# Effect of Indole-3-Acetic Acid and Nano-Urea on Agronomic Properties of Radish Crops


## ABSTRACT

This study aimed to evaluate the impact of nano-urea, indole-3-acetic acid (IAA), phosphorus (P), and potassium (K) on seed germination and various growth parameters of Raphanus sativus L. The experiment was carried out in a randomized block design with three replicates per treatment and a total of eight treatments. Both nano-urea and IAA were applied through foliar spray whereas P and K were given as in-soil treatment. The seed germination centage was measured on the 14th day after sowing. The results demonstrated that all treatments improved seed germination compared to the control. Nano-urea alone increased the germination percentage from 40.83% to 54.16%, while the combination of nano-urea and IAA further enhanced it to 67.5%. The highest germination percentage of 75.83% was achieved with the simultaneous application of nano-urea, IAA, P and K. Additionally, the treatments influenced the number of leaves at different stages of growth. The treatment with IAA, nano-urea, P and K resulted in the highest leaf count of 61.26. Moreover, the length of leaves, roots, and shoots were significantly affected by the treatments. The combination of foliar applications of IAA (auxin) and nano-urea; and in soil treatments of P and K resulted in the longest leaf, root, and shoot lengths. These findings highlight the positive effects of the tested treatments on seed germination and various growth parameters of Raphanus sativus L. The results contribute to our understanding of the potential applications of nano-urea, IAA, P and K in improving crop productivity and growth. This information can aid in the development of sustainable agricultural practices for enhanced crop performance and yield.



*Keywords: Radish; indole-3-acetic acid; Nano-urea; foliar spray; plant growth regulators.*


## 1. INTRODUCTION

The radish (*Raphanus sativus* L.) belongs to the Brassicaceae family and probably originated in Europe or Asia [1,2]. It is an economically important root crop that is grown for its young, fleshy tuberous roots, which are primarily consumed as a salted vegetable or grated salad [3, 1, 4]. Having a long history, radish roots and leaves are excellent sources of calcium, phosphorus, ascorbic acid, folic acid, and potassium [5]. While the root is commonly eaten, the entire plant is edible, including the leafy tops [6, 7]. Sun-dried radish roots are cooked and consumed during the off-season and for long-term storage. Sun-dried radish has higher levels of sucrose, proline, and branched-chain amino acids [8]. Radish is a cool-season crop classified into two groups: European or temperate and Asiatic or tropical. Asiatic varieties thrive in tropical climates, producing roots and seeds, while European varieties grow roots in sub-tropical and tropical regions. However, European varieties require chilling temperatures in hilly areas for seed development. Asiatic varieties generally have higher yields but may lack quality attributes. European varieties are smaller in size, mildly pungent, mature early, and have high-quality parameters [9]. In India, radish production totals 3347MT, with Punjab contributing 385.15T (NHB, 2022).

Radish is a fast-growing and easy-to-cultivate vegetable. However, type of soil and various environmental stresses can harm its growth and yield [10, 11, 5, 1, 12, 2, 4, 7]. In order to counteract these negative effects, various eco-friendly approaches, including the use of fertilizers (nutrients) or applications of plant hormones, are adopted to manage plant growth [10, 13, 5]. It has been reported that plant hormones and growth regulators influence plant growth and development [5, 14]. Auxins (like indole-3-acetic acid), gibberellins, cytokinins, abscisic acid, ethylene, jasmonates, salicylic acid, and brassinosteroids play crucial roles [15, 16, 14, 17]. They have rapid impacts on vegetative growth and crop yield, making them time-efficient and environmentally friendly [18]. Besides these, integrated nutrient management aims to combine traditional and modern methods of nutrient management into environmentally sustainable and economically viable farming systems. This proves the importance of foliar application of macro elements as well (Poonkodi *et al*., 2019). Urea, containing 46% N, is an effective source of nitrogen that is absorbed and translocated by plants with minimal environmental impact. Spraying urea solution is a widely used method for nitrogen application, as it reduces handling costs. Foliar application quickly corrects mineral imbalances and enhances nutrient absorption efficiency, as per Shirani *et al.* [6].

Compared to traditional urea, foliar application of nano urea liquid during crucial crop growth phases of a plant effectively satisfies its nitrogen need and increases crop yield and quality [19]. Radish, given its short growth period and rapid growth rate, requires uninterrupted and rapid root growth nutrients, which can be provided through the application of both organic and inorganic fertilizers (Poonkodi *et al*., 2019) [20]. Foliar fertilization, especially with trace elements, has consistently shown positive effects on plant metabolism and yield under various practical cultivation conditions [21, 5, 1]. Therefore, the present study was designed to efficiently and effectively study the impact of foliar spray of nano-urea and indole-3-acetic acid; and in soil treatment effect of potassium and phosphorus on agronomic characteristics of radish.

## 2. MATERIALS AND METHODS

The field experiment covered an area of 200 square meters (20 m length and 10 m breadth) in the experimental field at latitude 31°25, 23N and longitude 75°48, 32, E, determined. The experiment followed a randomized block design with three replications and eight treatments. In this study, foliar spray of 1 mM indole-3-acetic acid (IAA) and nano-urea (Nano urea is a nitrogen source essential for crop growth and development, applied at a rate of 16 ml in 4 L) was used. Nano urea (IFFCO) was the nitrogen fertilizer source, with a total volume of 500 ml, of which 4 ml was mixed with 100 ml of water for foliar spray on the leaves. It was applied at intervals of 15 days, 45 days, 75 days, and 110 days to supplement nitrogen (N). Single super phosphate (@ 225.12 gm) was used as the source of phosphorous (P), and muriate of potash (MOP) (@ 450 gm) was used as the source of potassium in the soil. The following treatments (T0 - T7) were replicated in triplicates:

**Table 1. Details of treatments**

| Treatment Symbols | Treatments details |
|---|---|
| $T_0$ | Control: only irrigation water |
| $T_1$ | Nano-urea as a foliar spray about (4%). |
| $T_2$ | Phosphorous (P) + Potassium (K) alone as fertilizer in soil as per recommended. |
| $T_3$ | Nano-urea as a foliar spray, P+K as a fertilizer in soil. |
| $T_4$ | Indole-3 acetic acid (IAA) @ 1mM as a foliar spray. |
| $T_5$ | Indole-3 acetic acid and nano-urea as a foliar spray |
| $T_6$ | Indole-3-acetic acid as a foliar spray and P+K as a solid fertilizer. |
| $T_7$ | Indole-3-acetic acid as a foliar spray, nano-urea as a foliar spray and P+K as a solid form. |

### 2.1 Seed and Sowing

Selecting fresh and healthy seeds, they were thoroughly washed before sowing. The seeds were continuously sown in ridges, maintaining a seed-to-seed distance of 10 cm within each row. The row-to-row distance was 45 cm. Field sowing was completed on October 18, 2022.

### 2.2 Thinning and Weeding

Thinning is crucial in radish cultivation. Once the seedlings reached a height of two inches or around one week old, thinning was conducted to ensure a three-inch spacing between radishes. Crowded radishes hinder proper growth, leading to small and shriveled plants. One or two weeding were sufficient for this crop. The first weeding was done during earthing up, and if necessary, a second weeding was conducted a week later.

### 2.3 Soil Sampling and Plant Material Observations

Soil sampling was conducted in three different parts of the field, which was done before and after the experiment. Soil pH and electrical conductivity was measured by using pH and Electrical Conductivity Meter. Nitrogen (N) was measured by KEL PLUS semi auto analyzer by Kjeldahl method [22]. Phosphorus was analysed by Olsen's method and Colorimeter [23] whereas Flame Photometer [24] was used to analyze the potassium content.

## 2.4 Number of Leaves Per Plant and Length

The total number of leaves on three randomly selected plants from each plot was counted at the time of harvesting, and the mean was calculated. The length of leaves was measured using a meter scale on three randomly selected plants from each plot.

## 2.5 Root Length and Shoot Length (cm)

The root length of three randomly selected plants from each plot in each replication was measured using a meter scale, and the mean was calculated. The shoot length of three randomly selected plants from each plot in each replication was measured using a meter scale, and the mean was calculated.

## 2.6 Fresh Biomass and Dry Weight

The fresh biomass of the roots was measured by weighing the fresh roots of three randomly selected plants from each plot. The dry weight of the roots was measured by weighing the dried roots.

## 2.7 Statistical Analysis

The observed data for the various investigated characters were tabulated and were subjected to statistical analysis by using OPStat Excel Version software package. Mean and Standard Error of three replicates, One way Analysis of Variance (ANOVA) mentioned as F-ratio, Critical Difference (CD), and Coefficient of Variation (CV) was calculated and presented in the tables.

# 3. RESULTS AND DISCUSSION

The before and after experiment's soil observations are as follows: pH 7.60 (before experiment) and 7.10 (after experiment), N 160 kg $ha^{-1}$ (before experiment) and 167 Kg $ha^{-1}$ (after experiment), P 29 kg $ha^{-1}$ (before experiment) and 30 kg $ha^{-1}$ (before experiment), K 145 kg $ha^{-1}$ (before experiment) and 160 kg $ha^{-1}$ (before experiment), and electrical conductivity ($dSm^{-1}$) 0.06 (before experiment) and 0.08 (after experiment). There was no change in pH and it was moderately alkaline before and after experiment (7.10 and 7.60). The levels of N, P and K were enhanced whereas there was no impact on electrical conductivity of the soil. The average seed percent germination was increased on $14^{th}$ day after sowing. The minimum percent seed germination was recorded under controlled (no-treatment) conditions (51.667±2.205 %) on $14^{th}$ day after sowing. Therefore, co-application of all treatment affected the soil parameters and seedling germination percentage. The results obtained for various morphological parameters are presented below.

## 3.1 Number of Leaves at 30, 60, 90 and 135 Days after Sowing of Radish Plants

The number of leaves was monitored at 30, 60, 90, and 135 days after sowing. Upon seedling emergence, it was observed that untreated conditions (control) yielded an average of 56.113±0.388 leaves (Table 2). The application of nano-urea alone (58.33±0.616) and the co-application of nano-urea and indole-3-acetic acid (60.484±0.131) resulted in the lowest leaf count. Conversely, the highest leaf count (61.26±0.295) was observed with the co-application of indole-3-acetic acid, nano-urea, phosphorus, and potassium. The treatment applied significantly influenced various plant parameters, including the number of leaves per plant at different stages of growth. Jawad *et al.,* (2015) reported the maximum number of leaves with the application of nitrogen, while Monirumzzaman *et al.,* (2013) found that nitrogen application had a significant effect on the number of leaves per plant. Hence, foliar application nano-urea is effective in enhancing the number of leaves on plants thereby increasing the area for photosynthesis by the plants.

## 3.2 Effect of Root Length on Radish Plants at Different (30, 60, 90 and 135 DAS)

The length of roots was measured at 30, 60, 90, and 135 days after sowing. Upon the emergence of seedlings, it was observed that untreated conditions (control) resulted in an average root length of 40.91±0.795 (Table 3). The application of nano-urea alone (42.517±0.303) and the co-application of nano-urea and indole-3-acetic acid (46.76±0.162) resulted in the minimum root length. Conversely, the longest root length (48.3±0.097) was observed with the co-application of indole-3-acetic acid, nano-urea, phosphorus, and potassium. The present increase in growth is similar to previous studies on various plants, showing that plant growth regulators like GA3 and IAA contribute to plant height and the number of certain plant characteristics. Frankenberger *et al.* [25] discuss the effect of indole-3-acetic acid (IAA) on plant growth. The study found that the application of L-tryptophan, a precursor of IAA, promoted radish yield comparable to plants treated with IAA and other auxin precursors. The application of L-tryptophan increased the shoot dry weight and root dry weight of radish crops. Similarly, in the present study, root length was enhanced by application of IAA however, co-application of IAA and nano-urea is effective in enhancing the plant growth.

**Table 2. Effect of nano-urea, indole-3-acetic acid, potassium and phosphorus on number of leaves at 30, 60, 90 and 135 (DAS) of radish plants**

| Tr. No. | Number of leaves | | | |
|---|---|---|---|---|
| | **30 (DAS)** | **60 (DAS)** | **90 (DAS)** | **135 (DAS)** |
| $T_0$ | 15.79±0.386 | 25.963±0.223 | 50.52±0.096 | 56.113±0.388 |
| $T_1$ | 16.507±0.302 | 30.337±0.167 | 51.633±0.133 | 58.33±0.616 |
| $T_2$ | 15.807±0.285 | 18.793±0.283 | 54.59±0.62 | 59.66±0.127 |
| $T_3$ | 10.527±0.388 | 15.02±0.451 | 55.78±0.064 | 60.553±0.061 |
| $T_4$ | 14.287±0.521 | 16.107±0.087 | 58.553±0.166 | 60.7±0.484 |
| $T_5$ | 16.083±0.012 | 22.087±0.053 | 58.00±1.56 | 60.484±0.131 |
| $T_6$ | 20.743±0.472 | 26.007±0.255 | 57.513±1.157 | 60.437±0.224 |
| $T_7$ | 11.807±0.334 | 11.947±0.315 | 61.333±0.292 | 61.26±0.295 |
| F-ratio | 56.78 | 69.123 | 75.34 | 90.123 |
| CD | 0.814 | 0.832 | 0.446 | 1.117 |
| CV | 3.03 | 2.847 | 0.856 | 1.058 |

**Table 3. Effect of nano-urea, indole-3-acetic acid, phosphorus and potassium on root length at 30, 60, 90 and 135 (DAS)**

| Tr. No. | Root length (cm) | | | |
|---|---|---|---|---|
| | **30 (DAS)** | **60 (DAS)** | **90 (DAS)** | **135 (DAS)** |
| **T0** | 15.48±0.096 | 16.413± 0.113 | 33.227± 0.112 | 40.91±0.795 |
| **T1** | 16.907±0.325 | 17.92±0.357 | 34.557± 0.063 | 42.517±0.303 |
| **T2** | 17.63±0.035 | 18.213±0.072 | 35.543± 0.188 | 44.17±0.023 |
| **T3** | 16.363±0.764 | 19.393±0.163 | 36.483± 0.131 | 45.697± 0.037 |
| **T4** | 16.96±0.295 | 18.307±0.113 | 38.48±0.128 | 46.103±0.28 |
| **T5** | 17.633±0.982 | 19.69±0.329 | 39.697±0.127 | 46.76±0.162 |
| **T6** | 18.15±0.302 | 19.39±0.163 | 40.547±0.127 | 47.297±0.13 |
| **T7** | 17.557±0.609 | 21.333±0.126 | 42.737±0.148 | 48.3±0.097 |
| **F-ratio** | 2.701 | 6.878 | 14.675 | 36.123 |
| **CD** | N/A | 1.443 | 0.046 | 0.981 |
| **CV** | 5.264 | 2.617 | 0.609 | 1.227 |

**Table 4. Effect of nano-urea, indole-3-acetic acid, potassium and phosphorus on shoot length at 30, 60, 90 and 135 (DAS) of radish plants**

| Tr. No. | Shoot length (cm) | | | |
|---|---|---|---|---|
| | **30 (DAS)** | **60 (DAS)** | **90 (DAS)** | **135 (DAS)** |
| **T0** | 6.407±0.094 | 15.177±0.044 | 16.923±0.289 | 54.413±0.098 |
| **T1** | 6.66±0.548 | 14.017±0.132 | 22.837±0.094 | 60.557±0.064 |
| **T2** | 7.7±0.096 | 12.21±0.072 | 29.583±0.072 | 65.456±0.151 |
| **T3** | 8.253±0.364 | 10.413±0.202 | 30.547±0.064 | 66.483±0.155 |
| **T4** | 7.56±0.061 | 11.247±0.111 | 31.737±0.098 | 68.667±0.321 |
| **T5** | 8.363±0.26 | 13.433±0.127 | 32.657±0.17 | 69.546±0.012 |
| **T6** | 8.477±0.245 | 12.243±0.184 | 34.77±0.064 | 70.234±0.302 |
| **T7** | 8.627±0.131 | 16.067±0.09 | 36.587±0.099 | 75.453±0.401 |
| **F ratio** | 15.135 | 18.156 | 198.33 | 523.409 |
| **CD** | 0.802 | 0.503 | 0.446 | 0.377 |
| **CV** | 5.759 | 3.456 | 0.856 | 0.224 |

**Table 5. Effect of nano-urea, indole-3-acetic acid, phosphorus and potassium on length of leaves at 30, 60, 90 and 135 DAS**

| Tr. No. | Length of leaves (cm) | | | |
|---|---|---|---|---|
| | **30 (DAS)** | **60 (DAS)** | **90 (DAS)** | **135 (DAS)** |
| **T0** | 10.833±0.367 | 22.18±0.075 | 25.48±0.157 | 26.74±0.887 |
| **T1** | 12.793±0.326 | 26.25±0.41 | 26.413±0.147 | 27.883±0.905 |
| **T2** | 9.837±0.349 | 22.827±0.264 | 27.697±0.093 | 29.447±0.226 |
| **T3** | 8.840±0.255 | 18.23±0.087 | 28.52±0.075 | 30.253±0.034 |
| **T4** | 8.457±0.327 | 17.32±0.173 | 28.073±0.69 | 34.81±0.37 |
| **T5** | 7.980±0.765 | 16.86±0.391 | 29.7±0.095 | 35.433±0.388 |
| **T6** | 11.293±0.551 | 14.583±0.425 | 28.703±0.157 | 36.407±0.039 |
| **T7** | 11.537±0.280 | 14.06±0.395 | 30.447±0.166 | 37.623±0.132 |
| F ratio | 23.45 | 38.66 | 45.66 | 67.88 |
| CD | 0.654 | 1.016 | 1.121 | 1.234 |
| CV | 2.24 | 3.018 | 3.556 | 4.554 |

### 3.3 Effect of Nano-urea, Indole-3-Acetic Acid, Potassium and Phosphorus on Shoot Length at 30, 60, 90 and 135 Days after Sowing of Radish Plants

The length of the shoot was measured at 30, 60, 90, and 135 days after sowing. Upon the emergence of seedlings, it was observed that under untreated conditions (control), the average shoot length was 54.413±0.098 (Table 4). The application of nano-urea alone (60.557±0.064) and the co-application of nano-urea and indole-3-acetic acid (69.546±0.012) resulted in the shortest shoot length. Conversely, the longest shoot length (75.453±0.401) was observed with the co-application of indole-3-acetic acid, nano-urea, phosphorus, and potassium. Similar studies were found by Parveen *et. al.* [26] that the combined treatment of indole acetic acid (IAA) and gibberellic acid (GA3) at a concentration of 60 mg $L^{-1}$ (IAA2 + GA2) had the most significant impact on the growth and yield of mung beans, including increased biological yield by [27, 28]. IAA has been recognized to increase growth and photosynthetic pigments' concentration in the leaves of plants (Naeem *et al.,* 2004). As shown in the current study, IAA application was effective in enhancing shoot length when applied along with nano-urea and P and K.

### 3.4 Effect of Nano-urea, Indole-3-Acetic Acid, Phosphorus and Potassium on Length of Leaves at Different Days after Sowing

The length of leaves was measured at 30, 60, 90, and 135 days after sowing. Upon the emergence of length of leaves, it was observed that untreated conditions (control) resulted in an average leaf length of 26.74±0.887 (Table 5). The application of nano-urea alone (27.883±0.905) and the application of nano-urea and indole-3-acetic acid (35.433±0.388) resulted in the shortest leaf length. Conversely, the longest leaf length (37.623±0.132) was observed with the co-application of indole-3-acetic acid, nano-urea, phosphorus, and potassium. Various plant parameters, including leaf length, were recorded at different stages of growth and at the time of harvesting, influenced by different treatments. The effect of different levels of nitrogen on the growth and yield of radish has been studied. Mehwish *et al.* (2016) revealed that higher nitrogen content led to improved growth and yield, while the application of NPK significantly enhanced all growth attributes and yield by Parveen *et al.* [26]. Hence the present study also supports the previous reports as results indicate that IAA and N (nano-urea), P, K are only effective ion increasing the length of leaves when applied simultaneously.

## 4. CONCLUSION

The application of nano-urea, indole-3-acetic acid, phosphorus, and potassium demonstrated significant positive effects on seed germination and various growth parameters of *Raphanus sativus* L. Co-treatments of foliar spray of both IAA @ 1mM and nano urea as a N source (instead of commonly used urea) applied @ 4%, and in-soil application of both single super phosphate @ 225.12 gm as the source of P, and muriate of potash @ 450 gm as K source, improved seed germination percentages compared to the control. This indicates the potential of these treatments in promoting early seedling establishment and overall crop performance. However, the dose of these treatments needs to be ascertained for different crops grown under different agroclimatic conditions. Furthermore, the treatments influenced the number of leaves at different stages of growth, with the combination treatment resulting in the highest leaf count. This suggests that the application of these substances can enhance leaf development and contribute to increased photosynthetic activity, which is crucial for plant growth and productivity. Moreover, the treatments affected the length of leaves, roots, and shoots. In present study, the liquid nano-urea, muriate of potash and single super phosphate were used as sources of N, P, and K respectively, whereas plant hormone IAA was used as foliar spray. It is pertinent to note that no other fertilizer was applied in the current investigation. The combination treatment of these four agrochemicals consistently resulted in the longest lengths, indicating the positive impact of these substances on overall plant growth and development. This may be due to the regulation or modulation of pre-germinative and post-germinative metabolites through various physiological and biochemical changes at the genomic and transcriptomic level, which further amended the morphological or phenotypic characteristics of radish. To ensure these findings and utilize IAA, nano-urea, P and K as effective tools for improving seed germination, leaf development, and overall plant growth in *Raphanus sativus* L. further in-depth investigations are much warranted. Further research and field trials are warranted to explore the optimal application rates and combinations of these substances, as well as their long-term effects on crop performance and soil health. Overall, these findings provide valuable insights for agricultural practitioners and researchers working towards sustainable and efficient crop production systems. In the future, the foliar application of nano-urea can replace the in-soil application of urea. Combined treatments of IAA (auxin), nano-urea, P, and K can be applied to enhance plant growth and development. However, further intensive field trials and extensive studies are required to ensure and decide the adequate dose of fertilizers and time of applications of these fertilizers in different crops. Thereafter, incorporating these treatments into agricultural practices may contribute to enhanced crop productivity, yield, and ultimately, sustainable food production [29-31].

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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