at 60 DAT, T₇ and T₈ were found to be statistically at par with T₉. The contrariety within the treatments might be due to the cumulative impact of different dose of fertilizer application.

3.6. Root fresh weight (g)

Data presented in Table No. 2 revealed that root fresh weight was significantly influenced by the treatments. At 30 DAT, the maximum root fresh weight was registered in T₃ (7.27 g) and the minimum was observed in T₁ (3.44 g). At 60 DAT, the maximum root fresh weight was observed in T₃ (23.75 g) and the minimum was observed in T₁ (13.93 g). At 30 DAT, treatments T₇ and T₈ were found to be statistically at par with T₃ and at 60 DAT, T₇ was found to be statistically at par with T₃. Amongst the nano-DAP treated plants, the maximum root fresh weight was obtained in T₇ (7.24 g) and the minimum was recorded in T₄ (3.74 g) at 30 DAT. At 60 DAT, the maximum root fresh weight was observed in T₇ (22.69 g) but did not differ significantly from T₈, T₉, T₁₀ and T₁₁ and the minimum was observed in T₄ (19.30 g). Variability in root penetration and growth may have been mediated by the cumulative impact of different fertiliser dosages that improved the physical properties and soil composition, leading to the difference in root weight. Nath (2000) reported comparable results with cabbage.

3.7. Root dry weight (g)

Data presented in Table No. 2 reveals that root dry weight was significantly influenced by the treatments. At 30 DAT, the maximum root dry weight was observed in T₇ (2.25 g) and the minimum was observed in T₄ (0.72 g). At 60 DAT, the maximum root dry weight was again registered by T₇ (8.32 g) while the minimum (3.40 g) was found in untreated control plots (T₁). Within the nano-DAP treated plants, the minimum root dry weight was observed in T₄ (4.10 g) at 60 DAT. The difference in root dry weight may result from the synergistic impact of different fertiliser formulations that improved physical attributes and soil composition.

3.8. Days to harvest (days)

The data presented in Table No. 2 reveal that the treatments had a significant influence on days to harvest. The maximum number of days (88.30 days) to harvest was taken by T₅ (N & K 130:80 kg/ha + seedling root treatment @ 10 ml/ltr nano-DAP) but was statistically comparable with T₃, T₁₂ & T₁₃ while the minimum was observed in T₁ (77.30 days). Amongst the nano-DAP treatments, the minimum days was recorded in T₈ (80.30 days). The variations could be because of the fact that since nano-DAP also includes N, maturation is delayed by high N levels, extending vegetative growth at the expense of maturation (Nath, 2000). The graphical representation of the data is presented in FIG. 1.

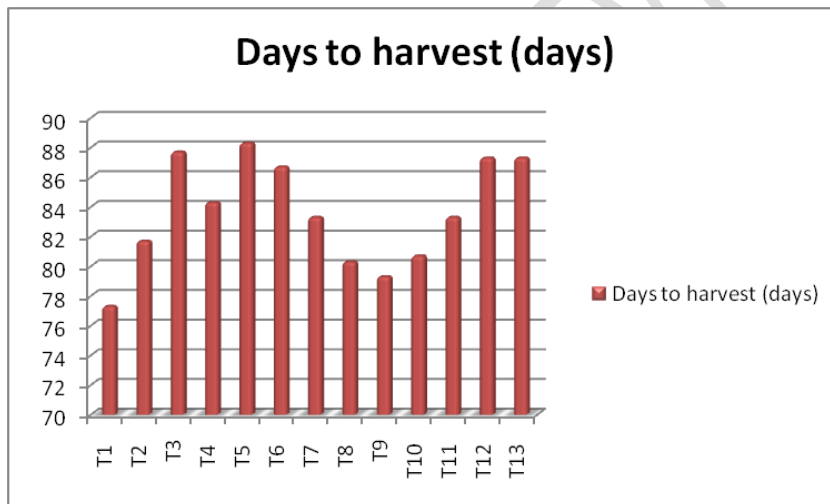


FIG 1. DAYS TO HARVEST (DAYS)

TABLE No. 2 Measurement of Leaf dry weight, Root fresh weight, Root dry weight, and Harvesting days

Treatments	Leaf dry weight	Leaf dry weight	Root fresh weight	Root fresh weight	Root dry weight	Root dry weight (g)	Days to harvest (days)
	(g)	(g)	(g)	(g)	(g)	(g)	
	30 DAT	60 DAT	30 DAT	30 DAT	30 DAT	60 DAT	
T ₁	0.05	0.91	3.44	13.93	0.91	3.40	77.30
T ₂	0.02	2.45	4.13	18.17	0.92	5.15	81.70
T ₃	1.29	4.98	7.27	23.75	2.11	7.03	87.70
T ₄	0.06	2.88	3.74	19.30	0.72	4.10	84.30
T ₅	0.07	2.86	5.57	19.36	1.19	4.27	88.30
T ₆	0.08	2.91	5.77	20.00	1.10	5.15	86.70
T ₇	0.95	3.94	7.24	22.69	2.25	8.32	83.30
T ₈	0.83	3.98	7.15	22.04	1.73	6.63	80.30
T ₉	0.84	4.11	5.54	21.85	1.09	4.53	79.30
T ₁₀	0.75	2.86	5.72	22.11	1.13	4.56	80.70
T ₁₁	0.93	3.66	6.48	22.12	1.26	5.65	83.30
T ₁₂	0.56	3.06	5.66	20.25	1.04	4.11	87.30
T ₁₃	0.81	3.30	5.80	19.98	1.22	4.40	87.30
SEd (±)	0.08	0.21	0.19	0.64	0.12	0.33	0.56

CD (5%)

0.16

0.43

0.40

1.32

0.25

0.68

1.15

ST: Seedling root-dip treatment FS: Foliar spray

4. CONCLUSION

The current study clearly shows that applying nano-DAP at different graded levels both as a spray on the foliage and seedling root dip therapy was highly successful in improving the growth characteristics of cabbage heads. Because nano-DAP significantly reduces the amount of applications. Thus, in terms of usage volume as well as cost, it can be utilised as a competitively priced and environmentally beneficial substitute for traditional inorganic fertilisers.

UNDER PEER REVIEW

REFERENCES

- Abbasifar, A., Shahrabadi, F. and ValizadehKaji, B. Effects of green synthesized zinc and copper nanofertilizers on the morphological and biochemical attributes of basil plant. *J. Plant Nutr.* **43**(8): 1104-1118. 2020.
- Abd El-Azeim, M. M., Sherif, M. A., Hussien, M. S., Tantawy, I. A. A. and Bashandy, S. O. Impacts of nano and non-nanofertilizers on potato quality and productivity. *Acta Ecol. Sin.* 2019; **40**(5): 388-397.
- Abdulhameed, M. F., Ali, A. T., and Raid, A. I. Improvement of cabbage growth and yield by nanofertilizers and nanoparticles. *Environ. Nanotechnol., Monit. Manag.* 2021; **15** (1): 100437- 100442.
- Abu, M. Effect of compound and single based fertilizers on shelf life of exotic/minor vegetable crops cultivated for fresh market. *Hortic. Int. J.* 2021, **5**(2): 90-95.
- Al-Juthery, H. W. A., Habeeb, K. H., Kadhim, F. J. L., Taey, K. D. A. L. L., Abdel, A. R. A. L. Effect of foliar application of different sources of nano-fertilizers on growth and yield of wheat. *Biosci. Res.* 2018; **15** (4): 3988-3997.
- Al-Juthery, H.W.A. and Al-Shami, Q.M.N. The effects of fertigation with nano NPK fertilizers on some parameters of growth and yield of potato (*Solanum tuberosum* L.). *Al-Qadisiyah J. for Agric. Sci.* 2019; **9**(2): 93. DOI: <https://doi.org/10.33794/qjas>.
- Ananda, A., Devi, A. K. B., Barik, S. P., Kouthoujam, J. and Bairwa, M. K. Effect of growth, physiological aspects and yield of cabbage (*Brassica oleracea* L. cv Rareball) in knolkhol and broad bean inter cropping system under Imphal West Condition. *Int. J. Curr. Microbiol. Appl. Sci.* 2018; **7**(10). ISSN: 2319-7706.
- Askary, M., Amirjani, M. and Saberi, T. Comparison of the effects of nano-iron fertilizer with iron-chelate on growth parameters and some biochemical properties of *Catharanthus Roseus*. *J. Plant Nutr.* 2016; **40** (7): 974- 982.
- Avila-Quezada, G. D., Avinash, P. I., Patrycja, G. and Mahendra R. Strategic applications of nanofertilizers for sustainable agriculture: Benefits and bottlenecks. *Nanotechnol. Rev.* 2022; **11** (1): 2123–2140.
- Bharadwaj, V. and Omanwar, P. K. Long term effects of continuous rotational cropping and fertilization of crop yields and soil properties. *J. Indian Soc. Soil Sci.* 1994; **42**: 387.
- Brown, H. D. and Hutchinson, C. S. *Vegetable Science. J. B. Lippincot Company, New York.* 1949; 21-30.
- Chamuah, S., Dutta, R., Haokip, W. and Beese, S. Nanofertilizers for second green revolution. *Adv. Agric. Environ. Sustain.* 2023; Pp: 9-19.
- Chamuah, S., Gogoi, S., Bhattacharjee, D., Barman, D., Dutta, S., Sharma, S. and Das, K. Effect of nano-DAP on soil characteristics and qualities of cabbage. *Int. J. Plant Soil Sci.* 2023; **35**(13): 52-59.
- Chatterjee, R., Jana, J. C. and Paul, P. K. Enhancement of head yield and quality of cabbage (*Brassica oleracea*) by combining different sources of nutrients. *Indian J. Agric. Sci.* 2012; **82**(4): 324-8.
- Chaudhury, M. M., Bhanvadia, A. S. and Parmar, P. N. (2015). Effect of integrated nutrient management on growth, yield attributes and yield of cabbage (*Brassica oleracea* var. *capitata* L.) under middle Gujarat conditions. *Biosci. Trends.* 2015; **8**(8): 2164-2168.

- Davarpanah, S., Ali, T., Davarynejad, G., Aran, M., Abadia, J. and Khorassani, R. Effects of foliar nano-nitrogen and urea fertilizers on the physical and chemical properties of pomegranate (*Punica granatum* cv. Ardestani) fruits. *Hortic. Sci.*2017;**52** (2): 288–294.
- Deenik, J., Hamasaki, R., Shimabuku, R., Nakamoto, S. and Uchida, R. Phosphorus fertilizer management of head cabbage. *Soil Crop Manage.* 2006; SCM-16.
- Deepika, J., Prasad, TNVKV., Rao, CSH., Luther, MM. and Rao, V. S. Emergence of nanoscale fertilizers in agriculture: A review. *Int. J. Chem. Stud.* 2020;**8**(6): 1164-1169.
- Dehkourdi, E. H. and M Ousa, M. Effect of anatase nanoparticles (TiO₂) on parsley seed germination (*Petroselinum crispum*) in vitro. *Biol. Trace Elem. Res.* 2013;**15** (1): 283–286.
- DeRosa, M. C., Monreal, C., Schnitzer, M., Walsh, R. and Sultan, Y. Nanotechnology in fertilizers. *Nat. Nanotechnol.* 2010; **5**.
- Devi, K. B. and Singh, N. I. Yield Response of cabbage (*Brassica oleracea* var. *capitata*) cv. Pride of India to varying levels of chemical fertilizers and vermicompost. *Int. J. Agric. Vet. Sci.*2012;**1**(3): 08-11.
- Dubey, S. N., Singh, R., Kumar, R. and Dubey, S. Effect of phosphorus and PSB on growth, nodulation and fertility status in different mungbean (*Vigna radiata* L.) varieties and its residual effect on fodder yield of sorghum in indo-gangetic plain zone of India. *Int. J. Agric. Sci.*2018;**14**(1): 196-201. e ISSN-0976-5670.
- E, mahil. and kumar, N. A. Foliar application of nanofertilizers in agricultural crops – A review. *J. Farm Sci.*2019; **32**(3): 239-249.
- Ekinci, M., Dursun, M., Yildirim, E., Parlakova, F. Effects of nanotechnology liquid fertilizers on the plant growth and yield of cucumber (*Cucumis sativus* L.). *Acta Sci. Pol.Hortorum Cultus.*2014; **13**(3): 135-141.
- El-Bassiouny, H. M. S., Abdallah, M. M. S., El-Enany, M. A. M. and Sadak, M. S. Nano-zinc oxide and arbuscular mycorrhiza effects on physiological and biochemical aspects of wheat cultivars under saline conditions. *Pak. J. Biol. Sci.* 2020; ISSN: 1028-8880.
- El-Henawy, A., El-Sheikh, I., Hassan, A., Madein, A., El-Sheikh, A., El-Yamany, A. and Faizy, S. E. D. Response of cultivated brocolli and red cabbage crops to mineral, organic and nanofertilizers. *Env.Biodivers. Soil Secur.*2018; **2**(2018): 221-231.
- Elizabeth, A., Bahadur, V., Mishra, P. and Prasad, V.P. Effect of different concentrations of iron oxide and zinc oxide nanoparticles on growth and yield of carrot (*Daucus carota* L.). *J.Pharmacogn.Phytochem.* 2017; **6**(4): 1266-1269.
- Farnia, A. and Omid, M. M.Effect of nano-zinc chelate and nano-biofertilizer on yield and yield components of Maize (*Zea mays* L.), under water stress condition. *Indian J. of Nat. Sci.* 2015; **5**(29). ISSN: 0976-0997.
- Fatimah, S.N., Norida, M. and Zaharah, S. S. Effect of different nitrogen fertilization on cabbage (*Brassica oleracea*) and development of diamond back moth (*Plutellaxylostella*). *Food Res.* 2019; eISSN: 2550-2166.
- Filho, A.B.C., da Silva, G.S. and Cortez, J. W. M. Phosphorus fertilization of 'Fuyutoyo' cabbages in phosphorus-rich eutruxox soil. *Chil. J. Agric. Res.* 2015; DOI:10.4067/S0718-58392013000300012.

- Hafeez, A., Razzaq, A., Mahmood, T., Jhazab, H.F. Potential of copper nanoparticles to increase growth and yield of wheat. *J. Nanosci. with Adv. Technol.* 2015; **1**(1): 6-11.
- Isfan, D. Nitrogen Physiological Efficiency Index in some selected spring barley cultivars. *J. Plant Nutr.* 1990; **13**: 1907-1914.
- Jackson, M. L. *Soil Chemical Analysis*. Prentice-Hall of India Privated Limited, New Delhi. 1967; 498p.
- Jackson, M. L. *Soil Chemical Analysis*. Prentice-Hall of India Privated Limited, New Delhi. 1973, 498.
- Jin, Z. J., Liu, Y., Xu, W. H. – Wang, C. and Hen, S. L. Effects of nano-potassium fertilizer on amino acid components and gln family gene expression in chinese cabbage. *Appl.Ecol. Environmen. Res.*2020;**18**(4):5325-5342.
- Kaminwar, S.P. and Rajagopal, V. Bioconversion of organic wastes for fuel and manure. *Fertility News*,1993;**38**(7): 21.
- Ketsira, P.The effects of zinc nanofertilizers on tomato plants. *Agric. Sci. Commons.* 2019.
- Khanm, H., Vaishnavi, B. A. and Shankar, A. G. Raise of nano-fertilizer era: effect of nano scale zinc oxide particles on the germination, growth and yield of tomato (*Solanum lycopersicum*). *Int. J. Curr.Microbiol. Appl. Sci.* 2018; **7**(5): 1861-1871.
- Kumar, Y., Tiwari, K. N., Singh, T. and Raliya, R. Nanofertilizers and their role in sustainable agriculture. *Ann. Plant Soil Res.*2021; **23**(3): 238-255.
- Laware, S. L. and Shilpa, R.Influence of zinc oxide nanoparticles on growth, flowering and seed productivity in Onion. *Int. J. Curr. Microbiol. Appl. Sci.* 2014; **3**(7) 874-881.
- Liu, R. and La, R.Synthetic apatite nanoparticles as a phosphorus fertilizer for soybean (*Glycine max*). *Sci.Rep.* 2014; **4**: 5686.
- Mandal, D. and Lalrinchani.Nanofertilizer and its application in horticulture. *J. Appl.Hortic.* 2021;**23**(1): 70-77.
- Merghany M, M., Shahein, M. M., Sliem, M. A., Abdelgawad, K. A. and Radwan, F. A. Effect of nano-fertilizers on cucumber plant growth, fruit yield and it's quality. *Plant Arch.* 2019;**19**(2): 165-172.
- Mijwel, A. K. and Jabbr, R. S. Impact of nano-fertilizer on the genetic and phenotypic parameters of tomato cultivars. *Res. Crops.* 2019; **20**(2): 338-344.
- Miller, M. H., Michell, W. A., Stypa, M. and Barry, D.A. Effects of nutrient availability and soil bulk density on crop yield and some chemical properties under wheat-maize rotation. *J. Indian Soc. Soil Sci.* 1987; **67**: 281-292.
- Mishra, B., Sahu, G. S., Mohanty, L. K., Swain, B. C. and Hati, S. Effect of nano fertilizers on growth, yield and economics of tomato variety Arka Rakshak. *Indian J. Pure Appl.Biosci.* 2020; **8**(6): 200-204.
- Moghadam,A. L., Vattani, H., Bhagaei, N. and Keshavarz, N. Effect of different levels of fertilizer nano iron chelates on growth and yield characteristics of two varieties of spinach (*Spinacia oleracea* L.): Varamin 88 and Viroflay. *Res. J. Appl. Sci. Eng. Technol.*2012;**4** (22): 4813-4818.
- Mohammed, M. M. and Mijwei, A. K.Effect of genotypes, nano-fertilization and plant density on growth and yield of cabbage. *Indian J. Ecol.* 2021; **48**(17): 57-61.

Comment [eN4]: It's best for writers to use reference sources that are no more than 5 years old

Comment [eN5]: Volume? Series? Page?

- Mustafa, N.S., Shaarawy, H. H., El-Dahshouri, M. F. and Sherin A. Mahfouze. Impact of nano- fertilizer on different aspects of growth performance, nutrient status and some enzymes activities of (Sultani) fig cultivar. *Biosci. Res.* 2018; **15**(4): 3429-3436.
- Narayan, S. Effect of nanofertilizers on growth and development of crops/plants: A review. *Int. J. Chem. Stud.*2017; **5**(1): 118-123.
- Nataranjan, A. and Sarkar, D. *Field Guide for Soil Survey*. National Bureau of Soil Survey and Land Use Planning (ICAR), Nagpur. 2009.
- Nath, A. K. Integrated effect of organic manures and inorganic fertilizers on growth, yield and quality of cabbage. 2000.
- Ngorwe, E. N., Nawiri, M., Murungi, J., Nyambaka, H. and Ongera, T. Effects of nanofertilizers on Cd and Pb uptake in kales grown in medially polluted experimental soil. *J. Appl. Chem.* 2020; **13**(5): 57-68.
- Nofal, A. S., Ashmawi, A. E., Mohammed, A. A., and Helaly, A. A. Effect of soil application of nano NPK fertilizers on growth, productivity and quality of Lettuce (*Lactuca sativa L.*). *Al-Azhar J. Agric. Res.* 2021; **46** (1): 91-100.
- Obiadalla-Ali, H. A., El-Shaikh, K. A. A., Marey, R. A. and Boktor Amal, Z. S. Effect of fertilization with mineral NPK and spraying with nano NPK on growth, yield and quality of onion. *J. Sohag Agrisci.* 2021; **6**(2): 151-169.
- Panda., J., Nandi, A., Kumar, A. P., Premananda, M., Kumar, N. and Asim, A. S. Effects of nano fertilizer on vegetative growth of tomato (*Solanum Lycopersicum L.*). *Int. J. Curr.Microbiol.Appl Sci.*2020; **9**(03): 1980-1986.
- Panase, V.G. and Sukhatme, P.V. Statistical Methods of Agricultural Workers. *Indian Council of Agricultural Research Publication.* 1985;87-89.
- Rameshaiah, G.N., Pallavi, J. and Shabnam, S.Nano fertilizers and nano sensors- an attempt for developing smart agriculture. *Int. J. Eng. Res. Gen. Sci.*2015; **3**(1). ISSN 2091-2730.
- Rawat, A., Kumar, R., Singh, V. P. and Bhatt, B. Effect of plant based nano-sized gypsum on growth parameters and yield of wheat (*Triticum aestivum L.*). *Int. J. Chem. Stud.*2020; **8**(4): 2991-2993.
- Roohizadeh, G., Majd, A., Arbabian, S. The effect of sodium silicate and silica nanoparticles on seed germination and growth in the *Vicia faba*. *Trop. Plant Res.*2015; **2**(2): 85- 98.
- Roshdy, K. A. and Refaai, M. M.Effect of nanotechnology fertilization on growth and fruiting of zaghoul date palms. *J. Plant Prod. Mansoura University.*2016; **7**(1): 93-98.
- Rostaman, T. H. W. and Nurjaya. The effects of nano inorganic fertilizer application on rice (*Oryza sativa L*) productivity. *Environ. Earth Sci.* 2021;**648** (2021).
- Sajyan, T. K., Alturki, S. M. and Sassine, Y. N. Nano-fertilizers and their impact on vegetables: contribution of nano-chelate super plus ZFM and Lithovit®-standard to improve salt-tolerance of pepper. *Ann. Agric. Sci.*2018; **65**: 200–208.
- Salama, D. M., Abd El-Aziz, M. E., Rizk, F. A., and Abd Elwahed, M. S. A. Applications of nanotechnology on vegetable crops. *Chemosphere.*2021; **266**(2021): 129026.

- Salama, H. M. H. Effects of silver nanoparticles in some crop plants, common bean (*Phaseolus vulgaris* L.) and corn (*Zea mays* L.). *Int. Res. J. Biotechnol.* 2012; **3**(10): 190-197.
- Samec, D., Zegarac, J. P., Bogovic, M., Habjanic, K. and Gruz, J. Antioxidant potency of white (*Brassica oleracea* L. var *capitata*) and chinese (*Brassica rapa* L. var. *pekinensis* (Lour.)) cabbage: The influence of development stage, cultivar choice and seed selection. *Sci.Hortic.* 2011; **128**(2011): 78-83.
- Shivay, Y.S. and Singh, S. Effect of Planting geometry and nitrogen level on growth, yield and nitrogen use efficiency of scented hybrid rice (*Oryza Sativa*). *Indian J. Agron.* 2003;**48**(1) : 42-44.
- Siddiqui, M. H., Whaibi, M. H. A., Firoz, M. and Mutahhar, Y. A. K. Role of nanoparticles in plants. *Nanotechnol. Plant Sci.*2015.
- Silva, A. C. M. M., Charlo, H. C. de O., Vargas, P. F., Torres, J. L. R., Neto, O. F. da. S. and Lemes, E. M. (2021). Nitrogen and potassium fertilization on cabbage biometrics and foliar nutritional levels. *Sci. Plena.* 2021;**17**(1).
- Singh, A., Kumar, A., Yada, S. and Singh, S. Effect of integrated nutrient management on growth and yield of cabbage (*Brassica oleracea* var. *capitata* L.). *Int. J. Chem. Stud.*2020; **8**(3): 1196-1200.
- Singh, V. and Singh, R. Effect of zinc nutrition on yield, quality and uptake of nutrients in cabbage (*Brassica oleracea*). *Ann. Plant Soil Res.*2017; **19**(3): 299-302.
- Sohair, E. E. D., Abdall, A. A., Abdallah, A. M. and Rabeh, H. A. Effect of nitrogen, phosphorus and potassium nano fertilizers with different application times, methods and rates on some growth parameters of Egyptian cotton (*Gossypium barbadense* L.). *Biosci.Res.*2018; **15**(2): 549-564.
- Solanki, P., Bhargava, A., Chhipa, H., Jain, N. and Panwar, J. Nanofertilizers and their smart delivery system. *Nanotechnol. Food Agric.* 2015. DOI 10.1007/978-3-319-14024-7_4.
- Sumanth, S. Impact on soil and foliar application of boron on physiological aspects of cabbage (*Brassica oleracea* var. *capitata* L.). 2019.
- Tarafdar, J. C., Raliya, R., Mahawar, H. and Rathore, I. Development of zinc nanofertilizer to enhance crop production in Pearl Millet (*Pennisetum americanum*). *Springer Agric. Res.*2014; **3**(1): 257–261.
- Valadkhan, M., Mohammadi, K. and Mohammad, T. K. N. Effect of priming and foliar application of nanoparticles on agronomic traits of chickpea. *Biol. Forum Int. J.*2015; **7**(2): 599-60.
- Zahra, Z., Habib, Z., Hyun, H., and Shahzad, H. M. A. Overview on recent developments in the design, application, and impacts of nanofertilizers in agriculture. *Sustainability.*2022; **14**(15): 9397.
- Zainab, M. A. and Alharbi, M. Effect of silver nanoparticles on seed germination of crop plants. *In. J. NuclearQuant. Eng.* 2015; **9**(6).