__Original Research Article__

Effect of nano-DAP on quality and soil characteristics of cabbage

ABSTRACT

An investigation was carried out at the Experimental Farm, Department of Horticulture, A.A.U., Jorhat during 2021-2022 to study the effect of nano-DAP on quality and soil characteristics of cabbage. The experiment was laid out in Randomised Block Design with thirteen treatments and three replications. The quality and soil characters showed significant differences among the treatments. The maximum compact heads (39.84) were obtained in T_3 and among nano-DAP treatments (29.88) in T_7. Observations recorded at harvesting stage showed highest number of wrapper and non-wrapper leaves at T_{12} (16.80) and T_3 (31.93). Leaf chlorophyll content was maximum in T_{11} (1.36 mg/g fw), T_5 (1.65 mg/g fw) and T_7 (1.66 mg/g fw) at 30, 60 DAT & at harvest. N content in leaves was highest in T_{10} (3.62 %), T_3 attained the maximum P (0.46 %) and K (3.95 %). The maximum available NPK in soil was obtained in T_9 (291.03 kg/ha), T_{13} (20.88 kg/ha) and T_4 (95.04 kg/ha). Thus nano-DAP can be a good economic and eco-friendly alternative to conventional inorganic fertilizers, reducing the quantity of application while sustaining the quality of the produce.

Keywords: Economic and Eco-friendly, Fertilizers, Quality, Soil, Nano-DAP

1. INTRODUCTION

India is the second-largest producer of vegetables in the world after China, with an area and production of 27.23 million tonnes and 329.86 million tonnes, respectively. The Brassicaceae family, which includes the cruciferous plants known as cole crops, descended from a common ancestor known as *Brassica oleracea* L. var. *sylvestris*, often known as wild cabbage, cliff cabbage, or colewort. Growing in almost all zones of the country, the crop has become one of the primary vegetables. Assam has the highest cabbage production among the North Eastern states, generating roughly 640.13 tonnes of cabbage annually, or about 7.80% of the major producing states (85%). Cabbage is used as salads, cole slaw, boiled vegetables, curries and also in processed form. Cabbage has many therapeutic properties. Gout, stomach, celiac, and diarrhoea are among the common conditions for which it is used. Due to the presence of Indole-3-carbinol, it possesses an anticancer activity which guards against bowel cancer. Scurvy disease can be treated with a cabbage product known as "Sauerkraut," which is made from shreds of cabbage leaves fermented under pressure in their own juice with salt added (Hazra, P., 2019) [11]. The juice of cabbage, which is prepared either alone or in combination with additional vegetables like carrot and celery, is frequently used in many diets to help people lose weight (Samec *et al*., 2011) [18].

Cabbage requires a lot of nutrients, primarily nitrogen, phosphorus, and potassium, for growth and increased output. These are the most crucial macro element for optimal plant growth and development, which increases crop output and quality to a greater extent by being essential to its biochemical and physiological processes. Generally soil phosphorus levels are either low or medium in soil. Crucial component of chlorophyll is nitrogen which gives plants their dark green colour and encourages the growth of leaves, stems, and other vegetative parts. In order to reduce the overuse of fertilizers and to increase the efficiency of nutrient consumption, a number of techniques and strategies have been developed. In this case, nanofertilizer technology offers a smarter way to provide nutrients with low application rates but high output, leading to successful crop development. By raising productivity, improving food quality and assisting in maintainence of the nutritional balance of agricultural land, this new technology is anticipated to increase the farm income profitably. Nanotechnology has produced fertilizers that are different from conventional fertilizers in a number of ways. Nano-fertilizers are substances comprising both macro and micronutrients that are applied to crops as tiny particles (DeRosa *et al*., 2010) [8]. The nano-fertilizer formulations supply nutrients gradually and deliberately, preventing unintentional losses of nutrients through direct plant uptake. Hence, the decrease in nutritional surplus leads to an increase in the efficiency of nutrient use. Nano-fertilizers have a bigger surface area, more capacity for absorption, and controlled release in the areas they are intended for (Rameshaiah *et al.*, 2015 [17]; Solanki *et al*., 2015 [20]). Diammonium phosphate (DAP) is the most popular phosphatic fertilizer because of its favourable physical properties and high analysis with N (18%) and P_2O_5 (46%) of the overall composition. Thus, employing this fertilizer in nano form will be very beneficial. The Ministry of Chemicals and Fertilizers has directed fertilizer manufacturing facilities to expedite the production of nano-DAP with the aim of making the fertilizer available within a year in order to reduce our country's reliance on imports.

Taking all of these factors into account, this study was designed to evaluate the effectiveness of applying nano-DAP in cabbage.

2. MATERIAL AND METHODS

The present experiment was carried out at the Experimental Farm, Department of Horticulture, Assam Agricultural University during 2021–2022 in the agro-climatic conditions of Jorhat, Assam. The experiment was laid out in Randomized Block Design (RBD) with three replications. The seedlings of cabbage variety “Angad” (Enza zaden) cultivar of cabbage were planted at a spacing of 60 cm x 45 cm in 3.2 m x 3.0 m plots. The investigation comprised of 13 different nutrient management treatments. The N, P, and K nutrients were applied as urea, single super phosphate (SSP) and muriate of potash (MOP). The nano-DAP was applied as applied as seedling root-dip treatment at 5 ml or 10 ml/ltr and also as foliar spray of 2, 4 and 6 ml/ltr.

The treatments of the experiment includes:

S.I. No.	Treatments
T_1	**Control (No Fertilizer)**
T_2	**100% RD of N & K (130:0:80 kg/ha)**
T3	**100 % RD of NPK (130:80:80 kg/ha)**
T_4	**T_2 + Seedling root-dip treatment of n-DAP @ 5 ml/ltr**
T_5	**T_2 + Seedling root-dip treatment of n-DAP @ 10 ml/ltr**
T_6	**T_2 + 1 FS of n-DAP @ 6 ml/ltr at 25-30 DAT**
T_7	**50% P, 100% N & K + FS of n-DAP @ 2 ml/ltr at 25-30 DAT**
T_8	**25% P, 100% N & K + FS of n-DAP @ 4 ml/ltr at 25-30 DAT**
T_9	**T_2 + ST @5 ml/ ltr + FS of n-DAP @ 6 ml/ltr at 25-30 DAT**
T_{10}	**25% P, 100% N & K + ST @ 5 ml/ ltr + FS of n-DAP @ 4 ml/ltr at 25-30 DAT**
T_{11}	**50% P, 100% N & K + ST @ 5ml/ ltr + FS of n-DAP @ 2 ml/ltr at 25-30 DAT**

T_{12}	**25% P, 50% N & 100% K + ST @ 5 ml/ ltr + FS of n-DAP @ 4 ml/ltr at 25-30 DAT**
T_{13}	**50% P, 50 % N & 100% K + ST @ 5 ml/ ltr + FS of n-DAP @ 2 ml/ltr at 25-30 DAT**

The observations on quality attributes viz., head compactness, wrapper leaves at harvest, non-wrapper leaves at harvest, leaf chlorophyll (mg/ 100g fw) at 30 DAT, leaf chlorophyll (mg/ 100g fw) at 60 DAT, leaf chlorophyll (mg/ 100g fw) at harvest, shelf life, nitrogen (%), phosphorus (%) and potassium (%) content in leaves and NPK status of soil (kg/ha) in accordance to their standard protocols. The comparison was done among the recommended dose of fertilizers and the nano-DAP treatments.Head compactness was determined using the formula of Pearson, 1931 [16] (Ananda *et al*., 2018) [2]; $Z = C/W^3 \times 100$ where Z (index of compactness), C (net weight of head) and W (equatorial and polar diameter of head). At the time of harvest, the number of non-wrapper leaves was counted from the sampled plants and average was taken for each treatment. After removing the non-wrapper leaves, the wrapper leaves per head was counted. For leaf chlorophyll, first green leaf samples were collected, washed, dried and were cut into small pieces avoiding the midribs. 0.25 g of leaf sample was weighed, homogenized with 10 ml of 80 % acetone in a mortar and pestle. The homogenate was centrifuged at 3000 rpm for 10 minutes and the supernatant was collected. The final volume of the supernatant was made upto 25 ml with 80 % acetone and O.D. readings were recorded at 645 and 663 nm in a spectrophotometer. The chlorophyll contents were calculated using the following formula given by Arnon (1949) [3]: Chlorophyll a = $(12.7\ (A_{663})- 2.69\ (A_{645}))\ V/ 100\ W$ mg/gfw, Chlorophyll b = $(22.9\ (A_{645})- 4.68\ (A_{663}))\ V/ 100\ W$ mg/gfw, Total chlorophyll = $(20.2\ (A_{645}) + 8.02\ (A_{663}))\ V/100\ W$ mg/gfw, where V = Final volume of extract (ml), fw = fresh weight of leaf sample (g), A_{645} and A_{663} are the optical density value at 645 and 663 nm wavelength of light, respectively. The NPK content in leaves, N & K content in soil were determined by using methods given by Jackson (1973) [12] and soil P was estimated using method outlined by Bray and Kurtz (1945) [5]. The data were statistically analysed using the analysis of variance as stated by Panse and Sukhatme (1985) [15].

3. RESULTS AND DISCUSSION

3.1 Head compactness

As evident from the data presented in Table 1, head compactness was significantly influenced by the treatments. The maximum compact heads (39.84) were obtained in T_3 (full NPK 130:80:80 kg/ha) while the minimum (24.43) was observed in T_1 (Untreated control). Among the nano-DAP treated plants maximum head compactness (29.88) was observed in T_7 (40 kgP/ha, N & K 130:80 kg/ha + Foliar spray of n-DAP @ 2 ml/ltr at 25-30 DAT), however, it was not significantly higher than other treatments. The disparities in head compactness may be caused by the buildup of nutrients provided by various fertiliser doses, while the decrease in other treatments might be due to application of high level of nitrogen which resulted in decrease in dry matter content, as observed by Chatterjee *et al*. (2012) [6].

3.2 Wrapper and non-wrapper leaves at harvest

Application of 65:20:80 kg NPK/ha combined with seedling root-dip treatment in 0.5% and foliar spraying 0.4% nano-DAP solution (T_{12}) resulted in the maximum number of wrapper leaves (16.80) which was significantly higher than application of full inorganic fertilizer (T_3) but was found to be at par with T_{13} & T_7. The number of wrapper leaves in T_3 was comparable with T_{13}, T_8, T_{11} & T_{10}. The plants in untreated control (T_1) plot registered the lowest number of wrapper leaves (9.86). Observations recorded at harvesting stage shows significant differences in number of non-wrapper leaves as well (Table 1). The highest number of non-wrapper leaves at harvest was counted in T_3 (31.93) which did not differ significantly from T_7, T_8, T_9T_{10}, T_{11} &T_{12}. Application of nano-DAP as root-dip treatment (T_4 & T_5) resulted in minimum number of non-wrapper leaves (25.33 & 25.47). Feeding full dose of NPK 130:80:80 kg/ha (T_3) resulted in maximum number of non-wrapper leaves at harvest. The variation might have been due to the fact that different fertilizer dosages had a synergistic effect and on the other hand other applied fertilizer doses did not have the same effect on nutrient release efficiency. These results were similar with that of Nath (2000) in cabbage [14].

3.3 Leaf chlorophyll content (mg/g fw)

Chlorophyll content (chl a: chl b) per miligram fresh weight of leaves was significantly influenced by the treatments. At 30 DAT, the maximum leaf chlorophyll content (1.36 mg/g fw) was observed in T_{11} (40 kg P/ha, 130 kg N/ha & 80 kg K/ha + ST @ 5 ml/ltr + FS of n-DAP @ 2 ml/ltr at 25-30 DAT) while the minimum (0.95 mg/gfw) was observed in T_1 (Untreated control). Among the nano-DAP treated plants the minimum leaf chlorophyll (1.13 mg/g fw) was obtained in T_6 and $T_{13.}$ At 60 DAT, the maximum leaf chlorophyll content (1.65 mg/g fw) was recorded in T_5 (T_2 + Seedling root-dip treatment @ 10 ml/ltr) and the minimum was in T_1 (1.22 mg/g fw). Among the nano-DAP treatments the minimum was in T_{10} (1.44 mg/g fw). At harvest, the maximum leaf chlorophyll content was obtained (1.66 mg/g fw) in T_7 (40 kg P/ha, 130 kg N&K/ha + FS of n-DAP @ 2 ml/ltr at 25-30 DAT) and the minimum in untreated control plot T_1 (1.25 mg/g fw). Among the nano-DAP treated plants the minimum (1.43 mg/g fw) was obtained in T_{10} . The variation in leaf chlorophyll may be because of result from the synergistic effects of various fertilizer doses as well as the environmental circumstances. The amount of leaf chlorophyll directly affects a plant's ability to photosynthesize which causes the plant to store more food and generate a higher yield (Sumanth, 2019 [21] and Nath, 2000 [14]).

3.4 Shelf life (days)

The data pertaining to shelf life (Table 1) showed a significant influence by the treatments. The maximum shelf life was observed in application of full inorganic fertilizer T_3 (8.33 days) and the minimum in T_1 (4.67 days). Treatments T_4, T_5, T_8, T_{11} and T_{12} were found to be statistically at par with T_3. Among the nano-DAP treated plants the maximum shelf life (8.00 days) was observed in T_{11} (50% P, 100% N & K + ST @ 5 ml/ltr + FS of n-DAP @ 2 ml/ltr at 25-30 DAT) but did not differ significantly from T_4, T_5, T_8 and T_{12} and the minimum was observed (5.67 days) in T_{10} (130:20:80 kg NPK/ha **+** ST of n-DAP @ 5 ml/ltr + FS of n-DAP @ 4 ml/ltr at 25-30 DAT). Increase in shelf life can be attributed to low rate of respiration in treated plants than that in the control (Abu, 2021) [1].

Table 1: Effect on head quality and leaf chlorophyll content

Treatments	Head compactness	Wrapper Leaves at harvest (nos)	Non-wrapper leaves at harvest (nos)	Leaf chloro-phyll at 30 DAT (a:b)	Leaf chloro-phyll at 60 DAT (a:b)	Leaf chloro-phyll at Harvest (a:b)	Shelf life (nos)
T1	24.43	9.86	12.57	0.95	1.22	1.26	4.67
T2	24.98	11.47	21.50	1.21	1.52	1.51	6.67

T3	39.84	15.37	31.93	1.22	1.56	1.60	8.33
T4	25.63	13.23	25.33	1.23	1.55	1.58	7.33
T5	27.30	14.03	25.47	1.25	1.65	1.64	7.67
T6	27.84	13.30	26.80	1.13	1.63	1.65	7.00
T7	29.88	16.53	31.67	1.15	1.54	1.66	7.00
T8	29.20	15.63	30.20	1.16	1.62	1.59	6.67
T9	27.23	14.23	29.53	1.31	1.50	1.56	7.33
T10	26.59	14.60	30.13	1.16	1.44	1.43	5.67
T11	27.44	14.83	30.50	1.36	1.60	1.52	8.00
T12	23.94	16.80	29.97	1.30	1.60	1.58	7.33
T13	26.75	16.00	27.70	1.13	1.55	1.57	7.00
SEd (±)	3.05	0.48	1.42	0.04	0.04	0.04	0.54
CD (5%)	6.30	0.99	2.93	0.08	0.08	0.08	1.11

ST: Seedling root-dip treatment FS: Foliar spray

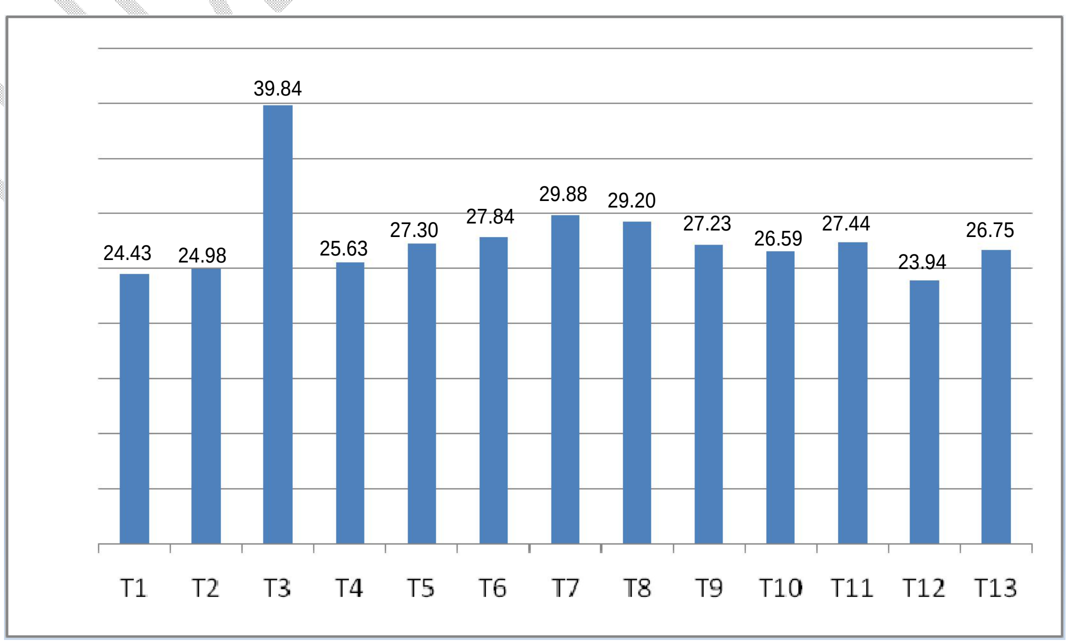

FIG. 1 HEAD COMPACTNESS

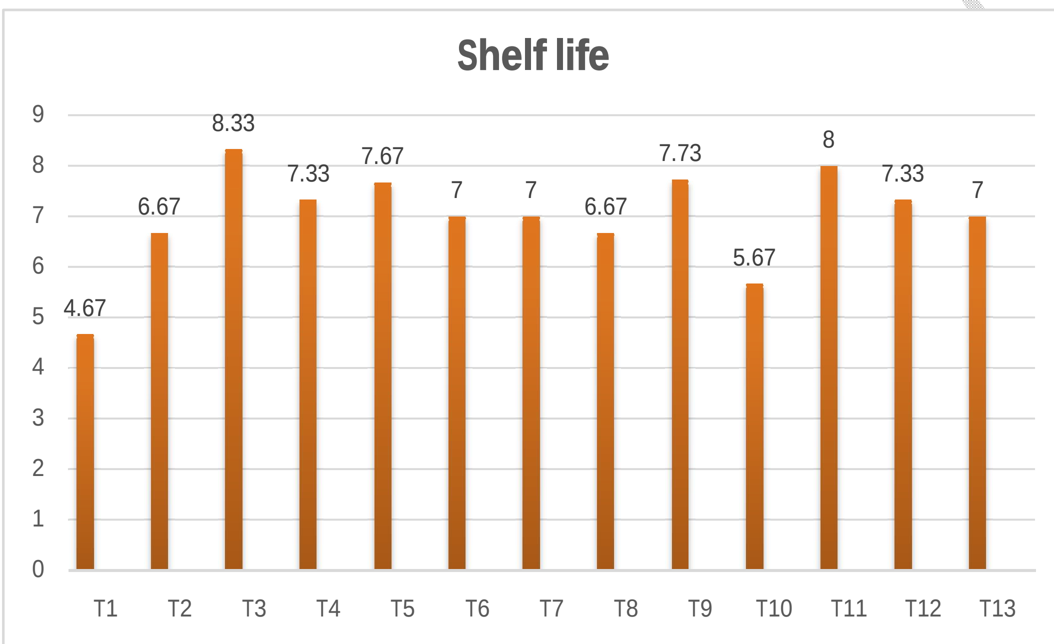

FIG. 2 SHELF LIFE (DAYS)

3.5 NPK content in leaf (%)

The maximum N content in leaf (3.62%) was obtained in T_{10} (130:20:80 kg NPK/ha **+** ST of n-DAP @ 5 ml/ltr + FS of n-DAP@ 4 ml/ltr at 25-30 DAT) and the minimum (1.32%) was observed in T_2 (Table 2). The maximum P content in leaf (0.46%) was observed in T_3 (Recommended inorganic fertilizer) and the minimum (0.08 %) in T_1 & T_2. Among the nano-DAP treated plants the maximum was in T_7 (0.44%) and the minimum in T_{12} (0.31%). The maximum K content was recorded in T_3 (3.95%) and the minimum was observed in untreated control plot T_1 (1.19%). The content in T_3 was in statistical parity with treatments T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12} and T_{13}. Among the nano-DAP treated plants the maximum K content was in T_7 (3.87%) and the minimum in T_6 (3.28%). The improvement in soil aeration and moisture retention in the root zone increased the availability of macro and micronutrients which may have contributed to the increase in nitrogen concentration (Fatimah *et al*., 2019) [9]. The increase in phosphorus content might be because phosphorus, when added to soil in inorganic form, gets fixed in the soil and is not immediately available to the plant and released to the plant slowly. The fixed phosphorus is solubilized by soil-dwelling microbes, making it readily accessible to plants. The results are similar to Filho and Cortez, 2015 [10] in Fuyutoyo cabbage. The maximum potassium content in leaf was recorded in T_3 and nano-DAP treated plot of T_7. This might be as a result of the soil receiving more potassium and the bacteria making it readily available to the plant. Silva *et al*., 2021 [19] also observed rise in N and K content due to the combined effect of various fertilizer doses.

Table 2: Effect on NPK content in leaf and soil

Treatments	N (%)	P (%)	K (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)
T1	1.41	0.08	1.19	195.91	11.25	84.01
T2	1.32	0.08	1.25	288.68	18.30	95.08
T3	3.54	0.46	3.95	283.43	22.53	94.01
T4	2.46	0.32	3.81	289.48	18.92	95.04
T5	2.36	0.33	3.56	286.89	18.78	93.07
T6	1.41	0.26	3.28	291.47	18.84	92.54
T7	2.08	0.44	3.87	288.23	20.47	92.78
T8	2.90	0.42	3.86	290.31	19.95	92.73
T9	3.18	0.37	3.81	291.03	19.71	92.89
T10	3.62	0.33	3.75	289.11	19.96	92.87

T11	3.14	0.37	3.81	290.06	20.31	92.67
T12	2.73	0.31	3.62	286.91	20.07	93.34
T13	2.48	0.33	3.65	279.59	20.88	92.62
SEd (±)	0.08	0.004	0.29	5.53	0.59	1.03
CD (5%)	0.18	0.01	0.61	11.40	1.21	2.13

ST: Seedling root-dip treatment   FS: Foliar spray

3.6 NPK status of soil (kg/ha)

The maximum available N in soil (291.03 kg/ha) was observed in T_9 (130:0:80 kg NPK/ha + ST of n-DAP @ 5 ml/ltr + FS of n-DAP@ 6 ml/ltr at 25-30 DAT) while the minimum in T_1 (195.91 kg/ha). Recommended inorganic fertilizer @ 130:0:80 kg NPK/ha (T_3) registered the maximum available P in soil (22.53 kg/ha) while untreated control (T_1) recorded the minimum (11.25 kg/ha). Among the nano-DAP treated plants the maximum available P was obtained in T_{13} (20.88 kg/ha) but did not differ statistically from T_7, T_8, T_9, T_{10}, T_{11} and $T_{12,}$ and the minimum recorded in T_5 (18.78 kg/ha). The maximum available K in soil (95.04 kg/ha) was obtained in T_4 (100% RD of N & K 130:80 kg/ha + Seedling root treatment of n-DAP @ 5 ml/ltr) and the minimum in T_1 (84.01 kg/ha). As because cabbage consumes a lot of nutrients, producers view NPK fertilizer as their most crucial production input. It was evident that the combined application of various fertilizer doses had a substantial impact on the amount of accessible nitrogen, phosphorous, and potassium in the soil resulting in higher crop harvest. The maximum N, P & K were obtained in T_9, T_3 and T_4. The immediate input and gradual release of nitrogen from the fertilizer added to the soil may be responsible for the rise in accessible nitrogen which is in agreement with Miller *et al*. (1987) [13] and Bharadwaj and Omanwar (1994) [4]. Increased activity of nitrogen-fixing bacteria might be responsible for the significant increase in soil accessible nitrogen caused by NPK and nano-DAP application. The treatments had a considerable impact on the soil P concentration after harvest which might be due to the application of P fertilizers in different forms and formulations. Deenik *et al*. (2006) [7] also observed that P fertilizer addition increased soil P levels compared to the control. Increase in level of NPK in soil increases the respective nutrient content leading to higher level of soil available NPK. In case of available soil potassium, combined effect of different doses of treatments resulted in higher level of soil potassium which might have increased the quantity of potassium in the soil, respectively. Similar positive results were also observed by Silva *et al*., 2021 [19].

CONCLUSION

From the present investigation it was evident that although supplementation of phosphatic nutrients conventionally through single super phosphate produced superior results, but use of nano formulation as seedling root-dip treatment and foliar spray also proved to be significantly effective in getting better quality cabbage heads, longer shelf life and NPK content in leaves. As use of nano-P forms minimizes quantity of application quite substantially, it can be a very viable economic, eco-friendly alternative to conventional inorganic fertilizers and in terms of volume of application.

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