Vegetable Science (2025) 52(2): 289-296

doi: 10.61180/vegsci.2025.v52.i2.08

ISSN- 0970-6585 (Print), ISSN- 2455-7552 (Online)

www.isvsvegsci.in

RESEARCH ARTICLE

# Effect of nano-fertilizer-based INM on growth, yield and quality of chow-chow (*Sechium edule* (Jacq.) Sw.) in Nagaland

**Imkongsunep Walling, S. P. Kanaujia, Moakala Changkiri*, Sentirenla Jamir and Ashwini Ananda**

## Abstract

A field experiment was conducted in Nagaland University, School of Agricultural Sciences, during two consecutive years, 2022-2023 and 2023-2024, to study the effect of nano-fertilizer-based integrated nutrient management on growth, yield and quality of chow-chow [*Sechium edule* (Jacq.) Sw.] in Nagaland. Results revealed that the application of different levels of nutrients either alone or in combination significantly increased the growth, yield and quality attributes of chow-chow. The results indicated that the highest growth, yield and quality parameters were observed in treatment [Poultry manure @ 5 t/ha + nano-urea (two sprays @ 0.5%) + microbial consortium] with number of leaves/plant (108.97), number of primary branches (4.21), leaf length (20.15 cm), leaf width (22.30 cm), leaf area (189.08 $cm^2$), vine length (7.01 m), number of fruits/plant (15.65), fruit length (13.89 cm), fruit diameter (8.98 cm), average weight of fruit (482.40 g), yield/plant (7.57 kg), yield/ha (681.40 q), vitamin C (4.99 mg/100 g) and calcium content (13.29 mg/100 g). Thus, nano-fertilizers showed great potential as a key component of INM and can be recommended to the farmers.

**Keywords**: Nano-fertilizer, INM, Chow-chow, *Sechium edule*, Growth, Yield, Quality.

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**Citation:** Walling, I., Kanaujia, S.P., Changkiri, M., Jamir, S., & Ananda, A. (2025). Effect of nano-fertilizer-based INM on growth, yield and quality of chow-chow (*Sechium edule* (Jacq.) Sw.) in Nagaland. Vegetable Science 52(2), 289-296.

**Source of support:** Nil

**Conflict of interest:** None.

**Received:** 28/05/2025 **Revised:** 17/09/2025 **Accepted:** 18/09/2025

## Introduction

Chow-chow [*Sechium edule* (Jacq.) Sw.] is a perennial cucurbitaceous vegetable crop valued for its nutritional content and adaptability to diverse growing conditions in North Eastern regions. In addition to the fruits, tender leaves and tubers are also consumed (Singh et al. 2012). Recent studies have highlighted its composition of essential amino acids, antioxidants and dietary fibre, making it an important crop for both nutritional security and commercial cultivation. Their abundance in fibre, vitamins and antioxidants promotes digestive health, strengthens the immune system and could lower the risk of chronic diseases such as heart disease, diabetes and some malignancies (Bhagya et al., 2021). In India, chow-chow cultivation has been steadily increasing, particularly in the hilly regions of the North Eastern states, Himachal Pradesh, Uttarakhand and some parts of South India, where it thrives in cool and humid climates (Singh et al., 2015; Pandey et al., 2018). The crop is well-suited for smallholder farming systems due to its low input requirements and high yield potential. Chow-chow productivity in India, however, remains suboptimal despite its adaptability, primarily due to inefficient nutrient management practices, with many farmers relying excessively on synthetic fertilizers that degrade soil health over time (Patel et al., 2022). To address the challenges, sustainable nutrient management strategies such as Integrated Nutrient Management and nano-fertilizers have emerged as promising alternatives. INM, which combines organic manures (farmyard manure, vermicompost, etc.), biofertilizers and chemical fertilizers in balanced proportions, has been shown to improve soil health, enhance nutrient use efficiency, and sustain long-term crop productivity (Moakala et al., 2015; Kanaujia et al., 2016). Nitrogen from chemical fertilizer (urea) is lost through leaching, de-nitrification and ammonia volatilization. Loss of mineral nutrients through leaching and runoff to surface and ground water, along with abundant volatilization, constitute growing concerns owing to economic losses and environmental pollution. Moreover, nitrogen volatilization results in the release of nitrous oxides and thus being the greenhouse gases and thus contribute to global warming and climate change. Hence, plant fertilizers with nutrients in the form of nanoparticles are released at a slow rate for a longer period, thus reducing loss from the soil and contamination of the soil and groundwater. Nano-fertilizers have the potential to enhance nitrogen use efficiency owing to higher nutrients uptake caused by the smaller surface area of nano-materials, which increases nutrient-surface interaction. Nano- urea is a source of nitrogen, which is a major essential nutrient required for the proper growth and development of a plant. Foliar application of nano-urea at critical crop growth stages of vegetable crops before flowering effectively fulfils their nitrogen requirement and leads to higher crop productivity and quality of vegetable crops in comparison to conventional urea. About 500 mL of nano-urea is equivalent to 45 kg of conventional urea. Nano-fertilizers - a novel innovation in precision agriculture offers controlled nutrient release, higher absorption efficiency and reduced environmental losses compared to conventional fertilizers (Kanaujia et al. 2024). Despite these advancements, research on the combined effects of INM and nano-fertilizers on chow-chow remains limited, particularly in the Indian context. Given the crop's growing economic importance and the realization of its nutritional benefits, optimizing fertilization strategies for chow-chow could significantly enhance productivity while promoting sustainable farming practices. Therefore, this study aims to evaluate the impact of nano-fertilizers based on INM on growth, yield and quality of chow-chow, with the goal of providing science-based recommendations for farmers and policy makers. The findings will contribute to the broader discourse on sustainable vegetable production and climate-resilient agriculture.

## Materials and Methods

The experiments were carried out in the experimental farm of the School of Agricultural Sciences, Nagaland University, Medziphema campus, Nagaland, during the two consecutive years 2022-2023 and 2023-2024 to determine the effect of nano-fertilizers based on INM on growth, yield and quality of chow-chow. The experimental farm is situated in a humid and subtropical climate region, characterized by an average annual rainfall ranging from 2000 to 2500 mm. The mean temperature typically falls within the range of 21 to 32°C during the summer, and even in winter, it seldom drops below 8°C due to the presence of high atmospheric humidity. The soil pH was recorded as acidic (4.2–4.5) and higher organic carbon (1.28–1.35%) was reported initially in the soil with low content of available N (172–176 kg/ha) and K (142–155 kg/ha) and moderate content of available P (13–16 kg/ha). The experimental field was laid out in a Randomized Block Design (RBD) with three replications. The experiment comprised 21 treatments, *viz.* $T_1$ - Full dose of RDF (N through urea), $T_2$ - N through nano-urea (2 sprays @ 0.5%), $T_3$ - FYM @ 20 t/ha, $T_4$ - Vermicompost @ 5 t/ha , $T_5$ - Poultry manure @ 10 t/ha, $T_6$ - FYM @ 20 t/ha + microbial consortium, $T_7$ - Vermicompost @ 5 t/ha + microbial consortium, $T_8$ - Poultry manure @ 10 t/ha + microbial consortium, $T_9$ - FYM @ 10 t/ha + ½ of RDF (N through urea), $T_{10}$ - FYM @ 10 t/ha + N through nano-urea (2 sprays @ 0.5%), $T_{11}$ - FYM @ 10 t/ha + ½ of RDF (N through urea) + microbial consortium, $T_{12}$ - FYM @ 10 t/ha + N through nano-urea (2 sprays @ 0.5%) + microbial consortium, $T_{13}$ - Vermicompost @ 2.5 t/ha + ½ of RDF (N through urea), $T_{14}$ - Vermicompost @ 2.5 t/ha + N through nano-urea (2 sprays @ 0.5%), $T_{15}$ - Vermicompost @ 2.5 t/ha + ½ of RDF (N through urea) + microbial consortium, $T_{16}$ - Vermicompost @ 2.5 t/ha + N through nano-urea (2 sprays @ 0.5%) + microbial consortium, $T_{17}$ - Poultry manure @ 5 t/ha + ½ of RDF (N through urea), $T_{18}$ - Poultry manure @ 5 t/ha + N through nano-urea (2 sprays @ 0.5%), $T_{19}$ - Poultry manure @ 5 t/ha + ½ of RDF (N through urea) + microbial consortium, $T_{20}$ - Poultry manure @ 5 t/ha + N through nano-urea (2 sprays @ 0.5%) + microbial consortium, $T_{21}$ - Farmers' practice (FYM @ 5 t/ha + ash @ 5 q/ha). Treatment farmers practice ($T_{21}$) is a practice adapted by the farmers of Nagaland, i.e., application of FYM @ 5 t/ha + ash @ 5 q/ha. The application of organic manure was done 20 days before sowing and the quantity of manure was added as per the recommended treatments. The chemical fertilizers were incorporated in the soil just before sowing as per the recommended dose, i.e., 100:60:60 kg NPK/ha, respectively. Nitrogen was applied in 2 split doses, half as basal and the remaining half as top dressing, 30 days after sowing. The entire quantity of P and K was applied as basal at the time of sowing. The application of nano-urea @ 5 ml/l was done twice as a foliar spray. The first application was done at 6–8 leaf stage and the second at 1 week before flowering. A microbial consortium was applied @ 5 mL/l by mixing with organic manure 15 days before sowing. The pre-germinated chow-chow seeds were treated with Captaf 50% WP, a broad-spectrum fungicide @ 2.5 g/l to check the seed-borne pathogens just before sowing and were drenched with chlorpyriphos @ 2 mL/l to avoid infestation by termites just after sowing. Observations were recorded on growth parameters (number of leaves/ plant, number of primary branches, leaf length, leaf width, leaf area, internodal length and vine length), yield and yield attributes (number of fruits/plant, fruit length, fruit diameter, average weight of fruit, yield/plant and yield/ha) and quality attributes (TSS, crude protein content, total chlorophyll content, vitamin C content, total carbohydrate content, fiber content, calcium content and total phenolic content). The total soluble solids of the fruits were determined with the help of ERMA, a hand refractometer calibrated at 20°Brix. The crude protein content of fruit was estimated through the Kjeldahl method, where digestion and distillation were followed for the estimation of nitrogen content and it was multiplied by 6.25. The chlorophyll content in fruits was estimated using a spectrophotometer as per the procedure given by Arnon (1949) and expressed in mg/100 g. Vitamin C content was determined by using 2,6-Dichlorophenol indophenols visual titration method as given by AOAC (1984) and expressed in mg/100 g. Total carbohydrate estimation was done by Anthrone's Method as given by Hedge and Hofreiter (1962) and expressed in %. Crude fibre content was estimated by the acid-alkali digestion method. The estimation of calcium content in the fruit was determined by using an atomic absorption spectrophotometer (Ruck, 1979). Total phenolic content was analyzed by using Singleton's method (Singleton et al., 1999). Data were statistically analysed as per the procedure given by Panse and Sukhatme (1989).

## Results and Discussion

### *Growth attributes*

Integrated application of nano-fertilizer, organic manures and microbial consortium alone or in combination has an appreciable effect in altering the growth attributes of chow chow. It is revealed from Table 1 that treatment $T_{20}$ [Poultry manure @ 5 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] recorded the highest number of leaves (108.97) and number of primary branches (4.21) followed by treatment $T_{12}$ [FYM @ 10 t/ha + N through nano-urea (2 sprays @ 0.5%)

**Table 1:** Effect of nano-fertilizer based integrated nutrient management on growth attributes of chow-chow (pooled data).

| *Treatments* | *Number of leaves/ plant* | *Number of primary branches* | *Leaf length (cm)* | *Leaf width (cm)* | *Leaf area (cm2)* | *Internodal length (cm)* | *Vine length (m)* |
|---|---|---|---|---|---|---|---|
| T1 | 92.54 | 3.65 | 19.01 | 21.46 | 171.44 | 7.79 | 6.72 |
| T2 | 64.82 | 2.62 | 15.24 | 17.91 | 160.82 | 9.19 | 5.50 |
| T3 | 72.04 | 3.68 | 17.90 | 19.20 | 166.04 | 8.56 | 5.34 |
| T4 | 75.65 | 3.19 | 17.03 | 18.64 | 167.05 | 9.70 | 5.84 |
| T5 | 67.31 | 3.44 | 17.02 | 18.83 | 168.97 | 8.59 | 5.61 |
| T6 | 78.80 | 2.53 | 14.66 | 18.52 | 167.07 | 8.49 | 5.53 |
| T7 | 85.10 | 2.62 | 16.75 | 18.81 | 171.81 | 8.30 | 5.57 |
| T8 | 70.82 | 2.58 | 14.98 | 18.64 | 165.71 | 8.64 | 5.55 |
| T9 | 77.55 | 2.82 | 17.77 | 20.50 | 167.82 | 8.31 | 5.33 |
| T10 | 80.11 | 2.65 | 17.02 | 17.98 | 169.31 | 8.40 | 5.52 |
| T11 | 71.39 | 3.01 | 17.67 | 20.37 | 170.46 | 8.19 | 5.48 |
| T12 | 92.68 | 4.15 | 19.56 | 21.79 | 176.66 | 7.74 | 6.86 |
| T13 | 73.36 | 2.46 | 18.22 | 19.08 | 174.74 | 8.51 | 5.37 |
| T14 | 73.19 | 2.85 | 15.71 | 17.99 | 176.92 | 8.42 | 5.33 |
| T15 | 79.80 | 2.50 | 16.54 | 18.68 | 174.74 | 8.20 | 5.59 |
| T16 | 87.33 | 3.97 | 18.41 | 21.30 | 175.32 | 8.00 | 6.68 |
| T17 | 83.44 | 3.06 | 17.07 | 18.44 | 174.73 | 8.48 | 6.42 |
| T18 | 64.40 | 2.49 | 16.29 | 17.94 | 172.19 | 8.41 | 5.40 |
| T19 | 81.66 | 2.78 | 17.52 | 19.71 | 168.53 | 8.30 | 5.41 |
| T20 | 108.97 | 4.21 | 20.15 | 22.30 | 189.08 | 7.82 | 7.01 |
| T21 | 63.33 | 2.40 | 13.69 | 16.50 | 154.55 | 8.50 | 5.17 |
| SEm± | 4.59 | 0.35 | 0.66 | 0.55 | 5.63 | 0.19 | 0.14 |
| CD (P=0.05) | 13.15 | 1.02 | 1.89 | 1.58 | 16.13 | 0.56 | 0.39 |

+ MC] with 92.68 and 4.15, respectively. Similarly longest leaf length (20.15 cm) and leaf width (22.30 cm) were also recorded in treatment $T_{20}$ [Poultry manure @ 5 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] followed by treatment $T_{12}$ [FYM @ 10 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] at 19.56 and 21.79 cm, respectively. The highest leaf area (189.08 cm$^2$) was recorded in $T_{20}$ [Poultry manure @ 5 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] followed by treatment $T_{12}$ [FYM @ 10 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] with 176.66 cm$^2$. Longest internodal length (9.70 cm) was recorded in $T_4$ - Vermicompost @ 5 t/ha followed by $T_2$ [(N through nano-urea (2 sprays @ 0.5%)] with 9.19 cm. Minimum internodal length (7.74 cm) was recorded in $T_{12}$ [FYM @ 10 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC]. Longest vine length (7.01 m) was recorded in $T_{20}$ [Poultry manure @ 5 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC], followed by treatment $T_{12}$ [FYM @ 10 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] with 6.86 m. The treatments $T_{21}$ (farmers' practices) recorded the lowest value of number of leaves, number of branches, leaf length, leaf width, leaf area and vine length, while treatment $T_{12}$ [FYM @ 10 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] recorded the shortest internodal length with 7.74 cm. Treatments involving nano-urea such as $T_{10}$ [FYM @ 10 t/ha + N through nano-urea (2 sprays @ 0.5%)], $T_{12}$ [FYM @ 10 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC], $T_{14}$ [VC @ 2.5 t/ha + N through nano-urea (2 sprays @ 0.5%)], $T_{16}$ [VC @ 2.5 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] and $T_{20}$ [PM @ 5 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] showed better performance than those using granular urea, highlighting the potential advantages of nano-urea in promoting leaf growth. The integrated application of poultry manure (5 t/ha) + N through nano-urea (2 sprays @ 0.5%) + microbial consortium ($T_{20}$) significantly enhanced vegetative growth parameters, recording the highest leaf count (108.97), primary branches (4.21), leaf length (20.15 cm), leaf width (22.30 cm), leaf area (189.08 cm$^2$) and vine length (7.01 m). Nano-urea enhances nitrogen uptake by 80 to 90% due to leaf penetration and targeted cellular assimilation, while organics and microbes improve soil physicochemical properties, enhancing root absorption. The significantly improved growth attributes under treatment $T_{20}$ [Poultry manure @ 5 t/ha + N through nano-urea (2 sprays @ 0.5%)] + microbial consortium are attributed to the synergistic benefits of integrated nutrient sources. The nano-urea provides nitrogen in nano-sized particles, enhancing foliar absorption, minimizing losses and improving nitrogen use efficiency (Liu and Lal, 2015). This results in more vigorous cell division and expansion, directly influencing plant height, leaf number, and surface area. Poultry manure is rich in readily mineralizable nitrogen and organic acids that promote microbial proliferation and nutrient mineralization, while the microbial consortium improves nutrient solubilization and uptake, including phosphorus and micronutrients (Merghany et al., 2019). The microbial colonization also stimulates root growth and rhizosphere activity, boosting plant biomass accumulation. Jagraj et al. (2018) and Singh et al. (2018) reported significant increases in leaf count and internodal elongation in cucumber under INM treatments. Similarly, Baghel et al. (2016) noted improved vegetative parameters in bottle gourd when integrating organics with reduced synthetic inputs.

### *Yield attributes*

Integrated application of nano-fertilizer, organic manures and microbial consortium alone or in combination has an appreciable effect in the altering of yield and yield attributes of chow-chow. It is revealed from Table 2 that Treatment $T_{20}$ [PM @ 5 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] recorded the highest number of fruits/plant (15.65) followed closely by $T_{12}$ [FYM @ 10 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] with a pooled value of 15.37 fruits/ plant. Largest fruit length (13.89 cm) and fruit diameter (8.98 cm) was recorded in treatment $T_{20}$ [PM @ 5 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] followed closely by $T_{12}$ [FYM @ 10 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] with a pooled value of 13.40 and 8.91 cm, respectively. Highest average weight of fruit (482.40 g), highest yield/ plant (7.57 kg) and yield/ha (681.40 q) were recorded in treatment $T_{20}$ [PM @ 5 t/ha+ N through nano-urea (2 sprays @ 0.5%) + MC] followed closely by $T_{12}$ [FYM @ 10 t/ ha + N through nano-urea (2 sprays @ 0.5%) + MC] with a pooled value of 450.42 g, 6.93 kg and 676.88 q, respectively. Treatment farmers' practices ($T_{21}$) recorded the lowest yield with a pooled average of 297.44 q/ha. The treatment difference between $T_{20}$ [PM @ 5 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC], $T_{12}$ [FYM @ 10 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] and $T_{16}$ [Vermicompost @ 2.5 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] was found statistically at par. Treatments incorporated with microbial consortium were recorded as intermediate performers. This superior performance was attributed to the synergistic effects of the controlled nitrogen release, organic nutrient supply from poultry manure and enhanced nutrient use efficiency due to microbial consortia along with the nano-fertilizers (Kharga 2020). On the contrary, the farmers' practices ($T_{21}$) exhibited the poorest performance across all six parameters, highlighting the critical role of balanced fertilization (Jagraj et al. 2018 and Aravinda et al. 2022). These results demonstrate that nano-urea-based INM ($T_{20}$) optimizes all yield-related parameters, while farmers' practices drastically limit productivity. These results are aligned with Thriveni et al. (2015) in bitter gourd and Jagraj et al. (2018) in cucumber.

### *Quality parameters*

Integrated application of nano-fertilizer, organic manures and microbial consortium alone or in combination has an

**Table 2:** Effect of nano-fertilizer based integrated nutrient management on yield and yield attributes of chow-chow (pooled data)

| *Treatments* | *Number of fruits/ plant* | *Fruit length (cm)* | *Fruit diameter (cm)* | *Average weight of fruit (g)* | *Yield/plant (kg)* | *Yield/ha (q)* |
|---|---|---|---|---|---|---|
| T1 | 15.17 | 12.07 | 8.11 | 417.04 | 6.33 | 605.56 |
| T2 | 11.37 | 9.55 | 8.62 | 313.99 | 3.57 | 456.93 |
| T3 | 11.01 | 11.14 | 7.20 | 354.91 | 3.91 | 391.19 |
| T4 | 10.40 | 11.45 | 7.24 | 327.73 | 3.41 | 370.90 |
| T5 | 12.17 | 10.96 | 7.96 | 306.61 | 3.73 | 381.36 |
| T6 | 11.90 | 11.44 | 7.85 | 404.89 | 4.81 | 479.83 |
| T7 | 11.40 | 10.48 | 7.67 | 337.07 | 3.84 | 385.91 |
| T8 | 11.47 | 11.57 | 7.53 | 313.82 | 3.59 | 360.15 |
| T9 | 12.27 | 9.76 | 7.68 | 311.23 | 3.82 | 383.57 |
| T10 | 12.67 | 11.07 | 8.24 | 378.93 | 4.80 | 479.97 |
| T11 | 13.97 | 11.16 | 8.02 | 356.27 | 4.98 | 503.89 |
| T12 | 15.37 | 13.40 | 8.91 | 450.42 | 6.93 | 676.88 |
| T13 | 13.20 | 10.58 | 7.97 | 306.92 | 4.05 | 405.41 |
| T14 | 13.63 | 9.66 | 7.38 | 307.74 | 4.20 | 419.37 |
| T15 | 14.20 | 10.64 | 7.06 | 365.21 | 5.19 | 518.66 |
| T16 | 15.47 | 11.69 | 8.50 | 428.28 | 6.62 | 662.32 |
| T17 | 13.37 | 10.28 | 7.01 | 302.84 | 4.05 | 403.80 |
| T18 | 12.80 | 11.02 | 7.41 | 302.82 | 3.88 | 389.34 |
| T19 | 14.13 | 10.85 | 7.07 | 360.17 | 5.09 | 509.63 |
| T20 | 15.65 | 13.89 | 8.98 | 482.40 | 7.57 | 681.40 |
| T21 | 9.37 | 9.20 | 6.09 | 259.45 | 2.98 | 297.44 |
| SEm± | 0.33 | 0.23 | 0.21 | 17.71 | 0.31 | 25.85 |
| CD (P=0.05) | 0.95 | 0.66 | 0.57 | 50.71 | 0.86 | 74.04 |

appreciable effect in altering the quality parameters of chow-chow. It is revealed from Table-3 that treatment $T_{20}$ [PM @ 5 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] records the highest vitamin C content (4.99 mg/100 g) and calcium content (13.29 mg/100 g). In contrast, farmers' practices ($T_{21}$) recorded the lowest vitamin C content with 3.31 mg/100 g and calcium content with 11.53 mg/100 g. However, Treatment $T_{16}$ [Vermicompost @ 2.5 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] recorded the highest TSS (4.66°B), total chlorophyll content (0.289 mg/100 g) and fibre content (0.209%) followed by treatment $T_{12}$ [FYM @ 10 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] with a pooled value of 4.54°B, 0.272 mg/100 g and 0.190%, respectively. The lowest pooled TSS, total chlorophyll content and fibre content were recorded in the farmers' practices ($T_{21}$) with 2.25°B, 0.141 mg/100 g and 0.137%, respectively. The highest content of crude protein (0.66%) was recorded in the treatment $T_{12}$ [FYM @ 10 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] and the lowest protein content (0.40%) was observed in the farmers' practices ($T_{21}$). The highest total carbohydrate content (3.83%) was recorded in the treatment $T_1$ [Full dose of RDF (N through urea)] and the lowest total carbohydrate content (2.92%) was observed in the farmers' practices ($T_{21}$). Treatments $T_{15}$ [Vermicompost @ 2.5 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] recorded the highest total phenolic content (1.77 mg/100 g), followed by $T_{16}$ [VC @ 2.5 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] with 1.73 mg/100 g. The lowest total phenolic content (1.27 mg/100 g) was observed in the farmers' practices ($T_{21}$). For crude protein content, treatment $T_{12}$ [FYM @ 10 t/ha + N through nano-urea (2 sprays @ 0.5%) + MC] exhibited the highest value with 0.66%, while the farmers' practices ($T_{21}$) performed the poorest, likely due to insufficient nitrogen for amino acid synthesis (Pranali et al. 2018; Thriveni et al. 2015). Chlorophyll content was maximized in $T_{16}$ (VC + N through nano-urea (2 sprays @ 0.5%) + MC], with statistically similar results in $T_{12}$ (FYM + nano urea + MC) and $T_{20}$ (PM + nano urea + MC), whereas conventional urea treatments ($T_{11}$, $T_{15}$,

**Table 3:** Effect of nano-fertilizer based integrated nutrient management on quality parameters of chow-chow (pooled data).

| *Treatments* | *TSS (ºB)* | *Crude protein content (%)* | *Total chlorophyll content (mg/100 g)* | *Vitamin C content (mg/100 g)* | *Total carbohydrate (%)* | *Fiber content (%)* | *Ca content (mg/100 g)* | *Total phenolic content (mg/100 g)* |
|---|---|---|---|---|---|---|---|---|
| T1 | 4.09 | 0.63 | 0.192 | 4.74 | 3.83 | 0.185 | 12.72 | 1.71 |
| T2 | 3.11 | 0.52 | 0.218 | 4.19 | 3.07 | 0.171 | 12.60 | 1.65 |
| T3 | 2.95 | 0.46 | 0.209 | 3.57 | 3.06 | 0.158 | 12.00 | 1.44 |
| T4 | 2.97 | 0.40 | 0.186 | 4.12 | 3.19 | 0.146 | 12.16 | 1.46 |
| T5 | 3.56 | 0.51 | 0.166 | 4.04 | 3.14 | 0.156 | 11.62 | 1.31 |
| T6 | 2.87 | 0.52 | 0.204 | 3.88 | 3.11 | 0.158 | 12.13 | 1.34 |
| T7 | 2.90 | 0.50 | 0.155 | 4.22 | 3.19 | 0.169 | 11.97 | 1.45 |
| T8 | 2.96 | 0.46 | 0.194 | 3.80 | 3.30 | 0.154 | 12.15 | 1.46 |
| T9 | 2.95 | 0.43 | 0.223 | 3.92 | 3.00 | 0.165 | 12.60 | 1.59 |
| T10 | 3.44 | 0.47 | 0.189 | 3.66 | 3.36 | 0.170 | 12.10 | 1.51 |
| T11 | 4.38 | 0.61 | 0.246 | 4.16 | 3.29 | 0.173 | 12.75 | 1.49 |
| T12 | 4.54 | 0.66 | 0.272 | 4.86 | 3.67 | 0.190 | 13.04 | 1.69 |
| T13 | 2.75 | 0.47 | 0.182 | 3.65 | 3.13 | 0.176 | 12.13 | 1.49 |
| T14 | 3.13 | 0.52 | 0.207 | 4.45 | 3.59 | 0.165 | 12.23 | 1.60 |
| T15 | 4.45 | 0.59 | 0.221 | 4.08 | 3.40 | 0.180 | 12.78 | 1.77 |
| T16 | 4.66 | 0.64 | 0.289 | 4.82 | 3.75 | 0.209 | 12.93 | 1.73 |
| T17 | 3.61 | 0.43 | 0.214 | 3.62 | 3.19 | 0.169 | 12.06 | 1.63 |
| T18 | 3.65 | 0.51 | 0.177 | 3.86 | 3.47 | 0.160 | 12.27 | 1.46 |
| T19 | 3.82 | 0.56 | 0.217 | 4.30 | 3.67 | 0.180 | 12.72 | 1.63 |
| T20 | 4.39 | 0.61 | 0.210 | 4.99 | 3.79 | 0.200 | 13.29 | 1.68 |
| T21 | 2.25 | 0.40 | 0.141 | 3.31 | 2.92 | 0.137 | 11.53 | 1.27 |
| SEm± | 0.13 | 0.029 | 0.016 | 0.21 | 0.06 | 0.005 | 0.14 | 0.032 |
| CD (P=0.05) | 0.36 | 0.084 | 0.045 | 0.58 | 0.18 | 0.013 | 0.39 | 0.092 |

$T_{19}$) showed slightly lower but significant effects (Kharga et al. 2020). Vitamin C content was highest in the same nano-urea integrated treatments ($T_{12}$, $T_{16}$, $T_{20}$), attributed to balanced micronutrient supply, while the farmers' practices again ranked lowest (Sahu et al. 2022). Carbohydrate content peaked (3.83%) in $T_1$ (full RDF via urea), though $T_{12}$, $T_{16}$, and $T_{20}$ were statistically comparable, underscoring the role of optimized nitrogen in photosynthate production (Nayak *et al*., 2016). Fiber content was highest in $T_{16}$, linked to vermicompost, which supplements calcium and magnesium, contributing to cell wall strength, while the farmers' practices exhibited minimal fiber due to nutrient deficiencies. Calcium accumulation was highest in $T_{20}$ (PM + nano urea + MC), likely due to organic acid release from poultry manure, whereas the farmers' practices showed deficient levels (Islam et al. 2018). Phenolic compounds were most abundant in $T_{15}$ (VC + urea + MC) and $T_{16}$, with sole organic manure treatments lagging due to slow nutrient release. Collectively, integrated treatments combining nano-urea, organic amendments (especially vermicompost), and microbial consortium delivered superior outcomes, whereas the unfertilized control consistently underperformed across all metrics. These findings are in conformity with Sahu et al. (2022). Similar results were observed by Thriveni et al. (2015), Pathak et al. (2017).

## Summary

The radar chart provides a comprehensive visual summary of the comparative effectiveness of three top-performing integrated nutrient management (INM) treatments-$T_{12}$, $T_{16}$, and $T_{20}$ on chow-chow across key growth as shown in Fig 1, yield and quality parameters. These parameters include leaf area (growth attribute), yield per hectare (yield attribute) and vitamin C content, crude protein percentage, and total phenolic content (quality attributes). Among the treatments, $T_{20}$ (Poultry manure @ 5 t/ha + N through nano-urea (2 sprays @ 0.5%) + microbial consortium) demonstrates the most robust overall performance. It records the highest values

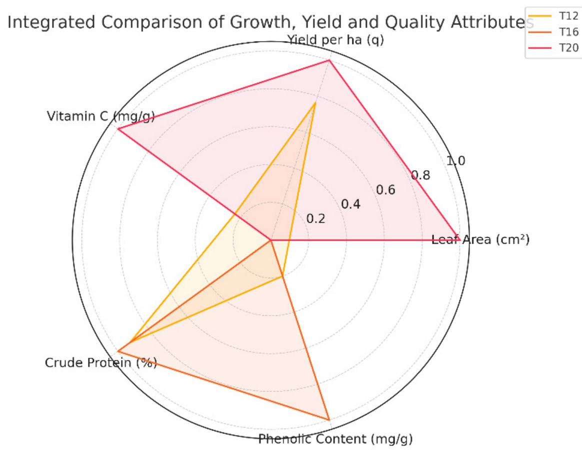


**Fig. 1:** Integrated comparison of Growth, Yield and Quality Attributes for three top-performing integrated nutrient management (INM) treatments-T12, T16, and T20

in both leaf area and yield per hectare, indicating superior vegetative development and economic output. Additionally, $T_{20}$ leads in vitamin C content, making it highly favorable from a nutritional standpoint. On the other hand, $T_{16}$ (Vermicompost @ 2.5 t/ha + N through nano-urea (2 sprays @ 0.5%) + microbial consortium) excels in crude protein and total phenolic content, suggesting it is particularly beneficial when the goal is to enhance the nutritional and functional quality of the fruit. $T_{12}$ (FYM @ 10 t/ha + N through nano-urea (2 sprays @ 0.5%) + microbial consortium) performs consistently across all parameters, offering balanced outcomes though not leading in any single trait. This integrated visualization aids in selecting treatments not only based on isolated traits but on multi-criteria performance, supporting evidence-based decision making for sustainable and productive cultivation of chow-chow.

Based on the present findings, it may be concluded that the application of poultry manure @ 5 t/ha + N through nano-urea (2 sprays @ 0.5%) + microbial consortium ($T_{20}$) was observed as the most effective treatment. It not only enhanced the crop growth, yield and quality but also proved to be the most economically viable option among the tested treatments. Thus, nano-fertilizers show great potential as a key component of integrated nutrient management (INM) and can be recommended to the farmers of Nagaland.

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## सारांश

नागालैंड विश्वविद्यालय, कृषि विज्ञान संकाय में, नागालैंड में चाउ-चाउ [सेचियम एडुले (जैक) स्व.] की वृद्धि, उपज और गुणवत्ता पर नैनो-उर्वरक आधारित एकीकृत पोषक तत्व प्रबंधन के प्रभाव का अध्ययन करने के लिए लगातार दो वर्षों 2022-2023 और 2023-2024 के दौरान एक क्षेत्रीय प्रयोग किया गया। परिणामों से पता चला कि विभिन्न स्तरों के पोषक तत्वों के अकेले या संयोजन में प्रयोग से चाउ-चाउ की वृद्धि, उपज और गुणवत्ता में उल्लेखनीय वृद्धि हुई। परिणामों से संकेत मिलता है कि उपचार में उच्चतम वृद्धि, उपज और गुणवत्ता पैरामीटर देखे गए [पोल्ट्री खाद @ 5 टी/हेक्टेयर + नैनो-यूरिया (दो स्प्रे @ 0.5%) + माइक्रोबियल कंसोर्टियम] पत्तियों की संख्या (108.97), प्राथमिक शाखाओं की संख्या (4.21), पत्ती की लंबाई (20.15 सेमी), पत्ती की चौड़ाई (22.30 सेमी), पत्ती क्षेत्र (189.08 सेमी2), बेल की लंबाई (7.01 मीटर), फलों की संख्या/पौधे (15.65), फल की लंबाई (13.89 सेमी), फल का व्यास (8.98 सेमी), फल का औसत वजन (482.40 ग्राम), उपज/पौधा (7.57 किलोग्राम), उपज/हेक्टेयर (681.40 क्विंटल), विटामिन सी (4.99 मिलीग्राम/100 ग्राम) और कैल्शियम सामग्री (13.29 मिलीग्राम/100 ग्राम I