



# Impact of Nano-Dap on Growth and Development of Cabbage

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## Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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## ABSTRACT

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. RBD was used to set up the study. The treatments followed were T<sub>1</sub> (Untreated control), T<sub>2</sub> (100% RDF of N & K), T<sub>3</sub> (100% RDF of 130:80:80 kg/ha), T<sub>4</sub> (T<sub>2</sub> + ST with nano-DAP @ 5 ml/ltr), T<sub>5</sub> (T<sub>2</sub> + ST @ 10 ml/ltr), T<sub>6</sub> (T<sub>2</sub> + 1 FS of nano-DAP @ 6 ml/ltr at 25-30 DAT), T<sub>7</sub> (50 % P, 100% N & K + FS nano-DAP @ 2 ml/ltr at 25-30 DAT), T<sub>8</sub> (25% P, 100% N & K + FS nano-DAP @ 4 ml/ltr), T<sub>9</sub> (T<sub>2</sub> + ST @ 5 ml/ ltr + FS nano-DAP @ 6 ml/ltr), T<sub>10</sub> (25% P, 100% N & K + ST @ 5 ml/ ltr + FS nano-DAP @ 4 ml/ltr), T<sub>11</sub> (50% P, 100% N & K + ST @ 5 ml/ ltr + FS nano-DAP @ 2 ml/ltr), T<sub>12</sub> (25% P, 50% N & 100% K + ST @ 5 ml/ ltr + FS nano-DAP @ 4 ml/ltr) and T<sub>13</sub> (50% P, 50% N & 100% K + ST @ 5 ml/ ltr + FS nano-DAP @ 2 ml/ltr).

Investigation was done comparing the results of the nano-DAP treatments with the suggested fertilizer dosage. The results revealed that the maximum plant spread and number of non-wrapper

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leaves was observed in T<sub>3</sub> (17.12 cm) and (7.67) at 30 DAT whereas in T<sub>3</sub> (34.77 cm) and (16.83) at 60 DAT. The highest leaf area was recorded in T<sub>3</sub> (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 T<sub>7</sub> (4.40 g) although in T<sub>3</sub> (12.46 g) at 60 DAT. The maximum number of days (88.30 days) to harvest was taken by T<sub>5</sub>. 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; nano-DAP.*

## 1. INTRODUCTION

India represents the second-largest supplier of veggies worldwide after China. 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 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 [1], 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.

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. 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. [2] and Solanki et al. [3], Siddiqui et al., [4] 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. 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 P<sub>2</sub>O<sub>5</sub> (46% of the overall constitution) so, it is generally favoured. Thus, applying this fertiliser in nano form is 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 T<sub>1</sub> (Control (No Fertilizer), T<sub>2</sub> (100% RD of N & K (130:0:80 kg/ha)), T<sub>3</sub> (100 % RD of NPK (130:80:80 kg/ha)), T<sub>4</sub> (T<sub>2</sub> + Seedling root-dip treatment of n-DAP @ 5 ml/ltr), T<sub>5</sub> (T<sub>2</sub> + Seedling root-dip treatment of n-DAP @ 10 ml/ltr), T<sub>6</sub> (T<sub>2</sub> + 1 FS of n-DAP @ 6 ml/ltr at 25-30 DAT), T<sub>7</sub> (50% P, 100% N & K + FS of n-DAP @ 2 ml/ltr at 25-30 DAT), T<sub>8</sub> (25% P, 100% N & K + FS of n-DAP @ 4 ml/ltr at 25-30 DAT), T<sub>9</sub> (T<sub>2</sub> + ST @ 5 ml/ ltr + FS of n-DAP @ 6 ml/ltr at 25-30 DAT), T<sub>10</sub> (25% P, 100% N & K + ST @ 5 ml/ ltr + FS of n-DAP @

4 ml/ltr at 25-30 DAT), T<sub>11</sub> (50% P, 100% N & K + ST @ 5ml/ ltr + FS of n-DAP @ 2 ml/ltr at 25-30 DAT), T<sub>12</sub> (25% P, 50% N & 100% K + ST @ 5 ml/ ltr + FS of n-DAP @ 4 ml/ltr at 25-30 DAT) and T<sub>13</sub> (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. Randomised Block Design (RBD) was used to statistically assess the data produced throughout the course of the study. By computing the recognised "F" values, the significance and non-significance of the variance were ascertained [5]. 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 1. The results revealed that the maximum plant spread was observed in T<sub>3</sub> (17.12 cm) at 30 DAT and the minimum was observed in T<sub>1</sub> (8.60 cm). The maximum plant spread was observed in T<sub>3</sub> (34.77 cm) at 60 DAT and the minimum in T<sub>1</sub> (19.26 cm). Treatments T<sub>5</sub>, T<sub>7</sub>, T<sub>8</sub>, T<sub>9</sub>, T<sub>10</sub> and T<sub>11</sub> were found to be statistically at par with T<sub>3</sub> at 30 DAT and T<sub>7</sub> & T<sub>8</sub> were statistically at par with T<sub>3</sub> at 60 DAT. Of the plants that were treated with nano-DAP, the highest plant spread was recorded in T<sub>5</sub> (16.47 cm) and T<sub>7</sub> (34.45 cm) at 30 & 60 DAT and the minimum plant spread was recorded in T<sub>12</sub> (14.61 cm) and T<sub>4</sub> (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 [6] and Sumanth [7] confirm this conclusion. Also similar results were observed by Chamuah et al., [8] and *Silva* et al., [9] in cabbage.

## 3.2 Number of Non-Wrapper Leaves

The data on number of non-wrapper leaves presented in Table 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 T<sub>3</sub>. The minimum number of non-wrapper leaves was recorded in T<sub>2</sub> (6.03) and T<sub>1</sub> (10.50) at 30 & 60 DAT, respectively. Treatment T<sub>7</sub> was found to be statistically at par with T<sub>3</sub> at 30 DAT while T<sub>7</sub>, T<sub>11</sub>, T<sub>12</sub> and T<sub>13</sub> were at par with T<sub>3</sub> at 60 DAT. Of the plants administered nano-DAP, the greatest no. of non-wrapper leaves was recorded in T<sub>7</sub> (7.60) at 30 DAT and the minimum was recorded in T<sub>6</sub> (5.23) at 30 DAT. At 60 DAT the maximum no. of non-wrapper leaves was recorded in T<sub>12</sub> (17.43) and the minimum was recorded in T<sub>6</sub> (11.50). Treatments T<sub>8</sub> and T<sub>11</sub> were found to be statistically at par with T<sub>7</sub> and treatments T<sub>7</sub> & T<sub>13</sub> were found to be statistically at par with T<sub>12</sub> 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 [6], Devi and Singh [10] and Sumanth [7] 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 T<sub>3</sub> (107.56 sqcm) at 30 DAT and at 60 DAT (226.54 sqcm) and the lowest was recorded in T<sub>1</sub> (17.27 sqcm) at 30 DAT and at 60 DAT T<sub>1</sub> (37.70 sqcm). Amongst the crops that were treated with nano-DAP at 30 & 60 DAT the highest leaf area was recorded in T<sub>7</sub> (88.33 and 183.70 sqcm). The lowest leaf area was recorded in T<sub>4</sub> (27.40 sqcm) at 30 DAT and in T<sub>4</sub> (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 [11] and [12].

## 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 T<sub>7</sub> (4.40 g), however, did not differ significantly from T<sub>3</sub>, T<sub>8</sub>, T<sub>9</sub> and T<sub>11</sub>. At 60 DAT the leaf fresh weight was recorded maximum in T<sub>3</sub> (12.46 g) while the minimum leaf

fresh weight was in T<sub>1</sub> (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 T<sub>7</sub> (4.40 g) and T<sub>11</sub> (10.61 g), respectively and the minimum weight at 30 & 60 DAT were recorded in T<sub>4</sub> (1.39 g) and (9.27 g). At 30 DAT T<sub>8</sub>, T<sub>9</sub> and T<sub>11</sub> were found to be statistically at par with T<sub>7</sub>. At 60 DAT treatments T<sub>6</sub>, T<sub>7</sub>, T<sub>8</sub> and T<sub>9</sub> were found to be statistically at par with T<sub>11</sub>. The agronomic qualities of the produce were enhanced by higher levels of nitrogen [11] and [13].

### 3.5 Leaf Dry Weight (g)

A significant difference was found in leaf dry weight (Table 2). At 30 DAT, the maximum leaf dry weight was obtained in T<sub>3</sub>(1.29 g) while the minimum was observed in T<sub>2</sub> (0.02 g). Application of 100% NPK 130:80:80 kg/ha (T<sub>3</sub>) proved to be superior in leaf dry weight (4.98 g) among all the treatments at 60 DAT the minimum being in T<sub>1</sub> (0.91 g). Among the nano-DAP treated plants, the maximum leaf dry weight at 30 DAT was recorded in T<sub>7</sub> (0.95 g) and the minimum was in T<sub>4</sub>(0.06 g) while at 60 DAT the maximum leaf dry weight (4.11 g) was observed in T<sub>9</sub> (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 T<sub>5</sub> and T<sub>10</sub>. At 30 DAT, treatments T<sub>8</sub>, T<sub>9</sub>, T<sub>11</sub> and T<sub>13</sub> were found to be statistically at par with

T<sub>7</sub> and at 60 DAT, T<sub>7</sub> and T<sub>8</sub> were found to be statistically at par with T<sub>9</sub>. The contrariety within the treatments might be due to the cumulative impact of different dose of fertilizer application which may be similar to the results obtained by Panda et al., [14] in tomato.

### 3.6 Root Fresh Weight (g)

Data presented in Table 2 revealed that root fresh weight was significantly influenced by the treatments. At 30 DAT, the maximum root fresh weight was registered in T<sub>3</sub> (7.27 g) and the minimum was observed in T<sub>1</sub> (3.44 g). At 60 DAT, the maximum root fresh weight was observed in T<sub>3</sub> (23.75 g) and the minimum was observed in T<sub>1</sub> (13.93 g). At 30 DAT, treatments T<sub>7</sub> and T<sub>8</sub> were found to be statistically at par with T<sub>3</sub> and at 60 DAT, T<sub>7</sub> was found to be statistically at par with T<sub>3</sub>. Amongst the nano-DAP treated plants, the maximum root fresh weight was obtained in T<sub>7</sub> (7.24 g) and the minimum was recorded in T<sub>4</sub> (3.74 g) at 30 DAT. At 60 DAT, the maximum root fresh weight was observed in T<sub>7</sub> (22.69 g) but did not differ significantly from T<sub>8</sub>, T<sub>9</sub>, T<sub>10</sub> and T<sub>11</sub> and the minimum was observed in T<sub>4</sub> (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 [6] reported comparable results with cabbage.

**Table 1. Measurement of Plant Spread, Number of non-wrapper leaves, Leaf Area, and Leaf fresh weight**

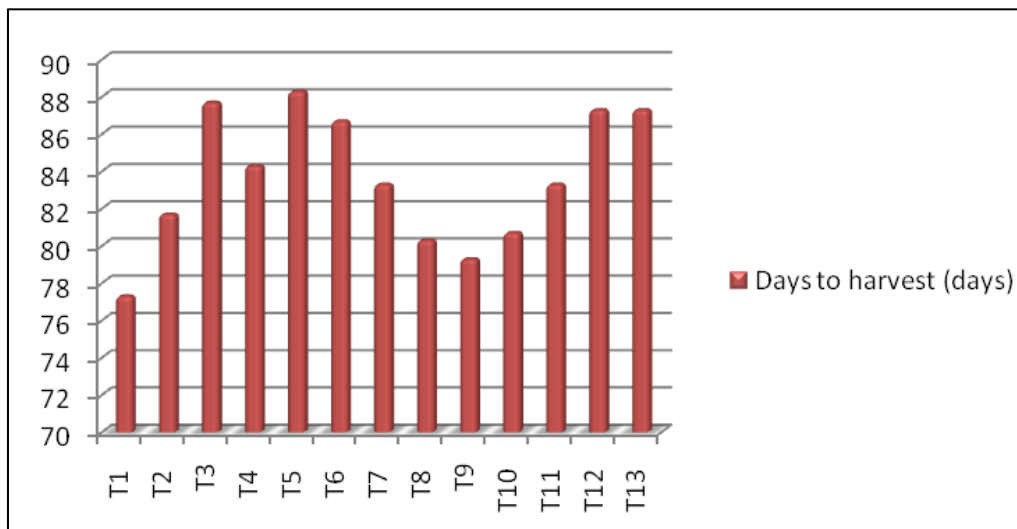
Treatments	Plant spread (cm) 30 DAT	Plant spread (cm) 60 DAT	Number of non-wrapper leaves 30 DAT	Number of non-wrapper leaves 60 DAT	Leaf area (sqcm) 30 DAT	Leaf area (sqcm) 60 DAT	Leaf fresh weight (g) 30 DAT	Leaf fresh weight (g) 60 DAT
T <sub>1</sub>	8.60	19.26	6.40	10.50	17.27	37.70	0.91	5.25
T <sub>2</sub>	13.11	21.85	6.03	1.50	18.97	44.03	1.16	7.81
T <sub>3</sub>	17.12	34.77	7.67	16.83	107.56	226.54	4.13	12.46
T <sub>4</sub>	15.04	25.56	6.43	12.40	27.40	54.69	1.39	9.27
T <sub>5</sub>	16.47	28.45	5.70	14.97	27.88	58.41	1.41	9.41
T <sub>6</sub>	15.41	26.20	5.23	11.50	37.94	63.41	1.77	9.93
T <sub>7</sub>	16.36	34.45	7.60	16.77	88.33	183.70	4.40	10.50
T <sub>8</sub>	16.20	32.46	7.37	15.27	78.95	158.81	4.07	10.17
T <sub>9</sub>	15.60	26.59	6.50	14.60	63.70	127.81	3.88	9.84
T <sub>10</sub>	15.35	29.42	6.23	15.03	55.68	111.07	2.98	9.72
T <sub>11</sub>	16.39	32.01	7.33	15.80	65.83	130.57	4.03	10.61
T <sub>12</sub>	14.61	30.16	6.40	17.43	57.96	113.56	3.28	9.61
T <sub>13</sub>	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

**Table 2. Measurement of Leaf dry weight, Root fresh weight, Root dry weight, and Harvesting days**

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



**Fig. 1. Days to Harvest (Days)**

### 3.7 Root Dry Weight (g)

Data presented in Table 2 reveals that root dry weight was significantly influenced by the treatments. At 30 DAT, the maximum root dry weight was observed in T<sub>7</sub> (2.25 g) and the minimum was observed in T<sub>4</sub> (0.72 g). At 60 DAT, the maximum root dry weight was again registered by T<sub>7</sub> (8.32 g) while the minimum (3.40 g) was found in untreated control plots (T<sub>1</sub>). Within the nano-DAP treated plants, the minimum root dry weight was observed in T<sub>4</sub> (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 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 T<sub>5</sub> (N & K 130:80 kg/ha + seedling root treatment @ 10 ml/ltr nano-DAP) but was statistically comparable with T<sub>3</sub>, T<sub>12</sub> & T<sub>13</sub> while the minimum was observed in T<sub>1</sub> (77.30 days). Amongst the nano-DAP treatments, the minimum days was recorded in T<sub>8</sub> (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 [6]. The graphical representation of the data is presented in Fig. 1.

#### 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.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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