



**POTENTIALITY OF NANOFERTILIZERS IN INTEGRATED
NUTRIENT MANAGEMENT OF CHOW CHOW [*Sechium edule*
(Jacq.) Sw.] IN CHUMUKEDIMA DISTRICT OF NAGALAND**

THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

By

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May-2025**

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BY

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Submitted

In partial fulfilment of the requirements for the Degree of Doctor of
Philosophy in

Horticulture (Vegetable Science) of Nagaland University

Dedicated to my parents

Nagaland University

May, 2025

I, Imkongsunep Walling, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis had not been submitted by me for any research degree in any other university/institute.

This is being submitted to Nagaland University for the degree of Doctor of Philosophy in Horticulture (Vegetable Science).

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CERTIFICATE – I

This is to certify that the thesis entitled “**Potentiality of nanofertilizers in integrated nutrient management of chow-chow [*Sechium edule* (Jacq.) Sw.] in Chumukedima district of Nagaland**” submitted to Nagaland University in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Horticulture (Vegetable Science) is the record of research work carried out by Mr. Imkongsunep Walling Registration No. Ph.D./HOR/00452 under my personal supervision and guidance.

The result of the investigation reported in the thesis have not been submitted for any other degree or diploma. The assistance of all kinds received by the student has been duly acknowledged.

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CERTIFICATE – II

**VIVA VOCE ON THESIS OF DOCTOR OF PHILOSOPHY IN
HORTICULTURE**

This is to certify that the thesis entitled “**Potentiality of nanofertilizers in integrated nutrient management of chow-chow [*Sechium edule* (Jacq.) Sw.] in Chumukedima district of Nagaland**” submitted by Mr. Imkongsunep Walling Admission No. Ph-332/21 Registration No. Ph.D./HOR/00452 to the NAGALAND UNIVERSITY in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Horticulture (Vegetable Science) has been examined by the Advisory Board and External examiner on

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LIST OF ABBREVIATIONS

%	-	Percentage
@	-	at the rate of
₹	-	Rupees
:	-	Ratio
⁻¹ or /	-	Per
=	-	is equal to
°	-	Degree
°C	-	Degree Celsius
±	-	Plus or minus
A.O.A.C	-	Association of Official Analytical Chemist
B	-	Brix
CB	-	Cost Benefit ratio
CD	-	Critical Difference
CV	-	Coefficient of variance
cm	-	Centimetre
cv.	-	Cultivar
DAS	-	Days after sowing
df	-	Degree of freedom
et al.	-	et alia (and others/co-workers)
F- test	-	Fischer's test
Figure.	-	Figureure
FYM	-	Farm Yard Manure
g	-	Gram
g ⁻¹	-	per gram
g ⁻¹ plant	-	gram per plantha ⁻¹
ha	-	Hectare
i.e.	-	Id est (that is)
INM	-	Integrated Nutrient Management
K	-	Potassium
kg	-	Kilogram
L.	-	Linnaeus
m	-	Metre
Max.	-	Maximum
mg	-	Milligram
Min.	-	Minimum

m ²	-	Metre square
MC	-	Microbial consortium
mm	-	Millimetre
MOP	-	Muriate of Potash
msl	-	Mean Sea level
mt	-	Million tonnes
NPK	-	Nitrogen Phosphorus
PotassiumNS	-	Not significant
NU	-	Nagaland University
OC	-	Organic carbon
P	-	Phosphorous
pH	-	Negative logarithm of hydrogen ion activity in soil
PM	-	Poultry manure
q	-	Quintal
R	-	Replication
RDF	-	Recommended Dose of Fertilizers
RBD	-	Randomised block design
SAS	-	School of Agricultural Sciences
SEm±	-	Standard error of mean
Sl. No.	-	Serial number
SOV	-	Source of Variation
ss	-	Sum of square
SSP	-	Single Super Phosphate
t	-	Tonnes
T	-	Treatment
TSS	-	Total Soluble Solids
Var.	-	Variety
VC	-	Vermicompost
viz.	-	Videlicet (Namely)

ABSTRACT

The experiment titled "Potentiality of nanofertilizers in integrated nutrient management of chow-chow [*Sechium edule* (Jacq.) Sw.] in Chumukedima district of Nagaland" was carried out during 2022-23 and 2023-24 at the Horticulture Experimental Farm, School of Agricultural Sciences (SAS), Nagaland University, Medziphema. The study was set up in a randomized block design with 22 treatment combinations, incorporating nanofertilizers, inorganic fertilizers, organic manures, and microbial consortium, and was replicated three times. The initial status of the experimental soil was recorded as highly acidic with pH of 4.2-4.5, high content of organic carbon and moderate levels of available NPK.

The experimental results revealed that the combined application of PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) recorded the highest number of leaves per plant (108.97), number of primary branches (4.21), leaf length (20.15 cm), leaf width (22.30 cm), leaf area (189.08 cm²) and vine length (7.01 m). T₂₀ proved to be the best treatment in terms of growth parameters and also showed lower sex ratio (M:F) of 5.87. In terms of yield and yield parameters, T₂₀ recorded the maximum number of fruits per plant (15.65), fruit length (13.29 cm), fruit diameter (8.98 cm) and average fruit weight (482.40 g), leading to the highest yield per ha with 681.40 q ha⁻¹.

About quality attributes of the chow-chow, T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] recorded higher TSS (4.66 °B), crude protein (0.64 %), total chlorophyll (0.289 mg g⁻¹), vitamin c (5.00 mg g⁻¹) and fibre (0.209 %). However, this data was statistically on par with T₂₀. Combined application of PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) proved to be the best treatment in overall uptake of NPK with 41.20 q ha⁻¹, 9.45 q ha⁻¹ and 26.37 q ha⁻¹ respectively. The integrated treatment of FYM @ 10 t ha⁻¹ + ½ of RDF (N through urea) + MC (T₁₁) recorded better retention of nutrients after crop harvest, with available NPK levels of 260.34 kg ha⁻¹, 22.71 kg ha⁻¹, 218.09 kg ha⁻¹ and 1.33% soil organic carbon. Although, the nutrient concentration in T₂₀ was statistically comparable.

The treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] delivered the highest economic return in the study. It achieved the maximum gross return of ₹ 681398.45 (pooled), net return of ₹ 477528.45 (pooled) and C:B ratio of 2.34 (pooled).

Based on the findings of this study, it can be concluded that treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] not only enhanced crop growth and yield but also proved to be the most economically viable option among the tested treatments. Thus, nanofertilizers show great potential as a key component in integrated nutrient management (INM) and can be recommended to farmers in Nagaland.

Keywords: Nanofertilizers, INM, chow-chow, growth, yield and economics.

CHAPTER I

INTRODUCTION

INTRODUCTION

Vegetables are an essential part of our diet, as they are packed with vitamins and minerals along with other health-promoting compounds. It is also an indispensable source of antioxidants and contributes to a human diet (Boeing *et al.*, 2012). They are used and easily accessible and the various types are available year around. Besides their nutritional value, vegetables play a prominent role in culinary traditions, contributing depth, texture, and flavour to dishes across countries. Vegetables, whether raw in salads, steamed, grilled, or incorporated into soups, stews, and stir-fries, serve as the cornerstone of innumerable recipes, demonstrating their variety and adaptability in the kitchen. In addition to their culinary importance, vegetables play a substantial part in enhancing overall health and well-being. It offers many health benefits, making it an essential component of a balanced diet. They are abundant in fibre, vitamins, and antioxidants, which promote digestive health, strengthen the immune system, and could lower the risk of chronic diseases such as heart disease, diabetes, and some malignancies (Walling *et al.*, 2022).

The acreage and output of vegetables in India have expanded significantly in recent years, with an area of 10.07 million hectares and a production of approximately 191.76 million tons (NHB, 2019). India currently ranks second in both area and vegetable output globally, with West Bengal having the biggest area and production in India (NHB, 2019).

India is blessed with diverse climatic conditions, and different types of vegetables are being grown. One such vegetable is chow chow (*Sechium edule*), which is commonly grown in the hills of north-eastern states, Himachal Pradesh, Uttarakhand and Tamil Nadu (Bhat, 2007). Chow-Chow, also known as Chayote, belongs to the *Sechium* genus and species *edule* of the Cucurbitaceae family, with chromosome $2n = 28$. It is an underutilized crop that originated in Central America and Mexico (Whitaker and Davis, 2012). Chow-chow is a semiperennial plant with vines that can grow to be 12–15 meters long. Its blooms are monoecious, with male flowers borne in clusters and females borne (Newstrom, 1991). The colour of the bloom is creamy white and generally both male and female flowers are borne on the same axis. The fruit varied in

shape from rectangular to pyriform, and its colour ranged from green to yellowish to white (Saade, 1996; Vieira *et al.*, 2019).

Chayote is mostly utilized for human consumption. In addition to the fruit, stems, and tender leaves, the tuberous sections of the adventitious roots are also consumed (Sharma *et al.*, 1995). The fruit is low in calories (19 kcal 100 g⁻¹) and soluble carbohydrates (1.6 g 100 g⁻¹), but high in minerals like potassium, calcium, phosphorus, and magnesium, as well as vitamin C (11–20 mg 100 g⁻¹) (Melo *et al.*, 2006). Chayote root contains more starch than fruit. The fruits and seeds contain various amino acids, including aspartic acid, glutamic acid, alanine, arginine, cysteine, phenylalanine, glycine, histidine, isoleucine, leucine, methionine (only found in the fruit), proline, serine, tyrosine, threonine, and valine. (Flores, 1989). Chayote is a versatile fruit used in various applications worldwide, including baby food, liquids, sauces, and pastes. Its soft flesh is ideal for consistency and it is used in handicrafts like baskets and caps. In India and the Americas, the fruit and roots are used for human consumption and cow feed (Chakravarty, 1990). Chayote's medicinal properties have been explored, with recent research showing decoctions from the leaves or fruits can reduce urine retention, dissolve kidney stones and treat arteriosclerosis and hypertension (Yang and Walters, 1992). Pharmacological studies validate the diuretic, cardiovascular, and anti-inflammatory activities of the plant's leaves and seeds, as well as its fruit (Ribeiro *et al.*, 1988).

Chow-Chow is best grown in a sub-temperate climate, but it can also be grown at a moderate temperature in tropical and subtropical environments (Saade, 1996). If the temperature goes above 36°C then there is poor production of female flowers, resulting in a lower yield (Kanaujia *et al.*, 2020). A well-drained loamy soil rich in organic matter is preferred, but it can be grown on a wide range of soils. Chayote thrives in diverse climatic situations, making it a versatile plant. Homeowners typically plant chayote to grow over fences, shrubs, or straight up trees.

According to Saade (1996), the optimum temperature range for fruit production is 13–21 °C. Temperatures below 13 °C can harm the fruit, while temperatures above 28 °C can cause excessive growth, flower drop, and immature fruit. Normally, chayote is sown in February–March in the north Indian plains, but in the hills, it is sown in April–May. It is propagated by viviparous, single-seeded mature fruit or vine cuttings

(Kanaujia *et al.*, 2020). Chayote can be stored for 4–6 weeks under ideal circumstances of 7°C and 85–90% humidity (Sargent and Maynard, 2009).

Ideal crop nutrition is a precondition for crop output; hence, precise fertilization plays an important role in agriculture. Crop output is highly dependent on the application of macronutrients (N, P, K, S, Ca, Mg) and micronutrients (B, Fe, Mn, Cu, Zn, Mo, and Cl) to agricultural lands. They offer the nutrients that plants require for optimal growth and output. Still, existing agricultural practices are unable to satisfy rising food demand without the significant use of fertilizers. As a result, enhanced, advanced, and novel technologies must be introduced to attain global food security. One such advancement is the application of nanotechnology in horticulture production, processing, storage, packaging, and transportation (Ditta, 2015).

Nanoparticles are materials with single units between 1 and 100 nm in size in at least one dimension (Liu and Lal, 2015). Adding to its ultra-small size, the uptake of nutrients is very rapid and efficient, *i.e.*, better nutrient use efficiency, thereby boosting yield and reducing soil pollution (Naderi and Sharaki, 2013). On application of nanoparticles, even at a lower rate, there has been a significant increase in plant growth (Benzon *et al.*, 2015). Nanofertilizer is made up of nano-formulated nutrients that may be delivered to plants, allowing for long-term and uniform absorption (Shang *et al.*, 2019). Research has also demonstrated that nano fertilizers improve plant productivity by increasing nutrient usage, reducing soil toxicity, mitigating the potential negative consequences of excessive chemical fertilizer use, and increasing fertilizer application frequency. Furthermore, using nanofertilizers significantly decreases waste, saves money and safeguards the environment (Merghany *et al.*, 2019). Aher and Umesha (2023) studied baby corn and found that using nanourea in conjunction with zinc enhanced return. Similar findings were recorded in black gram by Islam *et al.*, 2022.

Biofertilizers are strains that contain living microorganisms (such as bacteria, fungi, or algae) that boost nutrient availability and uptake by plants, encouraging plant growth and production. Unlike chemical fertilizers, which give nutrients directly to plants in an inorganic form, biofertilizers act indirectly by permitting nutrient cycling and solubilization in the soil, thereby enriching soil health and boosting nutrient availability (Pathak *et al.*, 2017). One such biofertilizer is the microbial consortium.

Microbial consortiums are two or more strains of bacteria living symbiotically. It contains nitrogen fixing, phosphorous solubilizing and potassium mobilizing bacteria. The use of microbial consortia promotes plant growth and also triggers a defence mechanism during pathogen ingress (Sarma *et al.*, 2015). A study done by Dash *et al.* (2019) unearthed that the application of microbial consortium in radish had a considerable optimistic influence on vegetative growth, viz; plant height (31.74-33.50cm), leaves plant⁻¹ (10.27-10.47), yield and yield attributing parameters, viz; root length (15.24-15.67 cm), root circumference (9.69-10.23 cm) average root weight (152.63–160.26 g) and radish root yield (23.55–24.00 kg plot⁻¹ and 290.72–296.28 q ha⁻¹).

Organic manures, often known as bulky organic solids, are naturally occurring substances obtained from plants or animals. Organic manures, such as farmyard manure, vermicompost, night soil, and enriched compost, are produced through the decomposition of organic matter such as animal excreta, human excreta, crop residues, and vegetable matter. They are bulky, have low analytical value, and have no specific chemical composition. It enhances soil aeration, water retention, structure, and crop yield (Thampan 1993). Using both organic and inorganic plant nutrients improves crop productivity, profitability, and soil fertility over time (Patel *et al.*, 2019).

Farmyard manure (FYM) is a key source of organic matter in our country, providing nourishment and promoting soil health. It provides important plant nutrients that improve physicochemical qualities, boost water holding capacity, and promote soil microbial activity (Kale *et al.*, 1998). Farmyard Manure (FYM) is widely available and can be used for vegetable production. It contains trace or micronutrients (Yawalkar *et al.*, 2002), along with N (0.5%), P (0.2%) and K (0.5%) (Patel *et al.*, 2021).

Vermicompost consists of worm castings, organic matter, humus, live earthworms, cocoons, and other organisms. It lowers the carbon to nitrogen (C:N) ratio, boosts humic acid levels, and supplies plants with chelated macro and micronutrients such as nitrate, exchangeable phosphorus, soluble potassium, calcium, and magnesium (Talashilkar *et al.*, 1999). It modifies the soil's physical, chemical and biochemical properties. Vermicompost also improves fruit preservation quality, which could be exhibited to the large amounts of nutrients accessible and biologically active metabolites such as auxins, cytokinins, gibberellins, and group B vitamins (Meerabai

et al., 2007). Vermicomposting supplies all the nutrients in readily available form and enhances the uptake of nutrients by plants (Rai and Pandey, 2007).

Poultry manure is a type of organic fertilizer obtained from the waste produced by domesticated birds, usually poultry reared for meat (broilers) or egg production (layers). This manure is a valuable source of minerals, organic matter, and beneficial microbes that can help increase soil fertility and plant growth. Poultry manure contains significant amounts of essential plant nutrients, including nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and other micronutrients (Ashworth *et al.*, 2020). The addition of poultry manure to the soil is said to improve both its physical characteristics and chemical composition (Singh *et al.*, 2020).

The increase in the production of vegetables by increasing the area under vegetable cultivation is limited due to the rapid increase in population and the continuous exploitation of agricultural land. Hence, to increase the productivity of vegetables, the application of fertilizer is needed, and cultivation practices should be altered. Generally, vegetables require a high amount of nutrients to get an optimum yield where the available nutrients in the soil are not sufficient. So, the nutrient application through inorganic fertilizers and organic fertilizers is essential. However, the application of chemical fertilizer alone deteriorates and eliminates beneficial microorganisms in the soil (Masanta and Biswas, 2009). Therefore, a safe approach has been developed where the integration of inorganic fertilizer, organic manures and biofertilizer is used in combination to maintain the soil fertility, yield, soil sustainability and ecological balance of the soil. And this principle is called integrated nutrient management (INM) (Abrol and Katyal, 1990).

In INM, all possible sources of nutrients are applied based on economic considerations and the balance requirements of the crop. It helps to maintain soil health, improve the utilization of nutrients and also decrease the overall cost of production. In addition to maintaining crop productivity and soil health, the prudent use of organic manures in conjunction with chemical fertilizers may be useful in meeting the crops' need for nutrients (Pandey *et al.*, 2009).

Several studies on nano fertilizers have found signs of dependability and profitability in field trials. However, combining nano fertilizers with other nutrition sources may be more effective than using nano fertilizers alone. So, this study seeks

to explore the effectiveness of nano-urea along with other commercially used fertilizers in combination with organic manure and bio-fertilizers in a conventional field environment using the principles of INM.

Therefore, using the above principle and considering all these aspects, a field experiment was carried out for the farmers of Nagaland using different nutrient management in chow-chow under the topic ‘Potentiality of nano fertilizers in integrated nutrient management of chow-chow [*Sechium edule* (Jacq.) Sw.] in Chumukedima district of Nagaland’ with the following objectives:

1. To study the effect of nanofertilizers based integrated nutrient management on growth, yield and quality of chow-chow.
2. To study the effect of nanofertilizers based integrated nutrient management on nutrient uptake.
3. To assess the treatment effect on the fertility status of the soil.
4. To study the economics of chow-chow cultivation for different treatments.

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

This chapter presents a literature review and information on the effect of nanofertilizer-based nutrient management on various aspects of the present investigation. These aspects include the growth, yield, yield attributes, quality of chow chow, nutrient uptake, fertility status of the soil after harvest, and economics of chow chow cultivation. Additionally, related studies on cucurbits and other vegetables are also included under the following sub-headings:

2.1 Review of literature related to the effect of nanofertilizers based INM on growth parameters

Patil *et al.* (1996) reported the effect of N, P and K doses on the growth and yield of bottle gourd and revealed that the number of fruits per vine, yield of fruits per vine and yield per ha were significantly higher under potassium level 50 kg ha⁻¹ over rest of potassium levels.

Rekha and Gopalakrishnan (2001) reported that the sole application of organic manure (FYM) recorded minimum vine length (5.80 m) and number of branches per plant (12) as compared to the vines fertilized with an additional dose of inorganic fertilizers @ 70:25:50 kg NPK ha⁻¹ which improved the growth parameters and recorded maximum vine length (7.10 m) and number of branches in bitter gourd.

Shinde *et al.* (2003) recorded highest internode length (14.57 cm), number of branches per vine (4.09), number of leaves per vine (36.55) and highest fruit yield per ha (117.33q ha⁻¹) in case of ridge gourd cv. DPL-RG-17 due to application of 100:50:50 kg N:P:K ha⁻¹.

Prasanna *et al.* (2004) experimented on ridge gourd. Treatment consisted of three levels of nitrogen 0, 50 and 100 kg N ha⁻¹. The study revealed that vine length, number of leaves per vine and numbers of branches per vine were significantly superior over 100 kg N ha⁻¹ over rest of treatments.

Reddy and Rao (2004) recorded highest vegetative growth like maximum vine length and maximum number of branches per plant in bitter gourd due to the application of high doses of nitrogenous fertilizer.

Yadav *et al.* (2006) reported that the application of 90 kg N ha⁻¹ through urea,

poultry manure, FYM and vermicompost significantly increased maximum plant height, number of branches per plant, number of fruits, fruit length, girth of fruit and total yield of okra as compared to control.

Olaniyi and Fagbayide (2008) conducted a field trial on watermelon with four levels of nitrogen 0, 40, 60, and 80 kg ha⁻¹ and phosphorus 0, 8.8, 13.2 and 17.6 kg ha⁻¹. The results revealed that primary vine length and number of leaves per vine recorded significantly superior under 80 kg ha⁻¹ N over rest of treatments.

Shetty and Manohar (2008) carried out an experimental trial to study the influence of integrated nutrient management on the growth of coloured capsicum cv. Orobelle under naturally ventilated greenhouse. Further their result concluded that the integration of 25% of nitrogen through pongamia cake + 75% of RDF + 25 t ha⁻¹ of FYM 10 + *Azotobacter* @ 5 g plant⁻¹ was beneficial for improving the growth parameters in capsicum. An increased plant height (64.72, 127.34 and 225.93 cm) and number of branches per plant (12.47, 18.21 and 20.57) were observed when data was recorded on 60, 90 and 120 days after transplanting, respectively.

Sureshkumar and Karuppaiah (2008) reported the beneficial effect of different combination of inorganic, organic and biofertilizers in bitter gourd (*Momordica charantia* L.) under rice fallow condition. It was observed that treatment combination of 75% of NPK+ vermicompost at 5t ha⁻¹ + *Azospirillum* at 2kg ha⁻¹ gave maximum number of female flowers.

Eifediyi and Remisson (2010) conducted a field trial on the growth and yield of cucumber as influenced by farmyard manure and inorganic fertilizers with three levels of FYM (0, 5 and 10 t ha⁻¹) and five levels of fertilizer NPK 20: 20: 10 (0, 100, 200, 300 and 400 kg ha⁻¹) and observed that the application 200 kg ha⁻¹ fertilizer recorded significantly superior length of vine over rest of treatments.

Anjanappa *et al.* (2012) studied the growth attributes of cucumber cultivar Hassan Local as influenced by INM grown under protected condition for two consecutive seasons of summer 2005 and rabi 2006. The results concluded that the application of 75% RDF + 75% FYM + *Azotobacter* + PSB + *Trichoderma* was significantly superior for growth parameters like maximum vine length (250.33 cm, 255.16 cm), number of leaves (93.26, 96.50) and number of branches per plant (7.23, 7.78)

Moakala *et al.* (2015) conducted an experiment on response of INM on growth, yield and quality of broccoli (*Brassica oleracea* var. *italica*) cv. Calabrese under the foothill condition of Nagaland and observed that growth characters with respect to plant height (70.33 cm), number of leaves (28.45), stem diameter (3.25 cm) and plant spread (74.25 cm) were recorded maximum with the application of T18 (50% NPK + 50% vermicompost + Bio-fertilizer) which was significantly at par with T16 (50% NPK + 50% Pig manure + Bio-fertilizers).

Naorem and kumar (2015) reported that the application of 90 kg P ha⁻¹ + 80 kg K ha⁻¹ have maximum value of vine length, number of branches per plant, number of leaves per plant, maximum leaf area index, total chlorophyll content and dry matter production in bitter gourd.

Kanaujia and Daniel (2016) further revealed that the integrated combination of inorganic fertilizer with organic manure and biofertilizer is beneficial for improving vine growth, yield and quality of cucumber.

Baghel *et al.* (2017) conducted an experiment to find out the suitable combination of nutrient sources under integrated nutrient management of bottle gourd and further reported that plants applied with 100% RDF of NPK + FYM @ 10 t ha⁻¹ + vermicompost @ 5 t ha⁻¹ + poultry manure @ 2.5 t ha⁻¹ had a beneficial effect on bottle gourd in terms of growth parameters like maximum vine length (282.47 cm), internodal length (12.60 cm) and minimum number of days taken for first female flower initiation (49.87).

Gebremichael *et al.* (2017) studied the effect of integrated nutrient management on growth and bulb yield in Northern Ethiopia. According to the investigation, integrated nutrient management was found to be beneficial in bulbous crop like onion. Integration of organic manure along with inorganic fertilizers enhanced and improved growth attributing parameters and reported that the combined application of vermicompost @ 5 t ha⁻¹ + 50% inorganic N fertilizers recorded the highest plant height (71.67 cm), leaf number (16.15) and leaf length (45.19 cm) in onion.

Kumar *et al.* (2017) evaluated sixteen different parthenocarpic cultivar for protected condition to identify horticulturally superior, economically potential and nutritionally rich cultivar(s) of cucumber, namely Kafka, Dinamik, Fantasy, RS 03602833, Kian, KUK 6, Oscar, Valleystar, KUK 9, 52-23, Multistar, Y-225, JSCU

01, CBA 910569500, Ronino and Pruva. Variation in result was observed among various cultivars for different parameters like RS 03602833 was the earliest in first flowering (28.33 days) as well as picking (37.67 days). Maximum vine length (133.33 cm) and highest number of branches per plant (13.00) were recorded from the integrated combination of 50% NPK + 5 t vermicompost + biofertilizers.

Sheth *et al.* (2017) carried out an investigation to study the influence of integrated nutrient management on growth, yield and quality of sweet potato. Growth parameters like vine length and number of leaves per vine were significantly influenced by application of organic manure in combination with inorganic fertilizer under integrated nutrient management system. Sweet potato vines treated with 50% of recommended dose of nitrogen through inorganic fertilizer in combination with 50% of nitrogen through organic manure (vermicompost) along with the recommended dose of phosphorus and potassium recorded maximum vine length of 78.98 cm, 120.17 cm and 175.87 cm after 60 DAT, 90 DAT and at the time of harvest respectively.

Singh *et al.* (2017) conducted an experiment to study the effect of different organic and inorganic fertilizers on yield of cucumber under protected condition and the result revealed that the treatment combination of FYM (25%) + poultry manure (25%) + vermicompost (25%) + NPK (25%) gave significantly the best result among all the other treatments in terms of growth, yield and quality parameters like maximum plant height (370 cm), maximum number of leaves per plant (119.84), maximum number of branches per plant (3.51), maximum length of fruit (15.03 cm), fruit yield per plot (11.87 kg) and fruit yield per ha (824.30 q ha⁻¹).

Arjun and Bairwa (2018) conducted an experiment on the effect of INM and bio-regulators on growth, yield and quality of sprouting broccoli and reported that application of 50% of recommended dose of fertilizers through inorganic fertilizers and 3.5 t ha⁻¹ vermicompost recorded maximum plant number of leaves per plant and leaf area.

Patle *et al.* (2018) worked on integrated nutrient management studies in bottle gourd and reported that application of 50% RDF + 2.5 t ha⁻¹ FYM + 1.65 t ha⁻¹ VC + *Azotobacter* @ 5 kg ha⁻¹ + PSB @ 5 kg ha⁻¹ produced maximum vine length (551.56 cm), length of internode (15.88 cm) and a number of female flowers (17.44).

Rathod *et al.* (2018) conducted an experiment to study the influence of

integrated nutrient management on growth of ridge gourd in coastal region of Maharashtra and reported that the treatment receiving an integration of organic manure, chemical fertilizers and biofertilizers @ 50% N through poultry manure + 50% of RDF + *Azotobacter* was significantly superior and recorded maximum growth parameters like maximum vine length (435.56 cm), length of internode (21.00 cm) and highest number of branches (13.67).

Singh *et al.* (2018) studied on effect of integrated nutrient management on growth, flowering and yield attributes of cucumber and reported that treatment integrated with 75% RDF + 12.5% FYM + 12.5% VC ha⁻¹ had maximum effect on growth parameters like vine length (137.7 cm), number of leaves per plant (97.80), maximum number of primary branches per plant (8.5), maximum length and width of leaf (16.2 cm) and (17.70 cm) respectively.

Tripathi *et al.* (2018) conducted an experiment to study the influence of integrated nutrient management on vegetative growth and flowering of rainy season bottle gourd and reported the minimum number of days to first female flower emergence (66.81 days) and maximum number of female flower (30.06) from the plants treated with poultry manure @ 2.5 t ha⁻¹ + half NPK through chemical fertilizer.

Sankhala *et al.* (2019) conducted an experiment on the effect of organic nutrient management on growth and flowering in musk melon and reported that parameters like vine length at 30 DAS and 60 DAS, number of branches per plant, leaf area at 45 DAS, days taken to flower initiation, number of male and female flowers and sex ratio were recorded maximum with treatment 50% N from FYM + 50% N from poultry manure + biofertilizer (*Azospirillum* + PSB + KSM) + *Trichoderma viride* + neem oil.

Sahu *et al.* (2020) conducted an experiment on the effect of integrated nutrient management on growth and fruit yield of cucumber and recorded maximum growth characteristics like vine length (1313.00 cm) and primary branches per vine (3.00) at treatment integrated with 50% of RDF + FYM @ 10 t ha⁻¹ + VC @ 2 t ha⁻¹ + biofertilizer.

Patel *et al.* (2021) conducted an experiment on integrated nutrient management on growth and yield of ridge gourd and reported that growth parameters like days to first female flower (36.30 days), length vine at 60 DAS (199.50 cm) and final harvest (408.50 cm) were recorded maximum with the combined treatment of 50% RDF +25%

RDN from bio-compost + *Azotobacter* 2.5 l ha⁻¹ + PSB 2.5 l ha⁻¹.

2.2 Review of literature related to the effect of nanofertilizers based INM on yield and yield attributes

Jassal *et al.* (1970) studied that the treatment combination of 110 kg N ha⁻¹ with 55 kg P₂O₅ and K₂O significantly increased the weight of the fruit and yield in comparison with other interaction of muskmelon (*Cucumis melo* L.).

Singh and Chhonkar (1986) reported that the application of 100:60:60 kg ha⁻¹ NPK showed higher fruit yield per ha (184.65 q ha⁻¹) was observed by application of 60 kg K₂O ha⁻¹ in muskmelon.

Karuthamani *et al.* (1995) reported that an application of 75% of recommended dose of phosphorus along with phosphobacteria in pumpkin cv. CO-2 resulted in the increased fruit yield (12.11 kg plant⁻¹) as compared to the control (8.68 kg plant⁻¹) with 100% recommended dose of phosphorus without phosphobacteria.

Nirmala and Vadivel (1999) carried out an investigation to study the influence of integrated nutrient management in cucumber and observed significant increase in number of fruits per vine (9), length of the fruit (11 cm), girth of the fruit (9 cm) and fruit yield (1.43 kg vine⁻¹) with an integration of 30 t of FYM along with 35 kg nitrogen ha⁻¹ as compared to control in cucumber.

Shreeniwas *et al.* (2000) reported that the application of vermicompost @ 10 t ha⁻¹ + 50:25:50 kg NPK ha⁻¹ increased the fruit weight (225 g) and fruit yield per vine (2.03 kg) in ridge gourd cv. Pusa Nasdar and also reported that the fruit yield in ridge gourd increased with the increasing rates of vermicompost.

Singh and Mukherjee (2000) indicated that yield and yield attributes of chilli cv. RCH-1 were highly influenced by the foliar spray of urea. The maximum fruit yield (193.06 q ha⁻¹) was obtained with the treatment of 1.5% spray.

Rekha and Gopalakrishnan (2001) studied bittergourd under integrated nutrient management approach, it was found that the application of FYM @ 25 t ha⁻¹ in combination with inorganic fertilizers like NPK @ 70:25:25 kg ha⁻¹ recorded maximum fruit length (26.7 cm) and fruit thickness (17.5 cm).

Adam *et al.* (2002) reported that application of high mineral fertilizer (100:32:72 kg bed⁻¹) combined with biofertilizers at 3 kg produced highest total fruit yield and the most favourable fruit quality characteristics in *Cucumis melo* L.

Reddy and Rao (2004) carried out an investigation in bitter gourd where four levels of vermicompost (0, 10, 20 and 30 t ha⁻¹) and three levels of nitrogen (20, 40 and 80 kg ha⁻¹) were tested. It was observed that an application of vermicompost and nitrogen had superior result in terms of yield attributing characters. Bitter gourd vines fertilized with vermicompost @ 13.8 t ha⁻¹ and nitrogen @ 34.18 kg ha⁻¹ was found to be beneficial for improving yield in bitter gourd.

Tirakannanavar *et al.* (2005) studied that the application of nitrogen at 100 kg ha⁻¹ recorded significantly higher vine length, number of primary branches and number of fruits per vine. Maximum seed yield per hectare was recorded with application of 100 kg N (822.54 kg), 75 kg P (770.96 kg) and 50 kg K (793.10 kg) compared to other level of nitrogen, phosphorus and potassium in bitter gourd.

Prabhu *et al.* (2006) conducted an experiment to study the effect of INM in cucumber. The results indicated that the application of 50% recommended dose of fertilizers + vermicompost @ 2 t ha⁻¹ + biofertilizers (2 kg in each of *Azospirillum* and *Phosphobacteria*) increased the vine length, earliness in flowering, yield and yield components. The highest yield of 328 q ha⁻¹ and B:C ratio of 2.24 was also recorded in the same treatment.

Mulani *et al.* (2007) studied the combined application of organic manures and biofertilizers had beneficial effects on bitter gourd production. Among the organic N sources, poultry manure was more effective than FYM and neem cake at different levels and combinations. The application of 25% nitrogen through neem cake and 75% through poultry manure was superior in the enhancement of the growth, yield and quality parameters of bitter gourd: average vine length (5.38 cm), fruit weight (84.80 g), fruit length (26.94 cm), fruit girth (3.48 cm), pulp thickness (1.03 cm), number of fruits per vine (63.11), fruit yield (263.33 kg ha⁻¹) and shelf life (7.33 days).

Sareedha *et al.* (2007) reported that the combined application of FYM @ 25 t ha⁻¹ along with recommended dose of inorganic fertilizers (120:90:50 NPK kg ha⁻¹) and foliar application of vermiwash (1:5 dilution) was observed higher number of fruits per vine (88.35) and fruit yield per vine (408.17 g). while fruit length (5.76 cm), fruit

girth (4.99 cm) and single fruit weight (5.56 g) were observed in recommended dose of inorganic fertilizers (120:90:50 NPK kg ha⁻¹) compared to other treatments in gherkin (*Cucumis sativus*).

Bairwa *et al.* (2009) reported that okra plant fertilized with neem cake @ 6 q ha⁻¹ + vermicompost @ 10 q ha⁻¹ + *Azotobacter* + PSB + 60% recommended dose of NPK through inorganic source recorded highest number of fruits per plant (18.36), fruit weight (17.65 g), length of fruits (12.26 cm) and maximum fruit yield (135.18 q ha⁻¹).

Jilani *et al.* (2009) reported superior yield attributing parameters due to the application of biofertilizers and recorded enhanced fruit length, fruit weight and fruit yield in cucumbers.

Eifediyi and Remison (2010) evaluated the effects of farm yard manure and inorganic fertilizers in Ekpoma, Nigeria. It was found that the fruit length, fruit girth, fruit weight per plant and yield per ha in cucumber were significantly influenced by the application of farm yard manure and inorganic fertilizer. The highest weight of 2.43 kg per plant and highest yield per ha of 432.59 q ha⁻¹ were obtained from 10 t ha⁻¹ of farm yard manure combined with fertilizers, which were 166.42% higher than the control.

Kameswari *et al.* (2010) recorded the maximum fruit weight and fruit yield in ridge gourd when the vines were fertilized with vermicompost.

Narayanamma *et al.* (2010) studied the influence of combined application of different organic manures with inorganic fertilizers and biofertilizers in comparison with recommended dose of fertilizer (RDF) @ 100:50:50 kg ha⁻¹ of NPK on the cucumber production and quality. It was reported that the integration of FYM @ 10 t ha⁻¹ or VC @ 2 t ha⁻¹ + biofertilizers + ½ recommended dose of fertilizer (RDF) gave significantly higher yield of 111 q ha⁻¹ and 106 q ha⁻¹, respectively as compared to the application of RDF (84 q ha⁻¹).

Kameswari and Narayanamma (2011) observed significant differences in yields of ridge gourd with the application of organic manures in combination with inorganic fertilizers. 50% of poultry manure with 50% of recommended dose of nitrogenous fertilizers significantly increased the yields of ridge gourd with 33.8% increase over control (100% RDF).

Sarhan *et al.* (2011) recorded significant increase in fruit yield of summer squash plants treated with biofertilizer *i.e Azotobacter* when compared with those plants not treated with *Azotobacter*.

Anjanappa *et al.* (2012) studied yield parameters in cucumbers like number of fruits per vine (9.60, 11.66), fruit yield per vine (2.42 kg, 2.45 kg) and fruit yield per ha (627.6 q ha⁻¹, 636.8 q ha⁻¹) in cucumber was found to be highest in the treatment combination of 75% RDF + 75% FYM + *Azotobacter* + PSB + *Trichoderma*.

Saravaiya *et al.* (2012) reported the highest fruit yield in pointed gourd (183.7 q ha⁻¹) when vines were fertilized with 50% RDF of NPK along with FYM @ 20 t ha⁻¹ under an integrated nutrient management system whereas the minimum yield of 140.2 q ha⁻¹ was recorded from the sole application of bulky organic manure.

Sharma *et al.* (2012) conducted an experiment and their investigation revealed that the integrated source of nutrient management is highly effective and superior as compared to the application of chemical fertilizers alone and reported the highest yield of 213.85 q ha⁻¹ in cucumber variety Summer Green.

Abdel and Seham (2013) studied watermelon and concluded that treatment application of potassium 150 kg ha⁻¹ and irrigation interval at 7 days showed maximum fruit weight of 6.94 kg in the year 2010 and 6.60 kg in the year 2011 and application of potassium 225 kg ha⁻¹ and irrigation interval at 14 days showed maximum yield (31.77 t ha⁻¹).

Arshad *et al.* (2014) reported early flowering and fruiting, early harvesting with maximum number of fruits per vine, highest fruit weight and highest fruit yield in cucumber with an application of NPK as fertigation.

Arun and Kumar (2014) conducted an experiment in cucumbers under protected conditions. Superior yield attributing characters like maximum fruit length (16.8 and 18.2 cm), fruit diameter (4.6 and 5.3 cm) and number of fruits (39.1 and 37.2) were recorded from the vines treated with 125% RDF through water soluble fertigation + foliar application of micronutrient during both the seasons.

Khadija (2014) reported that the treatment of plants with recommended dose of NPK @ 90:60:60 kg ha⁻¹ + mustard oil cake @ 1.75 t ha⁻¹ not only gave the highest yield of 281.5 q ha⁻¹ in bitter melon but also improved the soil nutrient status and increased the nutritional value of soil.

Kadu (2015) studied the effect of soil application of potassium and foliar spray of zinc and boron on the yield and quality of watermelon in lateritic soil of Konkan and found maximum fruit girth (43.19 cm) and total sugar content (8.93%) of watermelon fruit in 75 kg K ha⁻¹.

Saeed *et al.* (2015) reported an increase in the efficacy of chemical fertilizers when they were applied in combination with biological components. The results revealed that the yield attributing characters in cucumber was increased by the application of chemical fertilizers along with biofertilizers.

Thriveni *et al.* (2015) reported that the application of 100% N: P: K integrated with vermicompost and biofertilizers (*Azotobacter* + *Azospirillum* + PSB) increased maximum vine length (534 cm), number of branches per vine (18.0), minimum days taken to appearance first male (39.6 days) and female flower anthesis (44 days), maximum number of fruits per plant (40), fruit weight (86.4 g) and fruit yield (403 q ha⁻¹) in bitter melon.

Ghosh *et al.* (2016) carried out an investigation to study the influence of organic and inorganic sources of nutrients on growth and yield of watermelon in red lateritic soil of Purulia, West Bengal. According to their investigation, it was observed that an integration of organic manure with inorganic fertilizers was beneficial for improving the productivity of watermelon. Their result revealed that the vines fertilized with 75% of vermicompost + 25% of the recommended dose of NPK gave highest yield per plant (51.32 kg) and highest yield per ha (231.4 q ha⁻¹) while the inferior response was observed in case of control.

Mohan *et al.* (2016) carried out an investigation in order to study the effect of INM on cucumber cv. Swarna Ageti under polyhouse conditions conducted during the kharif season of 2015. From the result, it was concluded that the most effective among all the combinations of organic, inorganic and biofertilizer sources of nutrients for a minimum number of days to 50% flowering (44.33), maximum fruit length (15.11 cm), maximum fruit weight (176.22 g), highest number of edible fruits per vine (9) and maximum fruit yield per ha (587.4 q ha⁻¹) was recorded from treatment combination of 60% each of RDF + 60% vermicompost + *Azotobacter* + *Trichoderma* + PSB.

Nayak *et al.* (2016) reported an enhanced fruit yield in the pointed gourd variety Swarna Alaukik (297.8 q ha⁻¹) through integrated application of inorganic fertilizer along with organic manure and biofertilizer.

Prasad *et al.* (2016) recorded an increase in fruit yield and number of branches with an application of NPK fertilizers in combination with cow manure in bottle gourd.

Sureshkumar *et al.* (2016) studied the effect of organic and inorganic manures on flowering and yield attributing characters in bitter gourd. It was observed that vines fertilized with 75% RDF of NPK @ 45:22.5:22.5 kg ha⁻¹ + vermicompost @ 2.5 t ha⁻¹ + biofertilizers (*Azospirillum* and *Phosphobacteria*) each of 2 kg ha⁻¹ + panchgavya @ 3% foliar spray recorded superior yield attributing characters in bitter gourd and gave maximum number of fruits per plant (42.32), maximum fruit length (4.13 cm), maximum fruit diameter (2.98 cm), maximum fruit weight (33.46 g) and maximum fruit yield per plant (1.38 kg).

Baghel *et al.* (2017) reported that an integrated nutrient combination comprising of 100% RDF of NPK + FYM @ 10 t ha⁻¹ + vermicompost @ 5 t ha⁻¹ + poultry manure @ 2.5 t ha⁻¹ in bottle gourd gave the maximum fruit length (22.71 cm), fruit girth (8.68 cm), minimum pedicle length (7.58 cm), maximum fruit weight (568.43 g), fruit weight per lot (34.75 kg) and fruit yield per ha (463.31 q).

Kumar *et al.* (2017) studied the effect of cow urine and biofertilizers based fertigation schedule at varying levels of drip irrigation on growth, yield and quality parameters and economics of cucumber under protected condition and reported that combined application of biofertilizers and fertilizers through fertigation had positive effect on growth, yield and quality parameters due to addition of nutrients and saving of at least 50% of water. The yield and B:C (benefit cost) ratio was highest in the plants treated with 100% of recommended dose of NPK where 1/3rd dose of N and full dose of P and K were applied as a basal dose and the remaining 2/3rd dose of N was applied through fertigation along with *Azotobacter*, PSB and 5% cow urine.

Meena *et al.* (2017) recorded that application of 110 kg N + 70 kg P₂O₅ ha⁻¹ recorded significantly higher length of main vine and per cent fruit set, fruit length (42.85 cm), girth (24.32 cm), fresh weight (1077.27 g) and number of fruits per plant (13.44) in bottle gourd.

Thriveni *et al.* (2017) studied the influence of INM on yield, secondary nutrient content and uptake of bitter gourd and reported that the treatment receiving 100% NPK + vermicompost + biofertilizers (*Azotobacter*, *Azospirillum* and PSB) @ 1:1:1 ratio gave 15% more fruits per plant and 15% higher fruits per ha yield as compared to that of treatment with 100% inorganic dose.

Dash *et al.* (2018) reported that addition of half FYM to full dose NPK + biofertilizer recorded more yield (94.41 q ha⁻¹) than addition of half vermicompost to full dose of NPK + biofertilizer (83.0 q ha⁻¹). This result indicated that vermicompost could not be a substitute of FYM in the case of cucumber.

Geethu *et al.* (2018) carried out an experiment to see the effect of organic manures and inorganic fertilizers on growth and yield of bitter gourd and reported that the treatment combination of 25% of NPK + 2 tonnes of vermicompost + 5 tonnes of poultry manure gave highest yield response with maximum fruit length (13.47 cm), maximum weight of fruits (57.77 g) and maximum fruit yield per plant (2.61 kg).

Ghayal *et al.* (2018) worked on the effect of different organic and inorganic fertilizers on yield, nutrient content and quality of cucumber to find out the most suitable treatment combination for cucumber cultivation in Konkan region. Further, the results revealed that the treatment receiving 50% RDF through inorganic plus 50% RDN (recommended dose of nitrogen) through poultry manure gave the highest yield of 165.12 q ha⁻¹ and was found to be superior to other treatments in terms of growth and yield attributing characters.

Kour *et al.* (2018) reported that the integration of inorganic fertilizer @ 75% of the recommended dose of fertilizers along with vermicompost gave superior results in sweet corn (*Zea mays* L. *saccharata*). Enhanced yield attributing characters like maximum cob length (18.66 cm), maximum cob diameter (14.35 cm) and highest number of green cobs per plant (1.46) was recorded from the same treatment.

Mahale *et al.* (2018) carried out an investigation to study the effect of integrated nutrient management in snake gourd. In the experimental trial, the influence of various organic manures like vermicompost and poultry manure either alone or in combinations with inorganic fertilizers on fruit yield were studied. The results revealed that the snake gourd vines fertilized with 50% N through poultry manure + 50% N through inorganic

fertilizers significantly increased fruit yield and the highest yield of 198.2 q ha⁻¹ was recorded from the same treatment.

Patle *et al.* (2018) recorded maximum yield per vine (7.61 kg) and yield per ha (380.61 q) in bottle gourd with the application of integrated source of nutrients combining 50% recommended dose of chemical fertilizer (50:25:25 kg ha⁻¹ of NPK) + 2.5 t ha⁻¹ of FYM + 1.65 t ha⁻¹ of vermicompost and *Azotobacter*, PSB each of 5 kg ha⁻¹.

Singh *et al.* (2018) worked on integrated nutrient management in cucumber and reported that maximum yield and yield attributing characters like minimum days taken to fruit formation (53.40), maximum number of fruits per plant (8.35), fruit length (20.2 cm), width of fruit (4.38 cm), weight of fruit (161.5 g) and fruit yield per plot (8.04 kg) were found in treatment 75% RDF + 12.5% FYM + 12.5% VC ha⁻¹.

Singh *et al.* (2020) conducted an experiment on the response of integrated nutrient management on cucumber hybrid under polyhouse conditions and reported that the treatment of RDF of NPK + VC @ 5 t ha⁻¹ + *Azotobacter* @ 5 kg ha⁻¹ had maximum number of fruits per plant (21.93), yield per plant (3.30 kg) and yield per plot (151.88 kg).

Patel *et al.* (2021) studied on integrated nutrient management on growth and yield of ridge gourd and reported that yield parameters like length of fruit at 2nd harvest (37.05 cm), girth of fruit at 2nd harvest (13.73 cm), average fruit weight (227.43 g) and total fruit yield (12.30 t ha⁻¹) were reported maximum at treatment T₇ (50% RDF + 25 % RDN from bio-compost + *Azotobacter* 2.5 l ha⁻¹ + PSB 2.5 l ha⁻¹).

2.3 Review of literature related to the effect of nanofertilizers based INM on quality parameters

Rao and Srinivas (1990) studied 100 kg ha⁻¹ nitrogen significantly increased fruit yield per plot and fruit yield, TSS, leaf and petiole N and reduced petiole and K, significant positive correlations between fruit yield, TSS, leaf N, leaf Ca, leaf Mg and petiole Mg were observed. However, the correlations were significantly negative between petiole and K with fruit yield and TSS in muskmelon.

Kanwar *et al.* (1994) studied the application of N and P had positive correlation with quality attributes, *i.e.* total soluble solids, ascorbic acid and mineral matter, during

both years. N and P @ 100 and 75 kg ha⁻¹ gave maximum fruit yield of 10.2 and 9.9 t ha⁻¹ respectively and fruit yield (kg) per plant in round gourd.

Arora *et al.* (1995) studied combinations of N @ 60 kg ha⁻¹ + seeds sown on both sides of beds + ethephon 100 ppm increased ascorbic acid and TSS contents of fruits. N @ 30 kg ha⁻¹ + seeds sown on one side of beds produced maximum acid content, while N @ 90 kg ha⁻¹ + seeds sown on one side of beds + ethephon 100 ppm resulted in maximum dry matter content of fruits. Hence, N improved the fruit quality considerably of ridge gourd cv. HRG-14.

Sharma *et al.* (1997) studied that during the first fortnight of May (May 5) with application of 125 kg N ha⁻¹ in three split doses, as this combination gave the best performance for primary branches per plant, male flower nodes per plant, plant length, yield per ha, fruit diameter, dry matter (%) and TSS of cucumber fruits.

Anuja and Archana (2011) studied in bitter gourd var. Long Green Fruit and reported that highest TSS content and increased ascorbic acid were observed with foliar spray of panchgavya @ 3% along with the application of organic manures like FYM @ 25 t ha⁻¹ and vermicompost @ 5 t ha⁻¹.

Anjanappa *et al.* (2012) recorded that application of 75% RDF+75% FYM + *Azotobacter* + *Phosphobacteria* + *Trichoderma* (T2) was significantly superior for quality parameters like ascorbic acid content (6.5; 5.91 mg 100 g⁻¹), moisture content (95.50; 96.06%) and shelf life (7.18; 7.86 days) of cucumber during summer and rabi season respectively.

Yeptho *et al.* (2012) observed the highest TSS (6.67 °Brix) and vitamin C content (79.70 mg 100g⁻¹) in tomato plants fertilized with the integrated nutrient source of 50% NPK + 50% poultry manure + biofertilizer

Krishnan (2014) carried out an investigation to study the influence of organic nutrient management in cucumber and their effect on the shelf life of harvested cucumber. The result revealed that an integration of two different organic manure *i.e.* poultry manure + fish amino acid recorded maximum shelf life of 8.47 days while the inferior response was observed in the case of treatment applied with NPK alone, in which the fruits were stored only up to 4.27 days

Das *et al.* (2015) conducted an experiment with the aim of yield maximization and quality improvement in bottle gourd cv. Pusa Naveen and reported that the

combined application of 75% of Nitrogen from an inorganic source along with 25% of nitrogen from organic source and biofertilizer *i.e.* PSB improved the quality parameters like total soluble solids (TSS) and ascorbic acid in bottle gourd fruit.

Sarma *et al.* (2015) reported an enhancement in the quality parameter of carrot root grown under integrated nutrient management system. Enhanced root quality in terms of TSS (12.30 °Brix), total sugar (6.60%) and highest reducing sugar (4%) was observed in the treatment combination of *Azotobacter* + FYM + rock phosphate + PSB.

Thriveni *et al.* (2015) found that the application of 100% N:P:K integrated with vermicompost and biofertilizers (*Azotobacter* + *Azospirillum* + PSB) increased maximum ascorbic acid (111.1 mg 100g⁻¹) and protein content (1.76%) in bitter melon.

Kanaujia and Daniel (2016) reported maximum vitamin C content and TSS content due to the application of 50% NPK + 5 tonnes of vermicompost and biofertilizers in cucumber.

Nayak *et al.* (2016) reported that an application of biofertilizers along with N, P and K resulted in higher metabolic activities which helped in production of higher number of acids and further contributed to total soluble solid content in the fruits of pointed melon. Also, vermicompost as an organic source helped in better assimilation of carbohydrates due to the slow but continuous supply of all major micronutrients in fruits.

Omoba and Onyekwere (2016) recorded constant degradation in the green colour pigment in cucumber peels due to the rapid eroding of chlorophyll pigment resulting in yellowing of the stored fruit sample. Their experimental finding also revealed an increase and a later decrease of the soluble solids in the chitosan and lemon grass extract treated cucumber fruits as well as the untreated samples during the storage period. The increase was significant from day 0 to day 7 while the decrease was significant on day 14 for both treated and the control cucumber fruits.

Singh (2016) carried out an experiment to study the effect of INM on growth, yield and quality of cucumber *cv.* Swarna Ageti under the polyhouse condition. The results revealed that the treatment combination of 25% FYM + 25% vermicompost + 50% RDF was significantly superior for the growth and yield parameters like minimum number of days to first flower initiation (37.33), maximum fruit length (15.50 cm), maximum fruit diameter (4.40 cm), maximum number of fruits per vine (8.63),

maximum yield per ha (562.7 q ha⁻¹) and quality parameters like TSS (2.10 °Brix) while the inferior response was recorded in control.

Chopra *et al.* (2017) studied the influence of integrated nutrient management on the quality attributing characters in tomatoes and reported the highest total carbohydrates (4.05 g 100g⁻¹) and total sugar (2.78 g 100g⁻¹) when the plants were fertilized with 50% RDF + agro residue vermicompost @ 5 t ha⁻¹. Combined application of inorganic fertilizers with vermicompost resulted in enhancement of quality attributes in tomato.

Sachan *et al.* (2017) reported that the integrated nutrient management practice where the plants were applied with NPK @ 75% + FYM @ 2.5 t ha⁻¹ + poultry manure @ 2.5 t ha⁻¹ + vermicompost @ 2.5 t ha⁻¹ was found to be superior and recorded highest TSS of 2.44 °Brix in okra.

Singh *et al.* (2017) studied on cucumber and reported that fruit pulp with lowest acidity (0.90%), highest vitamin C content (8.39 mg 100g⁻¹) and highest TSS in cucumber (4.10 °Brix) was obtained from the treatment combination of FYM (25%) + poultry manure (25%) + vermicompost (25%) + NPK (25%) under protected condition

Rathod *et al.* (2018) conducted an experiment to study the influence of integrated nutrient management on the quality of ridge gourd and reported highest TSS (7.10 °Brix), reducing sugar (7.28%) and total sugar (10.17%) in the treatment receiving an integration of organic manure, chemical fertilizers and biofertilizers.

Singh *et al.* (2018) studied on cucumber and concluded that the highest total soluble solids of edible fruit (4.11 °Brix) were reported from the plants applied with the treatment combination of 75% RDF + 12.5% FYM + 12.5% vermicompost ha⁻¹.

Dudhat and Patel (2020) conducted an experiment on evaluation of integrated nutrient management on the performance of quality and yield attributes of hybrid bitter gourd and reported that maximum TSS (3.19 °B), protein content (1.75%), ascorbic acid (81.35 mg 100g⁻¹) and shelf life (5.71 days) were recorded at 100% RDF + FYM @ 5 t ha⁻¹ + biofertilizers (*Azotobacter* and PSB) @ 4 kg ha⁻¹.

Joshiya *et al.* (2020) studied on effect of organic nutrient management on yield and quality of cucumber (*Cucumis sativus* L.) and reported that maximum TSS (3.93°B) was at treatment that was integrated with 50% N through neem cake + 50%

from poultry manure + biofertilizer (*Azospirillum* + PSB + KSM) + *Trichoderma viride* + Neem oil.

Vennela *et al.* (2021) worked on the effect of NPK and organic manures on plant growth, fruit yield and fruit quality of snake gourd and reported that on combination of 25% NPK + 75% VC, maximum TSS (3.11°B) and ascorbic acid (5.14 mg 100⁻¹ gm) were recorded.

2.4 Review of literature related to the effect of nanofertilizers based INM on nutrient uptake

Hariprakasa Rao and Srinivas (1990) from their field experiment on effect of different levels of N, P and K on petiole and leaf nutrients, and their relationship to fruit yield and quality in muskmelon and observed that the application of N, P and K @ 100: 50: 50 kg ha⁻¹ recorded maximum Nitrogen (4.395%) phosphorus (0.249%) and K (1.49%) content.

Bindiya (2004) tested organic manures alone and in combination with two kinds of biofertilizers (*Azotobacter* and PSB), inorganic fertilizers and *in situ* green manures in comparison with recommended dose (RD) of fertilizers in cucumber. The available NPK after harvest was significantly increased with the application of organic manures in combination with biofertilizers (*Azotobacter* and PSB) and inorganic fertilizers as compared to application of inorganic fertilizers alone and increased yield by 29% over control.

Jayprakash *et al.* (2004) studied the effect of organics and inorganics on soil properties and available nutrient status of soil under maize crop. Three levels of organic manures *i.e.*, no organics, FYM, VC as main plot treatments and five levels of inorganics *i.e.*, 100, 125, 150, 175 and 200% RDF as sub plot treatments were tested. Application of organics resulted in decline of soil pH from 8.5 to 8.2. The available NPK contents were found highest in the treatments involving VC (267.6, 84.0 and 362.6 kg ha⁻¹, respectively).

Tripathi *et al.* (2005) conducted an experiment on the response of bitter gourd to mycorrhizal diversity for growth, yield and nutrient uptake at Pantnagar with five treatments including control, a dose of 100:60:60 kg ha⁻¹ of N, P₂O₅ and K₂O was supplied in all the treatments. They observed that combined application of three

arbuscular mycorrhizal species (*G. fasciculatum*+ *G. aggregatum*+ *G. mosseae*) proved to be significantly superior as compared to other treatments along with the control with respect to the content of phosphorus, potassium, zinc and copper.

Lokhande (2007) From his field experiment on study the effect of fertilizer nitrogen, manures and bioinoculant on growth, yield and physio-chemical changes in lateritic soils of Konkan and reported that the treatment receiving application of 100% NIF + FYM @ 7.5 t ha⁻¹ recorded the highest uptake of total nitrogen (39.69 kg ha⁻¹), total phosphorus (8.09 kg ha⁻¹) and total potassium (48.25 kg ha⁻¹).

Vimala *et al.* (2007) conducted a field experiment on the effect of organic and inorganic fertilizers on growth, yield and nutrient content in chili and reported that the treatment receiving application of poultry manure recorded the maximum nitrogen (4.81%), phosphorus content (0.36%) and potassium content (5.48%).

Meenakshi *et al.* (2008) studied the nutrient uptake and dry matter production as influenced by fertigation in bitter melon (*Momordica charantia* L.) and reported that the application of 100% macro and micronutrients in water soluble fertilizer form significantly increased the nutrient content and uptake of N, P, K and Fe and proved most superior over rest of the fertigation levels in case of content and uptake of N, P, K and Fe, supplying 100% macronutrient in combination with micronutrient recorded the highest yield.

Shinde (2008) worked on the effect of integrated nutrient management on soil properties, yield and quality of okra grown in kharif season in lateritic soil of Konkan region at Central Experiment Station, Wakawali, and revealed that the treatment consisting RDF + ZnSO₄ (25 kg ha⁻¹) + Borax(5 kg ha⁻¹) + FYM (10 t ha⁻¹) + *Azospirillum* (2 kg ha⁻¹) recorded significantly highest uptake of nitrogen (25.50 kg ha⁻¹), phosphorus (3.09 kg ha⁻¹), potassium (38.67 kg ha⁻¹), calcium (39.32kg ha⁻¹), magnesium (19.66 kg ha⁻¹), zinc (528.13 g ha⁻¹) and boron (52.52 g ha⁻¹). However, application of RDF + ZnSO₄ (25 kg ha⁻¹) + Borax (5 kg ha⁻¹) + FYM (10 t ha⁻¹) observed significant improvement in nutrient uptake of nitrogen (23.40 kg ha⁻¹), phosphorus (2.25 kg ha⁻¹), potassium (31.89 kg ha⁻¹), calcium (37.82kg ha⁻¹), magnesium (18.75 kg ha⁻¹), zinc (524.47 g ha⁻¹) and boron (48.72 g ha⁻¹) content.

Narayanamma *et al.* (2009) observed that the application of poultry manure @ 2.5 t + ½ RDF ha⁻¹ and neem cake @ 1t in bottle melon recorded the highest total

nitrogen (2.1%), total P (0.28 %) and K (2.39%) content.

Sharma *et al.* (2009) studied the effect of organic manures (VC and FYM) and inorganic fertilizers on yield, nutrient buildup in the soil and nutrient uptake in okra - onion sequence. The highest available NPK contents (303, 28.1 and 345 kg ha⁻¹, respectively) were recorded under the treatment comprising 10 t ha⁻¹ VC in okra and 25 t ha⁻¹ VC in onion along with 100% NPK.

Patil (2010) studied the effect of different levels of N and K with and without biofertilizers on yield, quality and Nutrient uptake by Cowpea (*Vigna sinensis* L.) in lateritic soil of Kankan and reported that application of 30:50:30 NPK+ Biofertilizers registered the highest value of total N Uptake (170.82 kg ha⁻¹).

Anjanappa *et al.* (2012) conducted a field experiment to study the dry matter accumulation and uptake of nutrients by cucumber as influenced by organic, inorganic and bio- fertilizers and revealed that the treatment consisting 75% RDF + 75% FYM + *Azotobacter* + *Phosphobacteria* + *Trichoderma* observed significantly highest total nitrogen (19.58 kg ha⁻¹ and 21.47 kg ha⁻¹), maximum total phosphorous (11.36 kg ha⁻¹ and 8.23 kg ha⁻¹) content and maximum total potassium (42.12 kg ha⁻¹ and 50.69 kg ha⁻¹) content during summer 2005 and rabi 2006 respectively.

Heidari *et al.* (2012) studied the effect of the rate and time of nitrogen application on fruit yield and accumulation of nutrient elements in *Momordica charantia* L., in Iran. They suggested that the application of a 150 kg N ha⁻¹ had a beneficial effect on nutrient uptake pattern. Nitrogen application in the time of T3 (1/3 at 3 and 4 leaves, 1/3 before flowering, and 1/3 after fruit start) treatment had more favourable results than other times of application on nutrient uptake in *M. charantia*.

Malshi (2013) conducted field experiment on the chemical and biological properties of soil as influenced by different levels of P and K with and without biofertilizer to cowpea and reported that application of 25:75:50 NPK + BF was found to be beneficial in increasing in uptake of potassium.

Patil (2013) from field experiment on effect of organic manure and inorganic fertilizer on the nutritional quality and yield of finger millet (*Elusine corakana*) and reported that application of 50% N (FYM) + 50% N urea was found to increase total nitrogen, total phosphorous and total potassium uptake.

Feleafel *et al.* (2014) studied the effect of NPK fertigation rate and starter

fertilizer on the growth and yield of cucumber grown in greenhouse and concluded that the application of 125% of recommended dose (220:150:150, N: P₂O₅:K₂O kg ha⁻¹) through fertigation resulted significant increases in nitrogen (2.111%), phosphorus (0.104%) and potassium (1.614%) in cucumber fruit at first trial and nitrogen (2.019%), phosphorus (0.109%) and potassium (1.484%) in second trial.

Torane (2014) observed that the treatment receiving application of tar coated briquettes registered the highest value of P (0.87%) and K (1.74%) content in leaves of cucumber.

Akter *et al.* (2015) studied the effect of prilled urea, urea and NPK briquettes on the yield of bitter gourd and reported that the treatment receiving application of urea briquettes shown highest Total Nitrogen uptake (139.9 kg ha⁻¹) and K uptake (130.1 kg ha⁻¹).

Alekar *et al.* (2015) studied the effect of INM in pumpkin and they revealed that the treatment receiving of 50:25:25 kg NPK + seed treatment with PSB @ 25 g kg⁻¹ seed + FYM @ 25 t ha⁻¹ recorded significantly highest total nitrogen (4.23%), maximum total phosphorus (0.42%) and maximum total potassium (0.39%). They further reported that the treatment consisting 25:25:25 kg NPK + seed treatment with *Azotobacter* and PSB @ 25 g kg⁻¹ seed + FYM @ 25t ha⁻¹ showed significant improvement in total nitrogen (3.40%), total phosphorus (0.38%) and total potassium (0.35%) content.

Dodake *et al.* (2015) carried out a field experiment to study the effect of an integrated nutrient supply system on yield, fruit quality, nutrient uptake by bitter gourd and changes in soil properties of lateritic soils of coastal region at Central Experiment Station, Wakawali, Dr.Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli during 2006 and concluded that the treatment consisting 50% recommended dose of fertilizers + Biofertilizers (PSB + *Azotobacter* @ 250g 10 kg⁻¹ seed) recorded maximum uptake of N (56.53 kg ha⁻¹), P (8.79 kg ha⁻¹), K (77.02 kg ha⁻¹) and Ca (9.32 kg ha⁻¹). They also reported that the application of 50% R.D. + 50% N through Poultry manure observed significant improvement in nutrient uptake of N (52.43 kg ha⁻¹), P(8.02 kg ha⁻¹), K (68.06 kg ha⁻¹) and Ca (7.83 kg ha⁻¹).

Ibrahim *et al.* (2015) conducted a field experiment on the effect of soil amendment on growth, seed yield and NPK content of bottle gourd grown in clayey

soil during two summer seasons of 2012 and 2013 and reported that significantly higher values of total nitrogen 3.82% and 3.86%, phosphorous 0.32% and 0.34% and potassium 3.93% and 3.94% by the treatment receiving 75% NPK + humic acid over the rest of the treatment in two summer season 2012 and 2013.

Kadu (2015) carried out a field experiment to study the effect of soil application of potassium and foliar spray of zinc and boron on the yield and quality of watermelon during Rabi season 2013-14 and concluded that the application of 75 kg $K_2O\ ha^{-1}$ through soil along with 0.5% Zn and 0.1% B through foliar application had significantly higher nitrogen (3.18%), phosphorus (0.18%), potassium (0.28%) content, zinc (40.86 mg kg^{-1}) and maximum boron (40.77 mg kg^{-1}) content in watermelon leaves at harvest.

Thriveni *et al.* (2015) studied the effect of integrated nutrient management on nutrient uptake and recovery of bitter gourd during kharif 2013 and revealed that treatment consisting 100% NPK + Vermicompost + Bio-fertilizers (*Azotobacter*, *Azospirillum* and Phosphate Solubilising Bacteria) recorded maximum dry matter production in fruit and vine (361; 1900 kg ha^{-1}). They observed that the significantly highest nitrogen (3.58, 1.80%), phosphorus (0.75; 0.33%), potassium (3.20; 3.3%) and sulphur (0.47; 0.046%) content in fruit and vine of the bitter gourd. The total uptake and recovery of nitrogen (46.70 kg ha^{-1} , 21.3 %), phosphorus (12.24 kg ha^{-1} , 20.1%), potassium (76.8 kg ha^{-1} , 40.0 %) and sulphur (4.25 kg ha^{-1} , 8.8 per cent) were observed in above mentioned treatment.

Kapse (2016) conducted a field experiment to study the effect of different sources of organic manures and their combination on yield and nutrient uptake by chilli cv. Konkan Kirti on lateritic soils of Konkan at Vegetable Improvement Scheme, Wakawali during Kharif 2015 and reported that the application of 50% N through poultry manure + 50% N through urea recorded significantly highest nutrient uptake of N (36.08 kg ha^{-1}), P (3.40 kg ha^{-1}), K (69.00 kg ha^{-1}), Fe (586.69 g ha^{-1}), Mn (2434.36 g ha^{-1}), Zn (892.60 g ha^{-1}) and Cu (837.81 g ha^{-1}).

Mahale (2017) opined that the total N content in snake gourd leaves ranged from 1.38 to 2.10, 1.09 to 1.47 and 0.77 to 1.07% at 60, 90 DAS and at harvest, respectively. The treatment receiving application of 50 per cent N through poultry manure + 50 per cent N through inorganic fertilizer exhibited higher total nitrogen

content of 2.10, 1.47 and 1.07% at all growth stages viz., 60, 90 DAS and at harvest, respectively. He further reported that the total nitrogen content in snake gourd fruit ranged from 1.16 to 1.86%.

Rathod (2018) reported that the maximum nitrogen content in ridge gourd leaves was seen (2.50%) at 60 DAS, (2.40%) at 90 DAS and (1.53%) at harvest as a result of the application of 50% RDN + 50% N through poultry manure + P and K + *Azotobacter*. Further, this application was significantly superior to all other treatments. While, the highest N content in fruit (2.12%) was recorded in the treatment receiving application of 50% RDN + 50% N through poultry manure + P and K + *Azotobacter* which was significantly superior over rest of the treatment combinations except treatment (T7) receiving application of i.e. 50% RDN + 50% N through vermicompost + P and K + *Azotobacter*.

2.5 Review of literature related to the effect of nanofertilizers based INM on the fertility status of the soil after harvest

Kumar (2003) conducted an experiment to study the effect of integrated nutrient management on the sustainable production of cabbage and tomato at Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan. The nutrient status of the soil, when analysed at the end of the experiment revealed that treatment with farmyard manure @ 10 t ha⁻¹ + 150% of NPK recorded the highest available nitrogen (364.7 kg ha⁻¹, 376.0 kg ha⁻¹), available phosphorus (61.33 kg ha⁻¹, 61.67 kg ha⁻¹) and available potassium (335.5 kg ha⁻¹, 342.3 kg ha⁻¹) during first and the second season of the experiment, respectively.

Bindiya (2004) reported that the nutrient status and the bacterial population in the soil after harvest as influenced by different organic manures, biofertilizers and chemical fertilizer in cucumber was found to be highest in the treatment with vermicompost @ 2 t ha⁻¹ + *Azotobacter* and PSB each @ 5 kg ha⁻¹ + 50% recommended dose of fertilizer of NPK with the available NPK content of 261.5 kg ha⁻¹, 33 kg ha⁻¹ and 245 kg ha⁻¹, respectively along with the highest PSB population (147 CFU g⁻¹ soil × 10⁴) in the same treatment.

Hangarge *et al.* (2004) reported that the application of liquid organic slurry along with vermicompost @ 5 t ha⁻¹ in chilli resulted in higher available nitrogen,

phosphorus and potassium of 353 kg ha⁻¹, 21 kg ha⁻¹ and 284 kg ha⁻¹, respectively than those receiving RDF alone.

Lalitha *et al.* (2010) studied in ridge gourd and recorded those different combinations of recommended dose of fertilizer, vermicompost, FYM and poultry manure recorded the biometrical characteristics like vine length (9.23 m), fruit length (40.23 cm), girth (14.98 cm) and weight (298 g), number of fruits per vine (10.67) and yield (9.14 t ha⁻¹). The quality parameters like ascorbic acid (2.15 mg 100 g⁻¹), total sugars (11.40%) and reducing sugars (5.36%) while, soil parameters like organic carbon (0.54%), pH, EC, available N (298.4), P₂O₅ (53.70) and K₂O (349.9).

Vijaya and Seethalakshmi (2011) carried out an investigation to study the response of brinjal to integrated nutrient management practice and their influence on nutrient status of soil after experimentation. Analysis of soil after experiment revealed that the application of compost prepared from *Parthenium hysterophorous* @ 5 t ha⁻¹ in combination with 50% of recommended dose of fertilizers recorded highest available nitrogen, phosphorus, potassium and soil pH of 218.5 kg ha⁻¹, 15.4 kg ha⁻¹, 98.4 kg ha⁻¹ and 7.1 respectively.

Sevak *et al.* (2012) studied the effect of INM on growth, yield and quality of garlic. Maximum available N, P, K being 261.0, 28.5 and 252.0 kg ha⁻¹, respectively after harvest were found in treatment consisting of 50% N through FYM + 50% N through inorganics.

Krishnan (2014) recorded the highest amount of available nitrogen (534.00 kg ha⁻¹), phosphorus (31.37 kg ha⁻¹), potassium (314.95 kg ha⁻¹), organic carbon (1.44%) and EC (0.013 dS m⁻¹) from the nutrient combination recommended by Kerala Agricultural University which is commonly known as Adhoc POP. Adhoc POP is the nutrient admixture containing FYM @ 12 t ha⁻¹ + vermicompost @ 4 t ha⁻¹ + fresh cow dung slurry @ 1 kg litre⁻¹. In the experiment, cucumber vines were treated with Adhoc POP where vermicompost was applied in two split doses. Half dose of vermicompost was applied at vining stage while the other half dose was applied at flowering stage. Fresh cow dung slurry was applied at pit at every fortnight interval starting from the flowering stage.

Meena *et al.* (2014) studied the effect of various sources (FYM, VC and poultry manure) and rates of organic manure on fertility status of sandy clay-loam soil under

onion. Maximum OC buildup was 0.5% under 150% RDN through poultry manure followed by VC and FYM. The fertility status of soil was improved due to increased available N, P and K in all organic treatments over control. Application of organic manures with increased rate enhanced soil fertility over their lower doses.

Alekar *et al.* (2015) reported that the application of inorganic fertilizers @ 50:25:25 NPK kg ha⁻¹ in combination with FYM @ 25 t ha⁻¹ and seed treatment of pumpkin with PSB @ 25 g kg⁻¹ of seed recorded the highest amount of available nitrogen, phosphorus and potassium (190.23, 27.97, 386.91 kg ha⁻¹ respectively) in the soil after harvest of pumpkin crop. They further concluded that the treatment receiving 50:25:0 kg NPK + seed treatment with *Azotobacter* and PSB @ 25 g kg⁻¹ seed + FYM @ 25 t ha⁻¹ showed significant improvement in available nitrogen (190.21 kg ha⁻¹), available phosphorus (27.94 kg ha⁻¹) and available potassium (364.08 kg ha⁻¹) content in soil.

Dodake *et al.* (2015) conducted a field experiment on the effect of integrated nutrient supply system on nutrient uptake by bitter melon and changes in soil properties in lateritic soils of coastal region of Dapoli and observed that the treatment receiving 50% RDF through inorganic fertilizer + 50% Poultry manure registered the higher pH value (6.14), organic carbon (1.82 %), EC value (0.069 ds m⁻¹), available nitrogen (391.58 kg ha⁻¹), available phosphorus (11.34 kg ha⁻¹) and available potassium (250.88 kg ha⁻¹).

Ghosh *et al.* (2016) conducted an experimental trial to study the response of watermelon under an integrated nutrient management approach. After the experiment, they analysed the soil samples collected from various experimental plots, which were incorporated with combinations of different organic and inorganic fertilizers. Result from the soil analysis revealed that the plot of watermelon fertilized with 50% of farmyard manure + 50% of recommended dose of NPK recorded highest value of pH and organic carbon of 5.72 and 0.48% respectively.

Bhattarai and Sapkota (2016) conducted an experiment to analyse the soil nutrient status after harvest and recorded that the application of vermicompost @ 4 t ha⁻¹ gave highest organic matter content (3.675%) and maximum available nitrogen in the soil (341.54 kg ha⁻¹) while the available phosphorus and potassium were recorded to be maximum (121.47 kg ha⁻¹ and 388.76 kg ha⁻¹, respectively) along with the neutral

pH value (7.0) in the plots applied with the treatment combination of poultry manure @ 5 t ha⁻¹.

Kanaujia and Daniel (2016) conducted an experiment to study the influence of integrated nutrient management on cucumber and recorded the highest amount of available nitrogen (269.33 kg ha⁻¹) from the treatment with 100% of RDF of NPK @ (100:60:60 kg ha⁻¹) while the treatment comprising of an integrated source of 50% NPK + 5 t vermicompost + biofertilizers gave highest amount of available phosphorus (29.4 kg ha⁻¹) and potassium (164.6 kg ha⁻¹).

Mahale (2017) found that the application of poultry manure either alone or in combinations with chemical fertilizers has shown influence on soil pH. He further observed that the treatment receiving integration of 50% N through poultry manure + 50% N through inorganic fertilizer registered higher pH value 6.07 at 60 DAS, 6.12 at 90 DAS, 5.82 after harvest of snake gourd.

Chingak and Swami (2018) studied on soil properties and productivity of cabbage under an integrated nutrient management system in acid inceptisol and reported that application of 50% RDF + 50% N through vermicompost in combination helps in maintaining good soil physical, chemical and biological health after harvest. They concluded that maximum available soil nitrogen (275.97 kg ha⁻¹), phosphorous (28.16 kg ha⁻¹) and potassium (208.89 Kg ha⁻¹) were recorded at treatment (T7) 50% RDF + 50% N through vermicompost.

Ghayal *et al.* (2018) conducted a field experiment at Department of Horticulture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth Dapoli during kharif 2015 and revealed that treatment consisting 50% RDF through inorganic + 50% RDN through poultry manure recorded maximum pH (5.89), EC (0.301) and organic carbon (16.70 kg ha⁻¹) content. He also reported that significantly higher content of available nitrogen (477.70 kg ha⁻¹), available phosphorous (19.27 kg ha⁻¹) and available potassium (582.40 kg ha⁻¹), was recorded in the above-mentioned treatment as compared to all other treatments.

Rathod *et al.* (2018) observed that the treatment receiving integration of 50% RDN + 50% N through poultry manure + P and K + *Azotobacter* registered significant pH (5.88, 5.82 and 5.77) at 60, 90 DAS and harvest of the ridge gourd crop, respectively. He also observed that significantly maximum organic carbon content

18.70, 18.93 and 21.92 g kg⁻¹ at 60, 90 DAS and at harvest, respectively which was significantly superior over the rest of the treatment combinations.

Patle *et al.* (2019) studied on effect of integrated nutrient management on yield, plant and nutrient status in bottle gourd and observed that maximum total leaf nitrogen (3.5%), phosphorous (0.55%) and potash (3.05%) and maximum available soil nutrient status nitrogen (225.68 kg ha⁻¹), phosphorous (25.13 kg ha⁻¹) and potash (381.8 kg ha⁻¹) after harvest was found highest in the treatment 50% RDF + FYM 2.5 t ha⁻¹ + VC @ 1.65 t ha⁻¹ + *Azotobacter*, PSB @ 5 kg ha⁻¹.

Patel *et al.* (2021) worked on nutrient management in underutilized vegetable crop ivy gourd and reported that on application of 50% RDF + biocompost, maximum leaf nutrient content (N-1.753 ppm, P- 0.456 ppm), K- 1.653 ppm) and soil nutrient status (N- 211.7 kg ha⁻¹, P₂O₅- 69.5 kg ha⁻¹, K₂O- 498.96 kg ha⁻¹) were recorded.

2.6 Review of literature related to the nanofertilizer based INM on economics

Kumar *et al.* (2004) studied that the number of male and female flowers, number of fruits per vine and fruit weight, fruit length and fruit girth, fruit yield per vine, fruit yield per hectare and the net income was highest with 100:50:60 kg NPK ha⁻¹ compared to the other NPK combinations. The cost: benefit ratio was highest (1:3.12) with 50:50:60 kg NPK ha⁻¹ in the ridge gourd.

Prabhu *et al.* (2006) reported that on application of 50% RD of fertilizers + VC @ 2 t ha⁻¹ + biofertilizers (2 kg ha⁻¹ each of *Azospirillum* and *Phosphobacteria*) in cucumber var. Green Long increased the vine length, earliness in flowering, yield and yield components The highest yield (32.8 t ha⁻¹) and B:C ratio of 2.2:1 was recorded in this treatment and recommended as best nutrient combination.

Meerabai *et al.* (2007) studied the effect of different organic manures and biofertilizers on the growth, yield and economics of bitter gourd in KAU. They recorded that the basal dose of 25 t ha⁻¹ of FYM and application of poultry manure to supply the recommended doses of 70 kg N ha⁻¹ (on N equivalent basis) in combination with *Azospirillum* @1 kg ha⁻¹ was the best economic organic nutrient schedule in bitter gourd.

Singh and Krishna (2007) studied fruit yield and other yield characteristics (*i.e.* number of fruits per plant and fruit diameter) were higher when the fertilizers were

applied in three splits. The substitution of 25% nitrogen through FYM and 7% of the recommended NPK rate resulted in significantly higher fruit yield during the individual years and on a pooled data basis. This gain was consequently reflected in other characters (*i.e.* higher fruits per plant, fruit length, fruit diameter and fruit weight) on a pooled data basis. The same treatment also recorded higher benefit: cost ratio during the individual years and on pooled data basis of pointed gourd.

Narayanamma *et al.* (2010) evaluated the effect of different organic manure and their combinations with bio-fertilizer and inorganic fertilizers in comparison with RDF on the production and quality of cucumber. The result indicated that application of FYM @ 10 t ha⁻¹ + VC @ 2 t ha⁻¹ + biofertilizer + 50% RDF resulted in significantly higher yield of 111 q ha⁻¹ and 106 q ha⁻¹, respectively compared to the application of RDF @ 84 q ha⁻¹. Application of FYM @ 10 t ha⁻¹ + bio-fertilizer + 50% RDF recorded highest B:C ratio 1:2.1.

Singh and Rani (2012) recorded that application of 2.5 t ha⁻¹ vermicompost with half RDF significantly influenced all the characters in bottle gourd crop, *viz.*, number of primary branches per plant (5.37), nodes at which first fruit appear (3.67) earlier fruiting (69 days), fruit length (24.58 cm) yield (52.25 t ha⁻¹) and maximum gross return (₹ 104,500), net return (₹ 73,700), C:B ratio to the tune of 1:2.39 were recorded as compared to full RDF.

Kanaujia and Daniel (2016) studied the effect of INM on growth, yield, quality and economics of cucumber. The maximum number of fruits per plant (19.0) and fruit yield (41.2 t ha⁻¹) were recorded with the integrated application of 50% NPK + 5 t VC + biofertilizers. The highest B:C ratio of 4.9:1 was recorded with 50% NPK + 7.5 t ha⁻¹ pig manure + biofertilizers.

Mukherjee (2016) studied the effect of various source of nutrient in combination with bio-fertilizers and PSB on growth and yield of pea. Application of 75% RDF + 25% N through VC @ 1.90 t ha⁻¹ and seed inoculation with *Rhizobium* + PSB improved all the growth, yield attributes and yields of field pea. Maximum grain yield (26.7 q ha⁻¹) and highest B:C (2.6:1) ratio were registered with full dose of RDF along with *Rhizobium* and PSB.

Lodhi *et al.* (2017) studied the effect of inorganic and organic fertilizers on yield and economics of broccoli. Different doses of RDN, FYM, Poultry manure, VC

and their combinations were used. The maximum curd diameter (15.4 cm), curd yield per plot (7.4 kg) and curd yield (14.16 t ha⁻¹) were recorded in the plants treated with 50% RDN + 16.6% FYM + 16.6% VC + 16.6% poultry manure. Economic returns of the same treatment were also found best in term of gross income (₹ 3.6 lakhs ha⁻¹), net returns (₹ 2.7 lakhs ha⁻¹) and B:C (3.8:1) ratio.

Negi *et al.* (2017) conducted an experiment to study the effect of organic manures and bio-fertilizers on growth, yield, quality and economics of broccoli. Application of FYM @ 20 t ha⁻¹ + biofertilizer @ 5 kg ha⁻¹ (*Azotobacter* + PSB) recorded the highest value for yield (39.2 t ha⁻¹), gross income (₹ 3.1 lakhs ha⁻¹), net returns (₹ 2.6 lakhs ha⁻¹) and higher B:C (1:4.1) ratio.

Patle *et al.* (2018) worked on integrated nutrient management studies in bottle gourd and reported that maximum B: C ratio (2.94) was observed on the treatment integrated with 50% RDF + 2.5 t ha⁻¹ FYM + 1.65 t ha⁻¹ VC + *Azotobacter* @ 5 kg ha⁻¹ + PSB @ 5kg ha⁻¹.

Shilpa and Sharma (2018) studied the effect of INM system on higher productivity and profitability of sweet pepper. The study concluded that the use of 75% RD of NP + VC and EC (enriched compost) @ 2.5 t ha⁻¹ + PGPR along with full recommended K and FYM as basal application resulted in significantly maximum vegetative growth plant height (60.7 cm), fruit weight (54.9 g) and number of fruits per plant (27.2). The highest pepper fruit yield (36.7 t ha⁻¹) with a B:C (2.7:1) was also recorded under this treatment.

Vennela *et al.* (2021) studied on the effect of NPK and organic manures on plant growth, yield and quality of snake gourd and reported that maximum net return (₹ 6.11.921) and B: C ratio (4.47) was recorded highest on treatment combined with 25% NPK + 75% VC.

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

A study titled "Potentiality of nano fertilizers in integrated nutrient management of chow-chow [*Sechium edule* (Jacq.) Sw.] in Chumukedima district of Nagaland" was conducted at the experimental farm of the School of Agricultural Sciences, Nagaland University, Medziphema campus, Nagaland. The following details and techniques used in the experiment are explained below.

3.1 General information

3.1.1 Location

The experimental farm is situated in the foothills of Nagaland with geographical location of 25°45'43''N latitude and 95°53'04''N longitude at an elevation of 310 meters above sea level.

3.1.2 Climatic and weather conditions during investigation period.

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 21-32°C during the summer, and even in winter, it seldom drops below 8°C due to the presence of high atmospheric humidity. Detailed information on meteorology during the investigation has been presented and illustrated. The maximum temperature was recorded during month of were recorded from Agro Meteorology Observatory, Indian Council of Agricultural Research, ICAR Complex for NEH Region, Nagaland Centre, Jharnapani, Nagaland.

Table 3.1 Meteorological data during the period of investigation

Sl.no.	Month	Temperature (°C)		Relative Humidity (%)		Total Rainfall (mm)
		Max	Min	Max	Min	
1	October (2022)	30.5	21.3	93.9	69.1	94.8
2	November	28.4	14.8	96	58	0.0
3	December	25.7	11.7	96	53	15.4
4	January (2023)	24.4	8.2	95	48	0.0
5	February	27.4	11.7	92	48	0.0
6	March	29.1	14.7	92	53	76.0
7	October	30.6	21.7	93	68	26.4
8	November	28.1	16.1	95	61	29.2
9	December	24.6	12.6	96	62	38.4
10	January (2024)	23.6	9.0	95	65	0.0
11	February	23.9	11.4	94	59	94.6
12	March	29.1	14.4	91	55	31.9

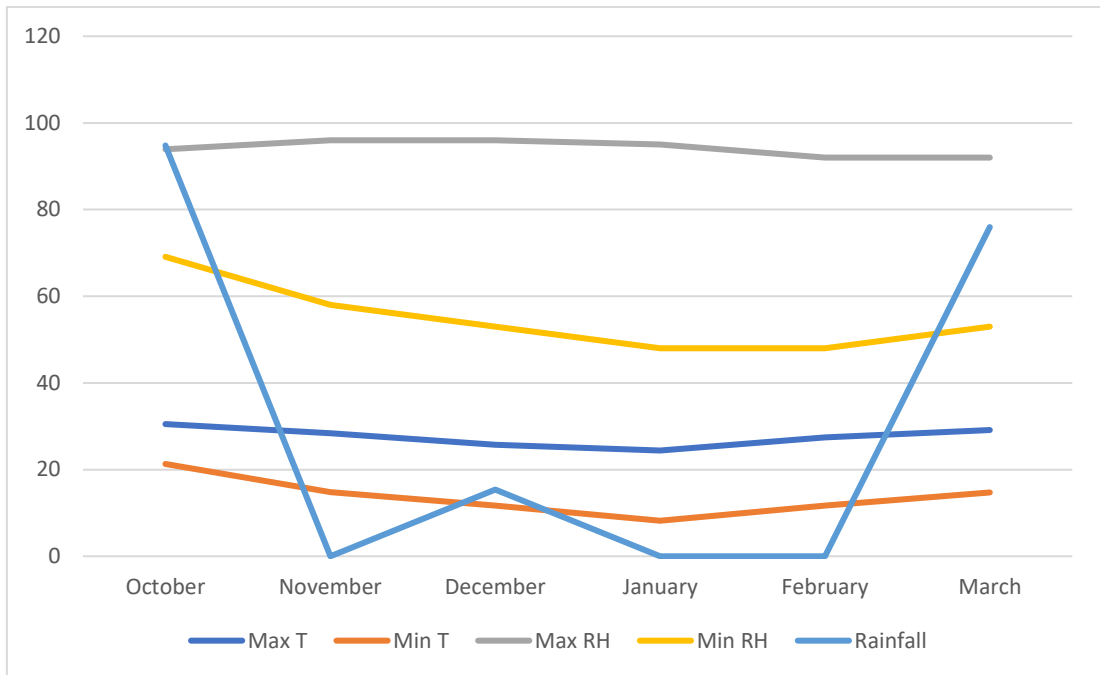


Figure 3.1: Monthly meteorological data during the investigation period 2022-23

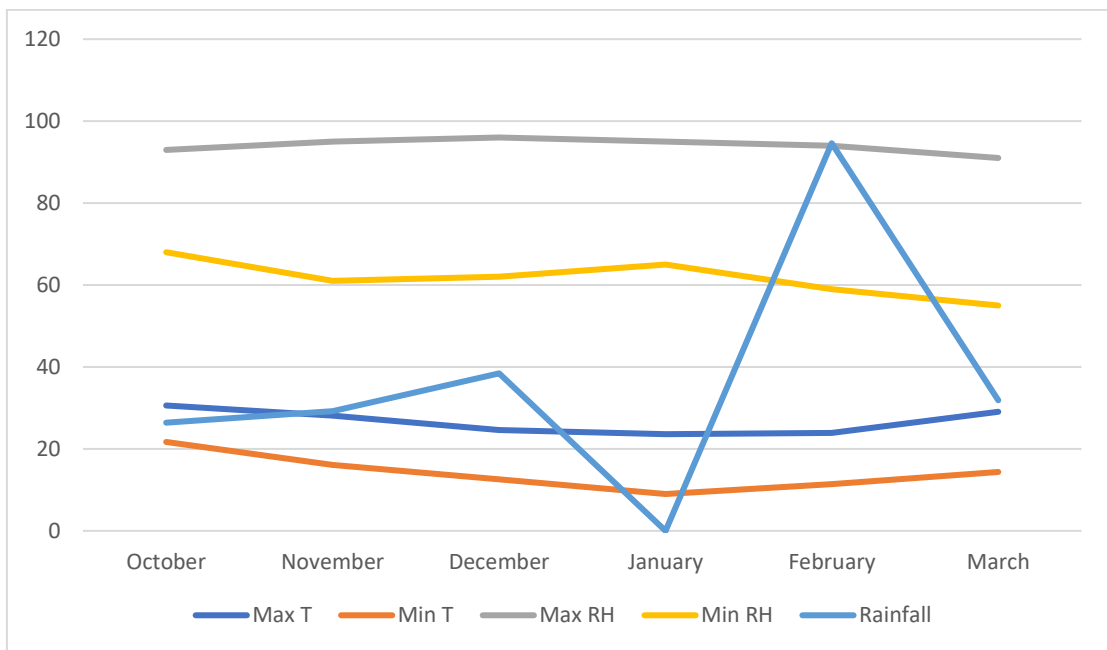


Figure 3.2: Monthly meteorological data during the investigation period 2023-24

3.1.3 Soil condition

The soil texture was observed to be sandy loam soil in which no crop was cultivated in the previous season. Initially, the soil samples were collected from the experimental site at a depth of 15 cm in both the investigation years (2022 and 2023) with the help of auger before the land preparation. The soil samples were dried and sieved. Soil nutrient analysis of N, P, K, OC and pH (Table 2) was done to determine the available nutrients in the soil before sowing of the crop. The soil pH was recorded as acidic with pH fluctuating in the range between 4.2- 4.5, higher organic carbon was reported initially in the soil with low content of available N and K and moderate content of available P.

Table 3.2 Initial soil fertility status of the experimental field

Characteristics	Methods adopted	Content	Content
		2022-23	2023-24
Soil pH	Digital pH meter (Single electrode meter)	4.2	4.5
Organic carbon (%)	Titrimetric determination (Walkley and Black method, 1934)	1.28	1.35
Available Nitrogen (kg ha ⁻¹)	Alkaline potassium permanganate method (Subbiah and Asija, 1956)	172.55	176.72
Available Phosphorous (kg ha ⁻¹)	Bray's I method (Bray and Kurtz, 1945)	13.12	16.02
Available potassium (kg ha ⁻¹)	Neutral normal ammonium acetate method (Hanway and Heidal, 1952)	142.22	155.65

Table 3.3 Nutrient content in organic manure

Manure type	Nitrogen (N %)	Phosphorus (P %)	Potassium (K %)
PM	1.6	0.75	0.5
FYM	0.5	0.2	0.5
VC	0.7	0.1	0.3

3.2 Experimental details

The experimental field was laid out in Randomized Block Design (RBD) consisting of three sources of manure, two types of fertilizers and a microbial consortium which were further divided into twenty-two treatments. A total of 66 plots were made and the different treatments were randomly allocated, and the trial was conducted twice.

3.2.1 Technical programme

Crop	: Chow-Chow
Cultivar	: Local
Design :	Randomised Block Design (RBD)
Number of treatments	: 22
Replications	: 3
Spacing	: 1 m × 1 m
Number of plants per plot	: 18
Plot size	: 6 m × 3 m

3.2.2 Treatments

- T₁ : Full dose of RDF (N through urea)
- T₂ : Full dose of RDF (N through nano urea)
- T₃ : FYM @ 20 t ha⁻¹
- T₄ : Vermicompost @ 5 t ha⁻¹
- T₅ : Poultry manure @ 10 t ha⁻¹
- T₆ : FYM @ 20 t ha⁻¹ + Microbial consortium
- T₇ : Vermicompost @ 5 t ha⁻¹ + Microbial consortium
- T₈ : Poultry manure @ 10 t ha⁻¹ + Microbial consortium
- T₉ : FYM @ 10 t ha⁻¹ + ½ of RDF (N through urea)
- T₁₀ : FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea)
- T₁₁ : FYM @ 10 t ha⁻¹ + ½ of RDF (N through urea) + Microbial consortium
- T₁₂ : FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + Microbial consortium
- T₁₃ : Vermicompost @ 2.5 t ha⁻¹ + ½ of RDF (N through urea)
- T₁₄ : Vermicompost @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea)
- T₁₅ : Vermicompost @ 2.5 t ha⁻¹ + ½ of RDF (N through urea) + Microbial consortium
- T₁₆ : Vermicompost @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + Microbial consortium
- T₁₇ : Poultry manure @ 5 t ha⁻¹ + ½ of RDF (N through urea)
- T₁₈ : Poultry manure @ 5 t ha⁻¹ + ½ of RDF (N through nano urea)
- T₁₉ : Poultry manure @ 5 t ha⁻¹ + ½ of RDF (N through urea) + Microbial consortium
- T₂₀ : Poultry manure @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + Microbial consortium
- T₂₁ : Farmers' practice (FYM @ 5 t ha⁻¹ + ash @ 5 q ha⁻¹)
- T₂₂ : Control

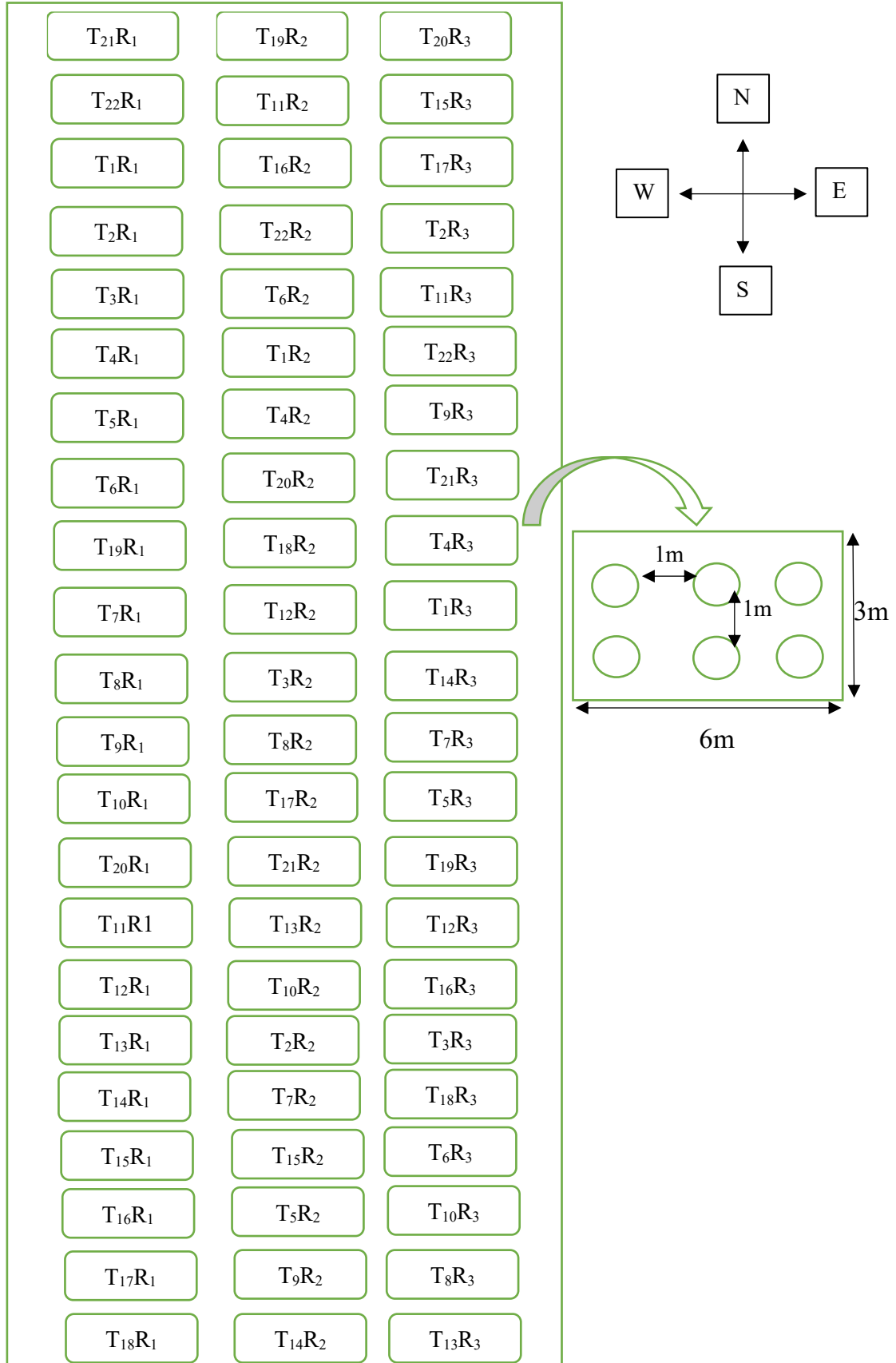


Figure 3.3: Farm layout of the experiment in RBD (Randomized Block Design)

3.3 Agronomic practices

3.3.1 Collection of planting materials

The planting material of chayote was collected from the Tsiepama village, Chumukedima district located at a latitude of 25°48'19''N and longitude of 93°57'18''E. After collection of matured chayote fruits, it was stored at room temperature to allow sprouting.

3.3.2 Selection and preparation of field

A well-drained plot of land was selected for carrying out the experimental trial. The land preparation consisted of using cultivators for ploughing, then followed by harrowing and rotavator was used for breaking the clods. After levelling the bed, 66 number of plots of 6m × 3m were prepared.

3.3.3 Application of manures, fertilizers and biofertilizers

The application of organic manures was done at 15 days before sowing and the quantity of manures 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 NPK respectively. N was applied in 2 split doses. Half as basal and remaining half as top dressing at 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 was done twice as foliar spray @ 5 ml l⁻¹ as per the IFFCO recommendation. The first application was done at 6-8 leaf stage and second at 1 week before flowering. Microbial consortium was applied @ 5 ml l⁻¹ by mixing with organic manures at 15 days before sowing.

3.3.4 Sowing

The pre germinated chayote seeds were treated with Captaf 50% WP, a broad-spectrum fungicide @ 2.5 gm l⁻¹ to check the seed borne pathogens just before sowing and were drenched with chlorpyrifos @ 2ml l⁻¹ to avoid infestation by termites just after sowing.

3.3.5 Intercultural operation

3.3.5.1 Training

When the plant attained 15-30 cm plant height, kniffin system of training was adopted to provide training support to the plant. It was done by erecting an iron angle

on both sides of the plot wherein aluminium wire was tied to the iron angle to provide support to the vines. The main vine was carried upward to the supporting wire by tying a jute rope to the aluminium wire.

3.3.5.2 Irrigation

After sowing of chayote fruits, light irrigation was applied every day for upto 15 days or till the plant was well established. After the plant was well established moderate irrigation was applied every alternate day till the final harvesting.

3.3.5.3 Weeding

Manual weeding was done twice at 25 DAS and 60 DAS. No chemical weedicides were used during the investigation period.

3.3.5.4 Earthing up

Due to regular irrigation, soil pan becomes hard and tight. So, loosening of the soil and earthing up was done twice manually at 25 DAS and 60 DAS.

3.3.5.5 Plant protection measures

Timely monitoring of the field was carried out to prevent disease incidence and pest infestation. Soil drenching with chlorpyrifos @ 2m l^{-1} was done to control termite infestation. Combination of copper oxychloride @ 2.5 gm l^{-1} and sulfex @ 1 gm l^{-1} was applied to check powdery mildew disease.

3.3.6 Harvesting

The ideal stage for harvest of the chayote is when the chayote becomes firm and light green. Picking of the fruit was done at proper maturity stage and the harvesting of the fruits was done manually. The total number of pickings varies from treatment and it was carried out in three to five batches as per its maturity.

3.4. Observations recorded

3.4.1 Growth parameters

To keep record of the growth attributes, five plants were selected randomly in each plot and tagged.

3.4.1.1 Number of leaves per plant

During the time of first harvest, the number of leaves produced per plant was recorded from each tagged plant and average number of leaves was recorded for each treatment.

3.4.1.2 Number of primary branches

The numbers of primary branches were counted from the tagged plants at the time of first harvest and the averages were recorded from each treatment.

3.4.1.3 Leaf length

Five random leaves were selected from the tagged plants at the time of first harvest and the average length of the leaf was measured in cm with the help of a scale.

3.4.1.4 Leaf width

Five random leaves were selected from the tagged plants at the time of first harvest and the average width of the leaf was measured in cm with the help of a scale.

3.4.1.5 Leaf area

Five random leaves were selected from the tagged plants at the time of first harvest and the average area of the leaf was measured in cm² with the help of a leaf area meter.

3.4.1.6 Internodal length

Five random internodes were selected from the tagged plants at the time of first harvest and the average length of the internode was measured in cm with the help of a scale.

3.4.1.7 Node at first female flowering

From the tagged plants, the nodes where the first female flowers appeared were recorded counting from the base towards tip and the average was calculated.

3.4.1.8 Node at first male flowering

From the tagged plants, the nodes where the first male flowers appeared were recorded counting from the base towards tip and the average was calculated.

3.4.1.9 Days to first female flowering

Number of days taken from the day of sowing to the initiation of first female flowering on the vines from the five labelled plants and its mean was calculated.

3.4.1.10 Days to first male flowering

Number of days taken from the day of sowing to the initiation of first male flowering on the vines from the five labelled plants and its mean was calculated.

3.4.1.11 Days to marketable maturity

The number of days taken from the day of sowing to the first harvest of the fruits was recorded from the tagged plants and the average was calculated.

3.4.1.12 Crop duration

The number of days taken from the day of sowing to the last harvest of the fruits was recorded from the tagged plants and the average was calculated.

3.4.1.13 Vine length

Vine length was measured from the base of the vine to the tip of the vine in all the five labelled plants in each treatment at the time of first harvest and mean was calculated and expressed in cm.

3.4.1.14 Sex ratio

The total number of male and female flowers was counted at the flowering stage from the tagged plants and the average sex ratio was calculated.

3.4.2 Yield parameters

3.4.2.1 Number of fruits per plant

During the harvest, the total number of fruits from the selected five plants were counted and recorded and the average was taken to get the number of fruits plant⁻¹.

3.4.2.2 Fruit length

The length of the fruit was measured using a measuring scale and the mean of all the selected fruits was calculated and expressed in cm.

3.4.2.3 Fruit diameter

The fruit of chayote was cut longitudinally into two halves and equatorial diameter was measured in cm and mean value were taken.

3.4.2.4 Average weight of fruits

From the tagged plants, five fruits were selected randomly and the average weight of the fruit was worked out and expressed in g.

3.4.2.5 Yield per plant

The average yield per plant was computed by calculating the total number of fruits harvested from the tagged plant and expressed in kg

3.4.2.6 Yield per ha

The fruit yield per hectare was calculated by using the following formula and expressed in q ha⁻¹

$$\text{Fruit yield ha}^{-1} = \frac{\text{Fruit weight (Kg plant}^{-1}) \times \text{No of plants ha}^{-1}}{100}$$

3.4.3 Quality parameters

3.4.3.1 Total Soluble Solids

The total soluble solids of the heads were determined with the help of ERMA, hand refractometer calibrated at 20° Brix. For estimating the TSS in chayote, the fruits were crushed and squeezed thoroughly to extract the juice and two to three drops of the juice were taken in the specimen chamber of the refractometer with the help of a glass rod.

The reading of the transaction point between the light and the shade portion was taken. The results were expressed in °Brix.

3.4.3.2 Crude protein content

The crude protein content of fruit was estimated through Kjeldahl method of digestion and distillation was followed for the estimation of nitrogen content and it was multiplied by 6.25 to get protein content (with assumption that protein contains 16 percent N).

3.4.3.3 Chlorophyll content

The chlorophyll content in fruits was estimated using spectrophotometer as per the procedure given by Arnon (1949) and expressed in mg g⁻¹.

$$\text{Total chlorophyll (mg g}^{-1}\text{)} = \frac{20.2 (A_{645}) + 8.02 (A_{663}) \times V}{1000 \times W}$$

Where,

A = Absorbance at specific wavelengths

V = Final volume of chlorophyll extract in 80% acetone

W = Fresh weight of tissue extracted.

3.4.3.4 Vitamin C content

Vitamin C content was determined by using 2, 6-Dichlorophenol indophenols visual titration method as given by A.O.A.C (1984) and expressed in mg per 100 g.

$$\text{Vitamin C} = \frac{\text{Titrated volume} \times \text{volume make up (25 ml)} \times 100}{\text{Aliquot of extract taken for estimation (5 ml)} \times \text{Vol. of sample taken for estimation (2.5 ml)}}$$

Aliquot of extract taken for estimation (5 ml) × Vol. of sample taken for estimation (2.5 ml)

3.4.3.5 Total carbohydrate content

Total carbohydrate estimation was done by Anthrone's Method as given by Hedge and Hofreiter (1962) and expressed in %.

$$\text{Amount of Carbohydrate (\%)} = \frac{\text{mg of glucose} \times 100}{\text{Volume of test sample}}$$

Where,

$$\text{mg of glucose} = 1 \text{ O.D} \times \text{Sample O.D.}$$

$$= „x“ \mu\text{g/ml}$$

$$= \text{mg/ml}$$

$$\text{Volume of test sample} = 5 \text{ ml}$$

3.4.3.6 Fiber content

Crude fibre content was estimated by the acid-alkali digestion method. The residue obtained after digestion was dried in a crucible and its weight was recorded (W2), the dried residue was ash in a muffle furnace at 600C for 3 to 4 hours and its weight (W1) was recorded. The difference between these two weights (W2 – W1) was taken as the weight of the crude fibre (Maynard, 1970).

$$\text{Crude fibre (\%)} = \frac{W2 - W1 \times 100}{\text{Weight of sample}}$$

Where,

W1: Weight of ash

W2: Weight of silica crucible

3.4.3.7 Calcium content

The estimation of calcium content in the fruit was determined by using atomic absorption spectrophotometer (AAS) (Ruck, 1979).

3.4.3.8 Total phenolic content

Total phenolic content was analyzed by using Singleton's method (Singleton *et al.* 1999). Gallic acid was used as a standard and absorbance was recorded at 650 nm by a spectrophotometer. Total phenolic content was represented as mg g⁻¹ FW of Gallic acid eq.

3.4.3.9 Shelf life

To study the shelf life of fruits, five fruits were collected after harvest from each treatment and kept at room temperature. Fruits were observed for their retention of freshness and firmness. The number of days the fruits were looking fresh was recorded based on visual observation and expressed in days.

3.4.4 Nutrient uptake by plants

The nutrient uptake by plants will be analysed after harvest from the sample plant.

3.4.4.1 Nitrogen

The nitrogen content in different plant parts was estimated by micro kjeldhal digestion-distillation method as per the procedure described by Jackson (1973).

3.4.4.2 Phosphorous

The phosphorous content in different plant parts was estimated by Vanado molybdate yellow colour method as suggested by Jackson (1973).

3.4.4.3 Potassium

Potassium content in different plant samples was analyzed by using Flame Photometer as outlined by Jackson (1973).

3.4.5 Fertility status of the soil after crop harvest

The soil samples were collected at random from five places near the base of the

plant in each experiment plot after harvest at a depth of 15 cm with the help of screw type auger. The collected soil samples were mixed and reduced into 500 g and dried under shade, ground and sieved for determination of following nutrient status.

3.4.5.1 Available N

The fruits and plant samples were digested with concentrated sulphuric acid in the presence of digestion mixture. Nitrogen plant samples were determined by modified Kjeldhal method as described by Black (1965).

3.4.5.2 Available P

The phosphorus was determined by wet digestion method. The plant samples were digested by di-acid mixture i.e. (HNO₃:HCl₄ : 3:1) (Baruah and Barthakur, 1999). Total phosphorus in plant samples was determined by Vanadomolybdate yellow colour method as outlined by Jackson (1973).

3.4.5.3 Available K

For the total potassium, the samples were digested by di-acid mixture (Baruah and Barthakur, 1999) and were determined by Flame photometry as described by Hanway and Heidal (1952).

3.4.5.4 Soil organic carbon

Soil organic carbon was determined by Walkley and Black Rapid Titration Method as described by Piper, 1966. Percentage of OC in soil was calculated by the following formula:

$$\% \text{ OC in soil} = 10 \times (B-T)/B \times 0.003 \times 100 / \text{W.S.}$$

Where,

B = Blank burette reading

T = Sample burette reading

W.S. = Weight of the soil sample

3.4.5.5 Soil pH

The pH of the soil was determined in 1:2 soil water suspensions using digital pH meter.

3.4.6 Economics of the treatments

Treatment wise economics was carried out by calculating the cost of cultivation

based on prevailing rates of input and output. Gross income was calculated by yield multiplied by wholesale rate of chayote @ Rs 10 kg⁻¹. Net income was estimated by deducing the total cost of cultivation (fixed cost + treatment cost) from gross income of the particular treatment. Cost benefit ratio was worked out by the relationship given below-

$$\text{Cost benefit ratio} = \text{Net return} / \text{Total cost of cultivation.}$$

3.4.7 Statistical analysis

Observations recorded during the field experimentation and data obtained from laboratory analysis were subjected to the statistical analysis of variance by Randomised Block Design (RBD) using the variance method (Panse and Sukhatme, 1989) and the significance and non-significance sources of variation due to different treatments were tested by error mean square using Fisher Shidecor 'F' test of probability at 5% level.



Plate 1: Field preparation of experimental site



Plate 2: Plot preparation of experimental site



Plate 3: Planting material of the experiment (Matured and germinated chow-chow fruit).



Plate 4: Planting of matured and germinated fruit in the field



Plate 5: Vegetative stage at 25 DAS



Plate 6: Adoption of kniffin system of training at knee high stage in the field



Plate 7: Application of nano urea in the field



Plate 8: Application of fungicides in the field



Plate 9: Female and Male inflorescence of chow-chow in the field



Plate 10: Fruiting of chow-chow in the field



Plate 11: Harvesting of fruit and tubers from the field



Plate 12: General view of the experimental field at vegetative stage

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

A field study on ‘Potentiality of nano fertilizers in integrated nutrient management of chow-chow [*Sechium edule* (Jacq.) Sw.] in Chumukedima district of Nagaland’ was conducted to examine various aspects including growth, yield parameters, quality, nutrient uptake, soil nutrient status, and economic considerations. This study was conducted during the 2022-23 and 2023-24 period and aimed to achieve the following objectives:

1. To study the effect of nanofertilizers based integrated nutrient management on growth, yield and quality of chow-chow.
2. To study the effect of nanofertilizers based integrated nutrient management on nutrient uptake.
3. To assess the treatment effect on the fertility status of the soil.
4. To study the economics of chow-chow cultivation for different treatments.

The results of the experimental data involving tabulations and graphs of the data collected during the study investigation are also presented in this chapter and reference to the conducted experiment. Subsequently, these results are thoroughly discussed to make valuable conclusions on the significance of these studies in the field of science and their practical applicability. The discussion is grounded on established principles that are supported by existing literature and evidence.

4.1 Growth parameters

4.1.1 Number of leaves per plant

The data presented in Table 4.1 and Figure 4.1 shows the influence of nanofertilizer based integrated nutrient management on the number of leaves in chow chow. The data indicates that there was a significant difference between the treatments as demonstrated by one way ANOVA. The pooled data imply that the treatment T₂₀ *i.e.*, PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC recorded the highest number of leaves with 108.97 while treatment T₂₂ (control) exhibited the lowest number of leaves with 59.79. Treatment T₁ [Full dose of RDF (N through urea)] and T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + Microbial consortium] was

statistically on parity with treatment T₂₀ in both the trial period as shown in the Table 4.1.

Treatments that incorporated microbial consortium generally had higher leaf counts and outperformed those without them. Additionally, treatments involving nano urea {such as T₁₀ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea)], T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC], T₁₄ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea)], T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] showed better performance than those using granular urea, emphasizing the possible advantages of nano urea in promoting leaf growth. Control (T₂₂) and farmers' practice treatment (T₂₁) have the lowest number of leaves, highlighting the positive impact of integrated nutrient management strategies.

4.1.2 Number of primary branches

The data presented in Table 4.2 and Figure 4.2 shows the effect of different sources of nutrients on the number of primary branches in chow chow. As demonstrated by one-way ANOVA, the data indicates that there is variation within the treatments and the CD value at a 5% significance level shows that differences greater than 1.02 (Pooled) across treatments are statistically significant. Treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] recorded the highest number of primary branches with 4.21 (Pooled) followed closely by treatment T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] with 4.15 (Pooled). The control treatment (T₂₂) and farmer's practice treatment (T₂₁) had the fewest number of branches, with pooled averages of 2.31 and 2.40, respectively, which are significantly lower than most treatments.

Table 4.1: Effect of nanofertilizer based INM on number of leaves per plant

Sl. no.	Treatment	Number of leaves per plant		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	92.23	96.86	94.54
T ₂	Full dose of RDF (N through nano urea)	61.12	64.52	62.82
T ₃	FYM @ 20 t ha ⁻¹	70.73	73.35	72.04
T ₄	VC @ 5 t ha ⁻¹	74.69	76.62	75.65
T ₅	PM @ 10 t ha ⁻¹	66.72	67.90	67.31
T ₆	FYM @ 20 t ha ⁻¹ + MC	77.75	79.84	78.80
T ₇	VC @ 5 t ha ⁻¹ + MC	83.86	86.34	85.10
T ₈	PM @ 10 t ha ⁻¹ + MC	69.94	71.71	70.82
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	76.45	78.64	77.55
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	79.07	81.14	80.11
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	70.90	71.87	71.39
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	91.48	93.87	92.68
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	72.11	74.61	73.36
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	70.65	75.73	73.19
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	78.71	80.88	79.80
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	86.36	88.30	87.33
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	82.04	84.85	83.44
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	61.31	63.48	62.40
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	80.73	82.59	81.66
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	108.46	109.48	108.97
T ₂₁	Farmers practise	61.40	65.26	63.33
T ₂₂	Control	59.05	60.52	59.79
SEm±		4.77	4.47	4.59
CD (P=0.05)		13.67	12.82	13.15

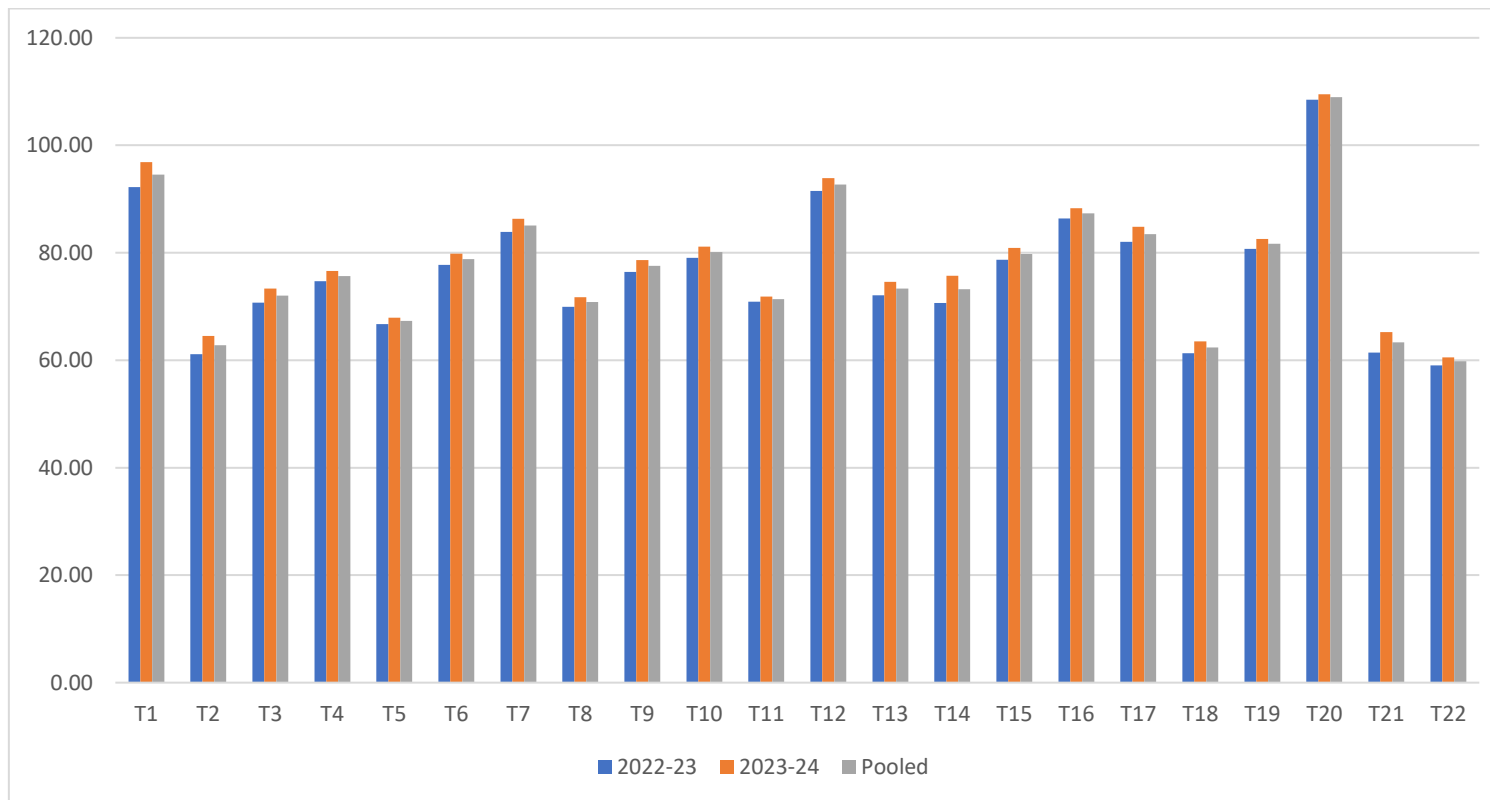


Figure 4.1: Effect of nanofertilizer based INM on number of leaves per plant

Table 4.2: Effect of nanofertilizer based INM on number of primary branches

Sl. no.	Treatment	Number of primary branches		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	3.42	3.89	3.65
T ₂	Full dose of RDF (N through nano urea)	2.58	2.66	2.62
T ₃	FYM @ 20 t ha ⁻¹	3.58	3.78	3.68
T ₄	VC @ 5 t ha ⁻¹	3.17	3.22	3.19
T ₅	PM @ 10 t ha ⁻¹	3.33	3.55	3.44
T ₆	FYM @ 20 t ha ⁻¹ + MC	2.50	2.55	2.53
T ₇	VC @ 5 t ha ⁻¹ + MC	2.58	2.66	2.62
T ₈	PM @ 10 t ha ⁻¹ + MC	2.50	2.67	2.58
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	2.75	2.89	2.82
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	2.42	2.89	2.65
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	2.92	3.11	3.01
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	4.08	4.22	4.15
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	2.36	2.55	2.46
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	2.58	3.11	2.85
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	2.33	2.66	2.50
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	3.83	4.11	3.97
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	3.00	3.11	3.06
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	2.42	2.55	2.49
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	2.67	2.89	2.78
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	4.08	4.33	4.21
T ₂₁	Farmers practise	2.25	2.56	2.40
T ₂₂	Control	2.17	2.44	2.31
SEm±		0.39	0.41	0.35
CD (P=0.05)		1.13	1.15	1.02

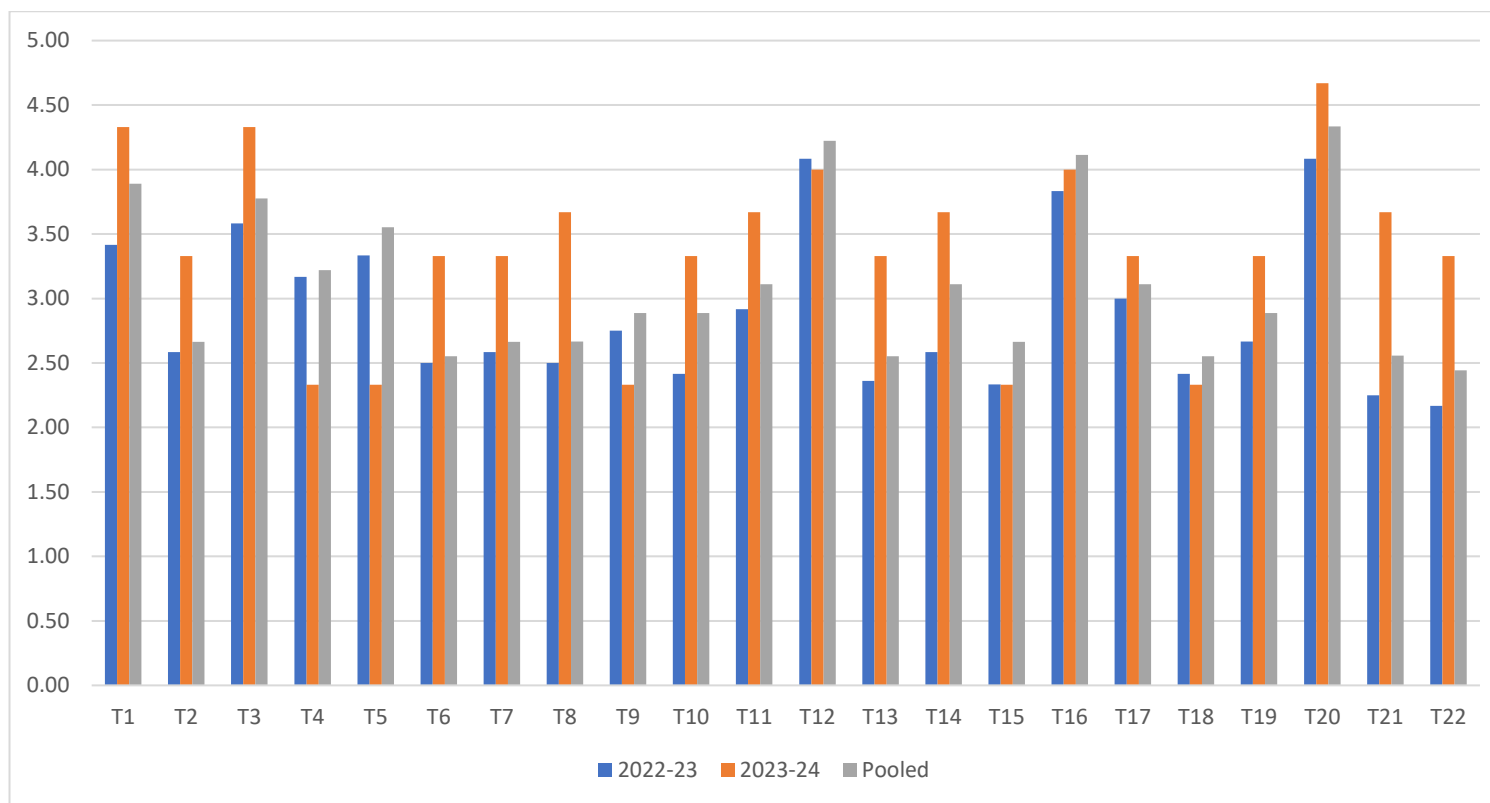


Figure 4.2: Effect of nanofertilizer based INM on number of primary branches

4.1.3 Leaf length

The data illustrated on Table 4.3 and Figure 4.3 describe the effect of different sources of nutrients on leaf length in chow chow. Table 4.3 shows that there were significant differences between the treatments as demonstrated by one way ANOVA. Treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] had the longest leaf length, with a pooled average of 20.15 cm, followed closely by treatment T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] at 19.56 cm. Treatment T₁ [Full dose of RDF (N through urea)] and T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] was statistically on par with treatment T₂₀ in both the trial period as indicated in the Table 4.3. Treatment T₂ [Full dose of RDF (N through nano urea)] with a pooled average of 14.24 cm, performed lower than most treatments, suggesting that nano urea alone may not be as effective as when combined with other organic inputs and microbial culture. Treatment control (T₂₂) had a lower pooled value of 14.21 cm and performed poorly as likened to other treatments showing that the use of organic inputs together with controlled application of fertilizers promotes better plant growth.

4.1.4 Leaf width

The data in Table 4.4 and Figure 4.4 represent the effect of nanofertilizer based integrated nutrient management on leaf width in chow chow. Table 4.4 shows that there were significant differences between the treatments as demonstrated by one-way ANOVA. Treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] recorded the largest leaf width with a pooled average of 22.30 cm while treatment T₁ [Full dose of RDF (N through urea)] and T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] was statistically on par with treatment T₂₀ as shown in Table 4.4. Treatment T₂ [Full dose of RDF (N through nano urea)] performed poorly with a pooled average of 17.41 cm while Treatment control (T₂₂) recorded the smallest leaf width with a pooled value of 16.81 cm.

Table 4.3: Effect of nanofertilizer based INM on leaf length

Sl. no.	Treatment	Leaf length (cm)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	18.80	19.22	19.01
T ₂	Full dose of RDF (N through nano urea)	13.92	14.56	14.24
T ₃	FYM @ 20 t ha ⁻¹	17.21	18.59	17.90
T ₄	VC @ 5 t ha ⁻¹	16.31	17.75	17.03
T ₅	PM @ 10 t ha ⁻¹	16.33	17.71	17.02
T ₆	FYM @ 20 t ha ⁻¹ + MC	13.65	15.66	14.66
T ₇	VC @ 5 t ha ⁻¹ + MC	16.05	17.45	16.75
T ₈	PM @ 10 t ha ⁻¹ + MC	14.14	15.82	14.98
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	16.71	18.83	17.77
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	16.11	17.93	17.02
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	16.86	18.47	17.67
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	19.15	19.97	19.56
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	17.95	18.49	18.22
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	13.96	15.45	14.71
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	16.11	16.97	16.54
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	17.69	19.13	18.41
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	16.42	17.73	17.07
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	15.37	17.21	16.29
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	17.23	17.80	17.52
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	19.91	20.39	20.15
T ₂₁	Farmers practise	14.02	15.36	14.69
T ₂₂	Control	13.53	14.89	14.21
SEm±		0.82	0.66	0.66
CD (P=0.05)		2.34	1.91	1.89

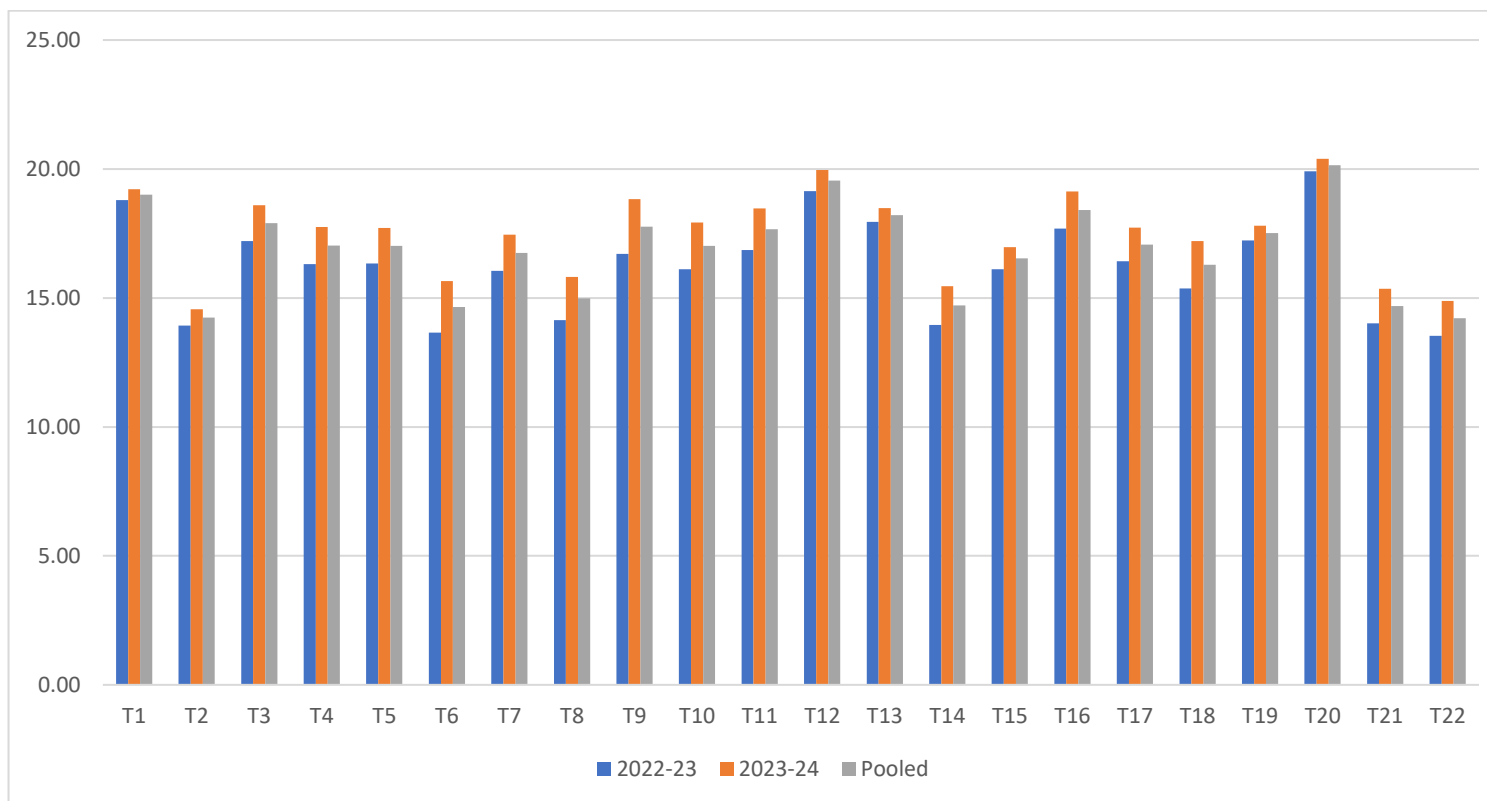


Figure 4.3: Effect of nanofertilizer based INM on leaf length

Table 4.4: Effect of nanofertilizer based INM on leaf width

Sl. no.	Treatment	Leaf width (cm)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	20.89	22.82	21.86
T ₂	Full dose of RDF (N through nano urea)	16.48	18.34	17.41
T ₃	FYM @ 20 t ha ⁻¹	17.88	20.52	19.20
T ₄	VC @ 5 t ha ⁻¹	17.58	19.69	18.64
T ₅	PM @ 10 t ha ⁻¹	17.53	20.14	18.83
T ₆	FYM @ 20 t ha ⁻¹ + MC	17.11	19.92	18.52
T ₇	VC @ 5 t ha ⁻¹ + MC	17.64	19.99	18.81
T ₈	PM @ 10 t ha ⁻¹ + MC	17.91	19.36	18.64
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	19.17	21.82	20.50
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	16.11	18.84	17.48
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	19.79	20.95	20.37
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	21.04	22.54	21.79
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	18.14	20.01	19.08
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	16.65	18.11	17.38
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	18.18	19.17	18.68
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	20.71	21.90	21.30
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	17.31	19.57	18.44
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	18.13	17.76	17.94
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	19.47	19.95	19.71
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	21.27	23.34	22.30
T ₂₁	Farmers practise	17.05	17.94	17.50
T ₂₂	Control	16.20	17.43	16.81
SEm±		0.68	0.75	0.55
CD (P=0.05)		1.95	2.13	1.58

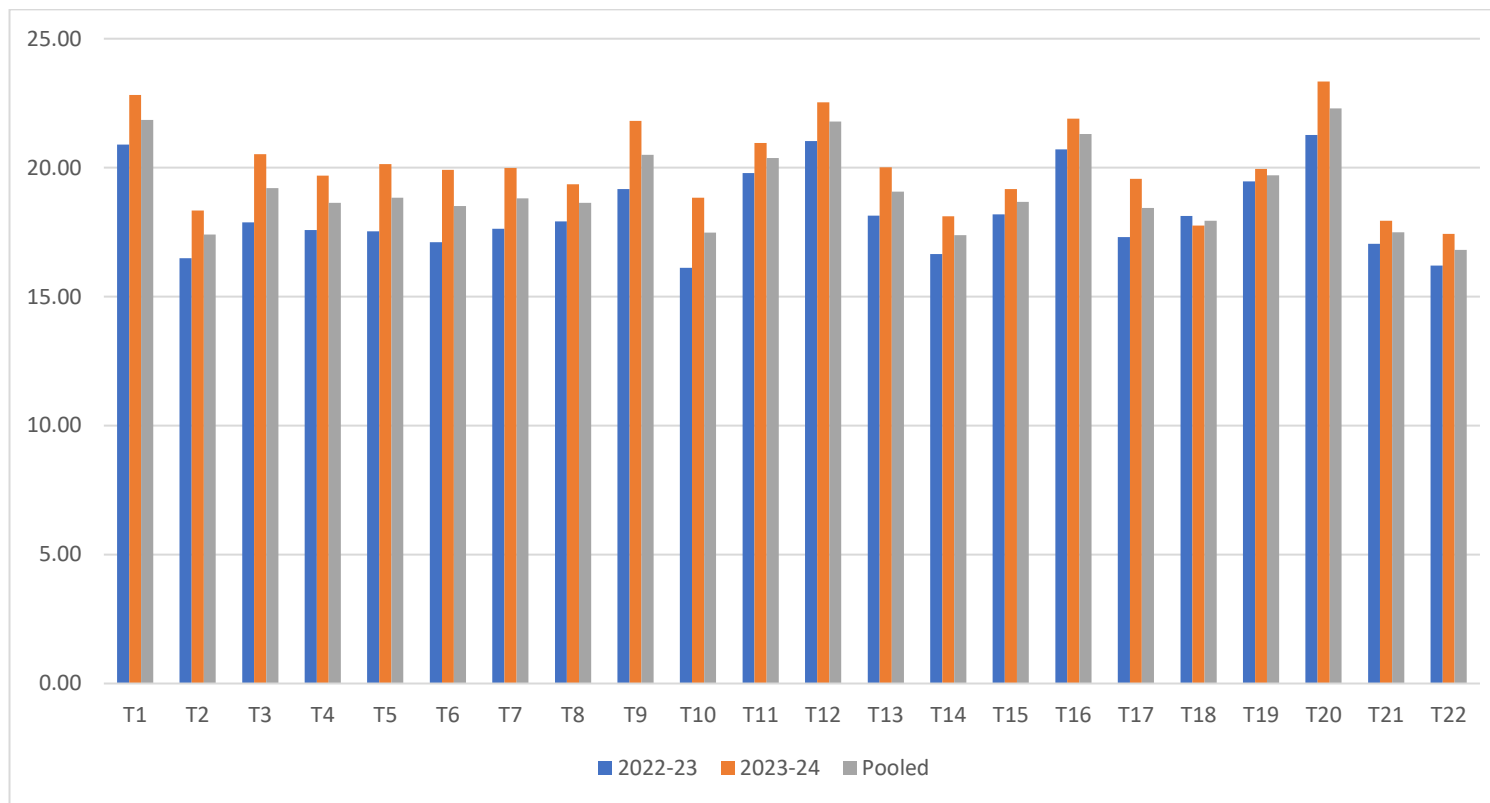


Figure 4.4: Effect of nanofertilizer based INM on leaf width

4.1.5 Leaf area

The data bestowed in Table 4.5 and Figure 4.5 show the effect of different sources of nutrients on the leaf area in chow chow. As demonstrated by one way ANOVA, the data indicates that there is variation within the treatments and the CD value at a 5% significance level shows that differences greater than 16.13 cm² (Pooled) across treatments are statistically significant. Treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] indicated the highest pooled leaf area with 189.08 cm² followed subsequently by treatment T₁ [Full dose of RDF (N through urea)] with 181.44 cm² and T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] with 176.66 cm². Treatment T₂₂ (control) and T₁₃ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through urea)] recorded the lowest pooled leaf area with 139.02 cm² and 144.74 cm². It was observed that when no microbial culture was used along with nano urea or organic amendments the response was not very high; therefore, an amalgamation approach can be indicated for better response.

4.1.6 Internodal length

The data bestowed in Table 4.6 and Figure 4.6 shows the influence of nanofertilizer based integrated nutrient management on internodal length in chow chow. The data on internodal length shows that there were significant differences between the treatments as demonstrated by one way ANOVA. Treatment T₄ (VC @ 5 t ha⁻¹) recorded the longest internodal length with an average pooled of 9.70 cm followed subsequently by treatment control (T₂₂) with 9.29 cm (Pooled) while treatment T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] recorded the shortest internodal length with 7.74 cm (Pooled) followed subsequently by T₁ [Full dose of RDF (N through urea)] and T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] with an average pooled of 7.79 cm and 7.82 cm respectively.

Table 4.5: Effect of nanofertilizer based INM on leaf area

Sl. no.	Treatment	Leaf area (cm ²)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	180.76	182.12	181.44
T ₂	Full dose of RDF (N through nano urea)	149.13	152.51	150.82
T ₃	FYM @ 20 t ha ⁻¹	144.35	147.73	146.04
T ₄	VC @ 5 t ha ⁻¹	145.88	148.21	147.05
T ₅	PM @ 10 t ha ⁻¹	148.65	149.29	148.97
T ₆	FYM @ 20 t ha ⁻¹ + MC	146.88	147.26	147.07
T ₇	VC @ 5 t ha ⁻¹ + MC	151.35	152.27	151.81
T ₈	PM @ 10 t ha ⁻¹ + MC	145.09	146.34	145.71
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	145.76	149.88	147.82
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	162.70	163.91	163.31
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	168.98	171.93	170.46
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	175.16	178.17	176.66
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	143.04	146.44	144.74
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	155.26	158.59	156.92
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	160.35	163.14	161.74
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	159.90	170.74	165.32
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	156.13	153.33	154.73
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	170.15	174.23	172.19
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	157.49	159.57	158.53
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	187.18	190.97	189.08
T ₂₁	Farmers practise	165.15	163.96	164.55
T ₂₂	Control	140.01	138.04	139.02
SEm±		5.66	7.04	5.63
CD (P=0.05)		16.21	20.15	16.13

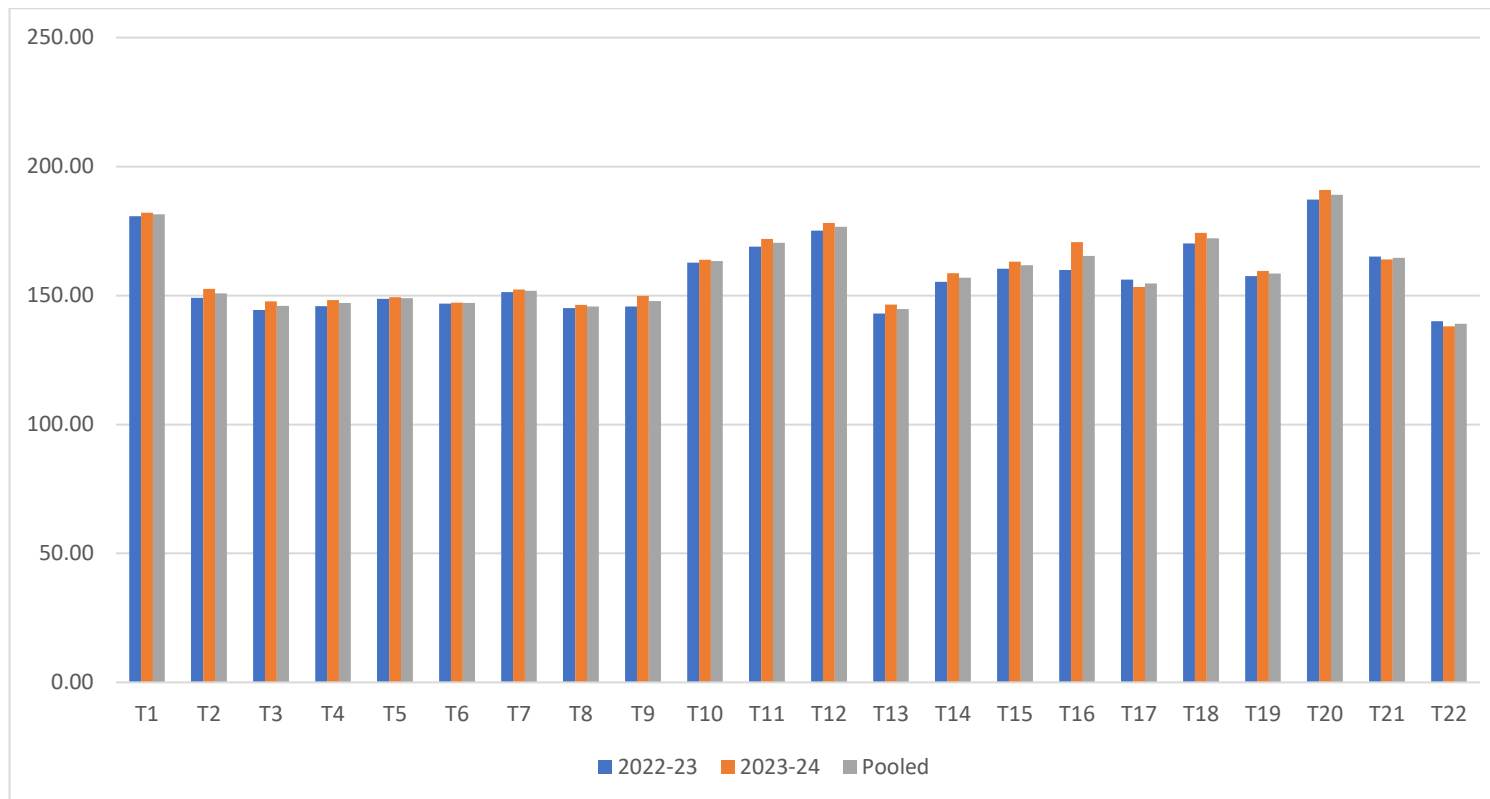


Figure 4.5: Effect of nanofertilizer based INM on leaf area

Table 4.6: Effect of nanofertilizer based INM on internodal length

Sl. no.	Treatment	Internodal length (cm)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	7.71	7.88	7.79
T ₂	Full dose of RDF (N through nano urea)	9.11	9.27	9.19
T ₃	FYM @ 20 t ha ⁻¹	8.41	8.71	8.56
T ₄	VC @ 5 t ha ⁻¹	9.61	9.79	9.70
T ₅	PM @ 10 t ha ⁻¹	8.54	8.64	8.59
T ₆	FYM @ 20 t ha ⁻¹ + MC	8.51	8.46	8.49
T ₇	VC @ 5 t ha ⁻¹ + MC	8.26	8.34	8.30
T ₈	PM @ 10 t ha ⁻¹ + MC	8.48	8.79	8.64
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	8.26	8.37	8.31
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	8.32	8.47	8.40
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	8.17	8.20	8.19
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	7.71	7.77	7.74
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	8.48	8.53	8.51
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	8.44	8.40	8.42
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	8.06	8.33	8.20
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	8.03	7.96	8.00
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	8.51	8.45	8.48
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	8.24	8.59	8.41
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	8.35	8.26	8.30
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	7.84	7.80	7.82
T ₂₁	Farmers practise	8.36	8.63	8.50
T ₂₂	Control	9.26	9.31	9.29
SEm±		0.25	0.28	0.19
CD (P=0.05)		0.73	0.81	0.56

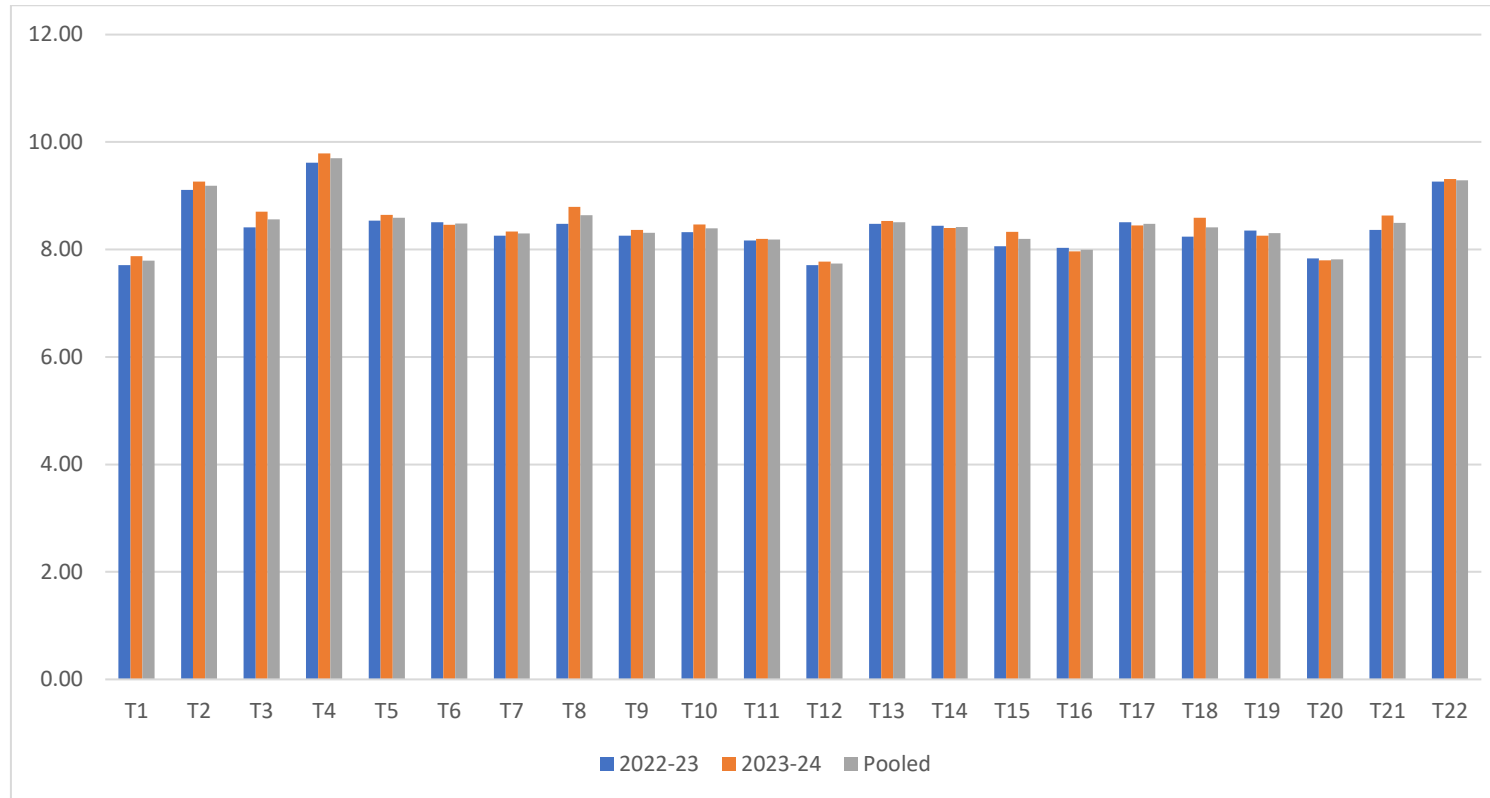


Figure 4.6: Effect of nanofertilizer based INM on internodal length

4.1.7 Node at first female flowering

The data on node at first female flowering in chow chow and its effect by different sources of nutrients are depicted in Table 4.7 and Figure 4.7. As demonstrated by one way ANOVA, the data indicates that there is variation within the treatments and the CD value at a 5% significance level shows that differences in the node of first female flowering greater than 0.78 (Pooled) across treatments are statistically significant. Treatment T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] recorded the earliest female flowering, with the first female flowering appearing at an average node of 14.50 (Pooled). Treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₁ [Full dose of RDF + ½ of RDF (N through urea)] also recorded relatively early flowering with an average node number of 14.67 (Pooled) and 14.83 (Pooled). Treatment control (T₂₂) where no additional inputs were used, recorded late flowering with the first female flower appearing at a pooled average of 16.60 node.

4.1.8 Node at first male flowering

The data on node at first male flowering in chow chow and its outcome by different sources of nutrients are depicted in Table 4.8 and Figure 4.8. As demonstrated by one way ANOVA, the data indicates that there is variation within the treatments and the CD value at a 5% significance level shows that differences in the node of first male flowering greater than 1.97 (Pooled) nodes across treatments are statistically significant. Treatment T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] recorded the earliest male flowering, with the first male flowering appearing at an average node of 10.31 (Pooled) followed by T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₁₅ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through urea) + MC] with a pooled average of 11.73 and 12.17 node respectively. Treatment control (T₂₂) recorded delayed male flowering with the first male flower appearing at a pooled average of 16.31 node.

Table 4.7: Effect of nanofertilizer based INM on node at first female flowering

Sl. no.	Treatment	Node at first female flowering		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	14.93	14.73	14.83
T ₂	Full dose of RDF (N through nano urea)	15.20	15.07	15.13
T ₃	FYM @ 20 t ha ⁻¹	15.33	15.13	15.23
T ₄	VC @ 5 t ha ⁻¹	15.60	15.33	15.47
T ₅	PM @ 10 t ha ⁻¹	15.53	15.27	15.40
T ₆	FYM @ 20 t ha ⁻¹ + MC	15.47	15.20	15.33
T ₇	VC @ 5 t ha ⁻¹ + MC	15.73	15.40	15.57
T ₈	PM @ 10 t ha ⁻¹ + MC	15.80	15.47	15.63
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	15.33	15.13	15.23
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	15.80	15.47	15.63
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	15.53	15.07	15.30
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	15.40	14.80	15.10
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	15.93	15.47	15.70
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	16.13	15.93	16.03
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	15.87	15.27	15.57
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	14.73	14.27	14.50
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	15.93	15.73	15.83
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	16.20	15.80	16.00
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	16.27	15.87	16.07
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	14.80	14.53	14.67
T ₂₁	Farmers practise	16.27	15.60	15.93
T ₂₂	Control	16.67	16.53	16.60
SEm±		0.26	0.35	0.27
CD (P=0.05)		0.75	0.99	0.78

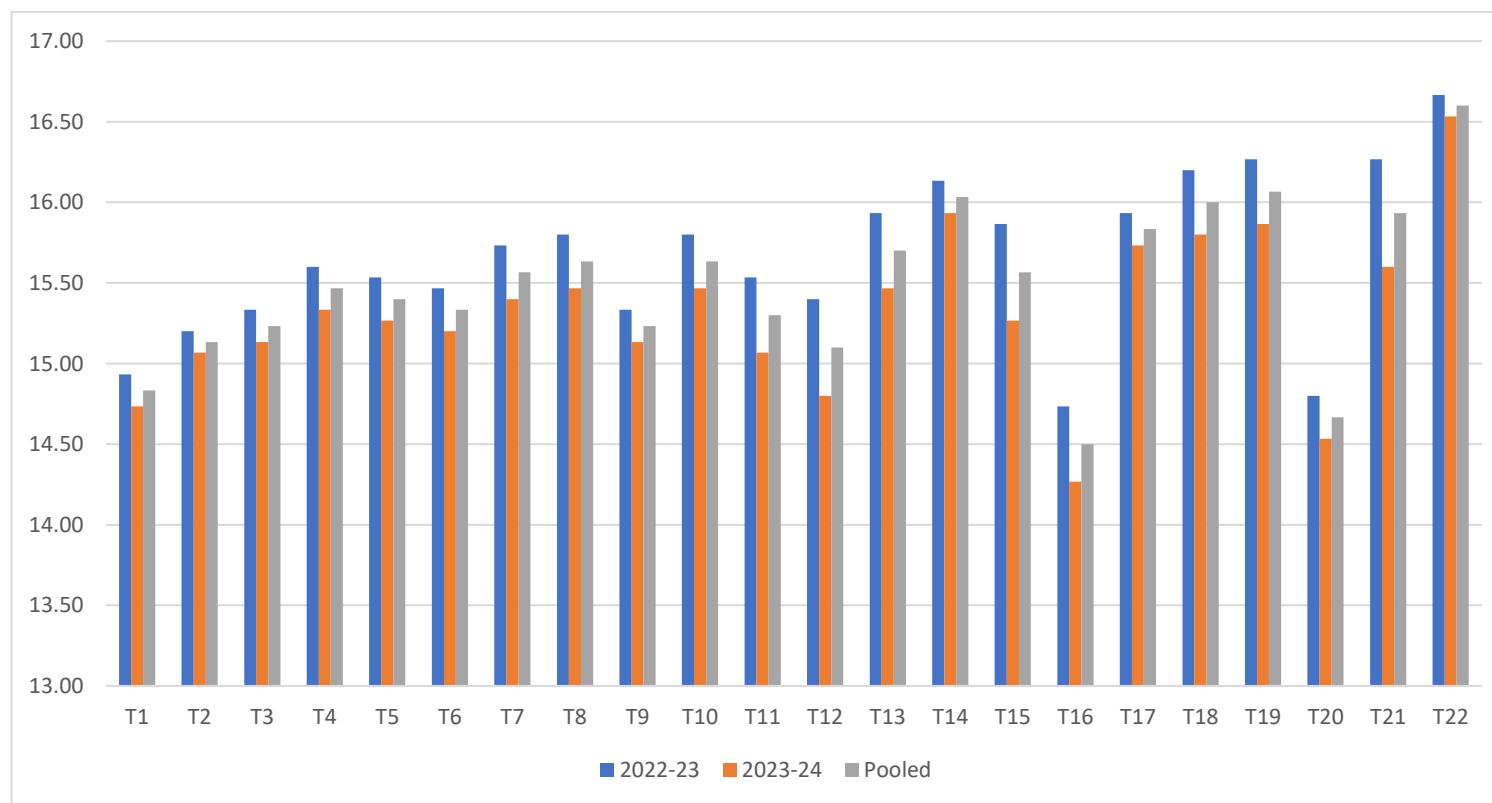


Figure 4.7: Effect of nanofertilizer based INM on node at first female flowering

Table 4.8: Effect of nanofertilizer based INM on node at first male flowering

Sl. no.	Treatment	Node at first male flowering		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	14.17	13.50	13.83
T ₂	Full dose of RDF (N through nano urea)	13.50	13.83	13.67
T ₃	FYM @ 20 t ha ⁻¹	13.33	13.72	13.53
T ₄	VC @ 5 t ha ⁻¹	14.33	16.99	15.66
T ₅	PM @ 10 t ha ⁻¹	14.50	14.66	14.58
T ₆	FYM @ 20 t ha ⁻¹ + MC	13.67	15.33	14.50
T ₇	VC @ 5 t ha ⁻¹ + MC	12.53	13.04	12.79
T ₈	PM @ 10 t ha ⁻¹ + MC	13.97	15.33	14.65
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	16.17	14.33	15.25
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	16.31	14.72	15.52
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	13.50	14.89	14.19
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	12.13	11.33	11.73
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	13.67	15.67	14.67
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	14.33	12.05	13.19
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	12.67	11.67	12.17
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	10.95	9.67	10.31
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	13.17	13.50	13.33
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	15.89	13.50	14.69
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	15.05	13.67	14.36
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	13.74	12.33	13.04
T ₂₁	Farmers practise	16.26	14.67	15.47
T ₂₂	Control	16.11	16.50	16.31
SEm±		0.95	1.06	0.68
CD (P=0.05)		2.73	3.05	1.97

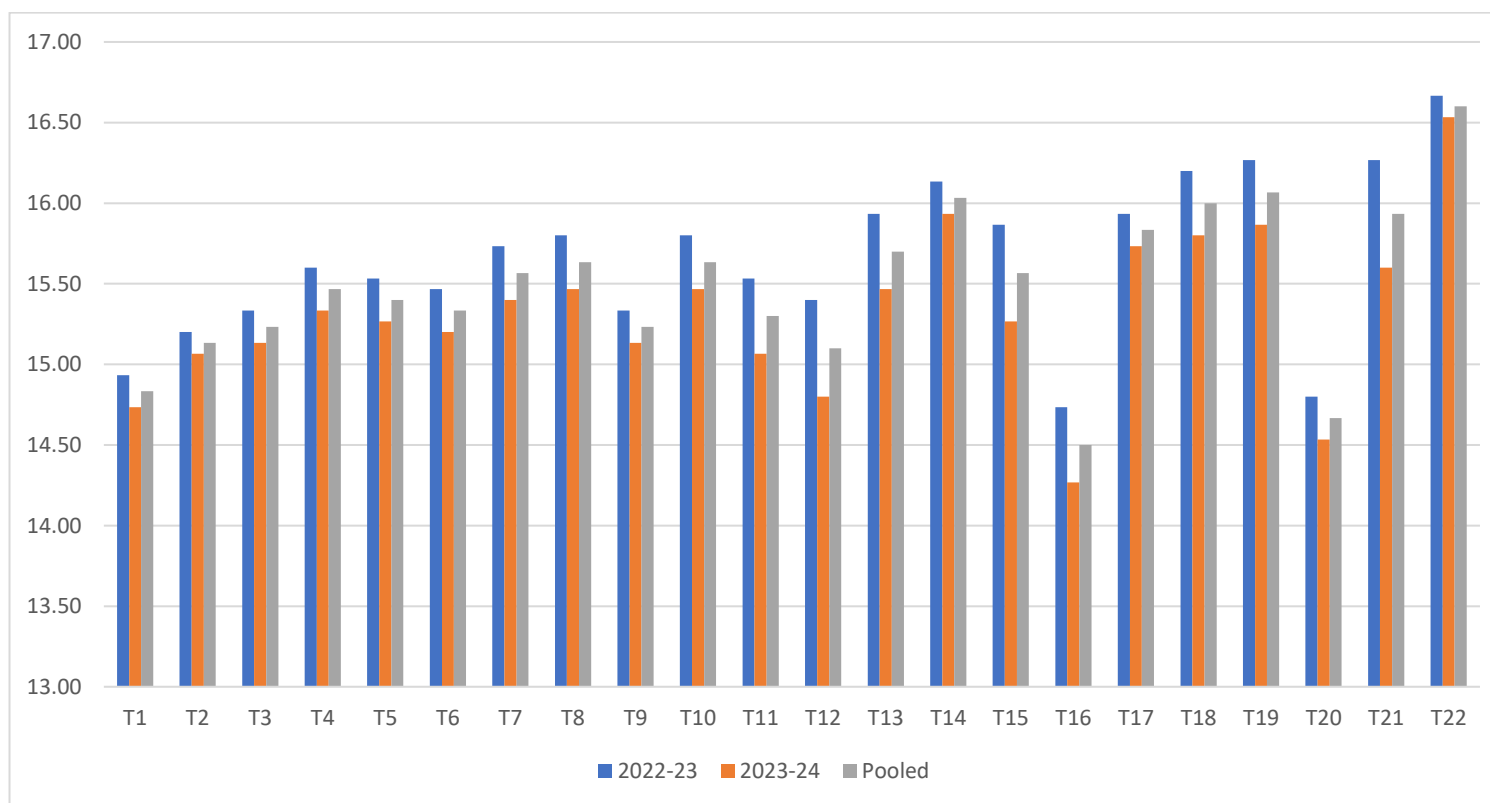


Figure 4.8: Effect of nanofertilizer based INM on node at first male flowering

4.1.9 Days to first female flowering

The data on days to the first female flowering in chow chow and its outcome by different sources of nutrients are depicted in Table 4.9 and Figure 4.9. As demonstrated by one way ANOVA, the data indicates that there is variation within the treatments and the CD value at a 5% significance level shows that differences in the days to first female flowering greater than 3.22 days (Pooled) across treatments are statistically significant. Treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] resulted in earliest female flowering, with flowers appearing in an average of 89.27 days (Pooled) followed subsequently by treatment T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₁ [Full dose of RDF (N through urea)] with an average pooled of 89.93 days and 90.09 days respectively. T₂₂ (Control) had the latest female flowering with an average of 99.07 days (pooled).

4.1.10 Days to first male flowering

The data on days to the first male flowering in chow chow and its impact by different sources of nutrients are depicted in Table 4.10 and Figure 4.10. As demonstrated by one way ANOVA, the data indicates that there is variation within the treatments and the CD value at a 5% significance level shows that differences in the days to first male flowering greater than 3.77 days (Pooled) across treatments are statistically significant. Treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] promoted early male flowering with an average pooled of 79.50 days while treatment T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₁ [Full dose of RDF (N through urea)] was statistically on parity with an average pooled of 80.10 days and 80.63 days respectively. T₂₂ (Control) resulted in the latest male flowering at 91.03 days (pooled) trailed by treatment T₄ (VC @ 5 t ha⁻¹) and T₃ (FYM @ 20 t ha⁻¹) with 87.77 days and 86.47 days respectively (Pooled).

Table 4.9: Effect of nanofertilizer based INM on days to first female flowering

Sl. no.	Treatment	Days to first female flowering		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	91.40	88.78	90.09
T ₂	Full dose of RDF (N through nano urea)	97.27	95.53	96.40
T ₃	FYM @ 20 t ha ⁻¹	98.43	95.50	96.97
T ₄	VC @ 5 t ha ⁻¹	99.13	96.30	97.72
T ₅	PM @ 10 t ha ⁻¹	97.67	94.27	95.97
T ₆	FYM @ 20 t ha ⁻¹ + MC	97.60	95.67	96.63
T ₇	VC @ 5 t ha ⁻¹ + MC	96.33	94.47	95.40
T ₈	PM @ 10 t ha ⁻¹ + MC	95.67	94.07	94.87
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	95.53	93.40	94.47
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	96.13	93.80	94.97
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	94.47	92.93	93.70
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	91.33	88.53	89.93
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	98.40	95.47	96.93
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	97.93	97.33	97.63
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	97.67	95.07	96.37
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	92.53	92.33	92.43
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	95.20	93.87	94.53
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	99.60	97.47	98.53
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	93.93	91.20	92.57
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	90.93	87.60	89.27
T ₂₁	Farmers practise	95.73	94.77	95.25
T ₂₂	Control	100.07	98.07	99.07
SEm±		1.45	1.47	1.12
CD (P=0.05)		4.16	4.23	3.22

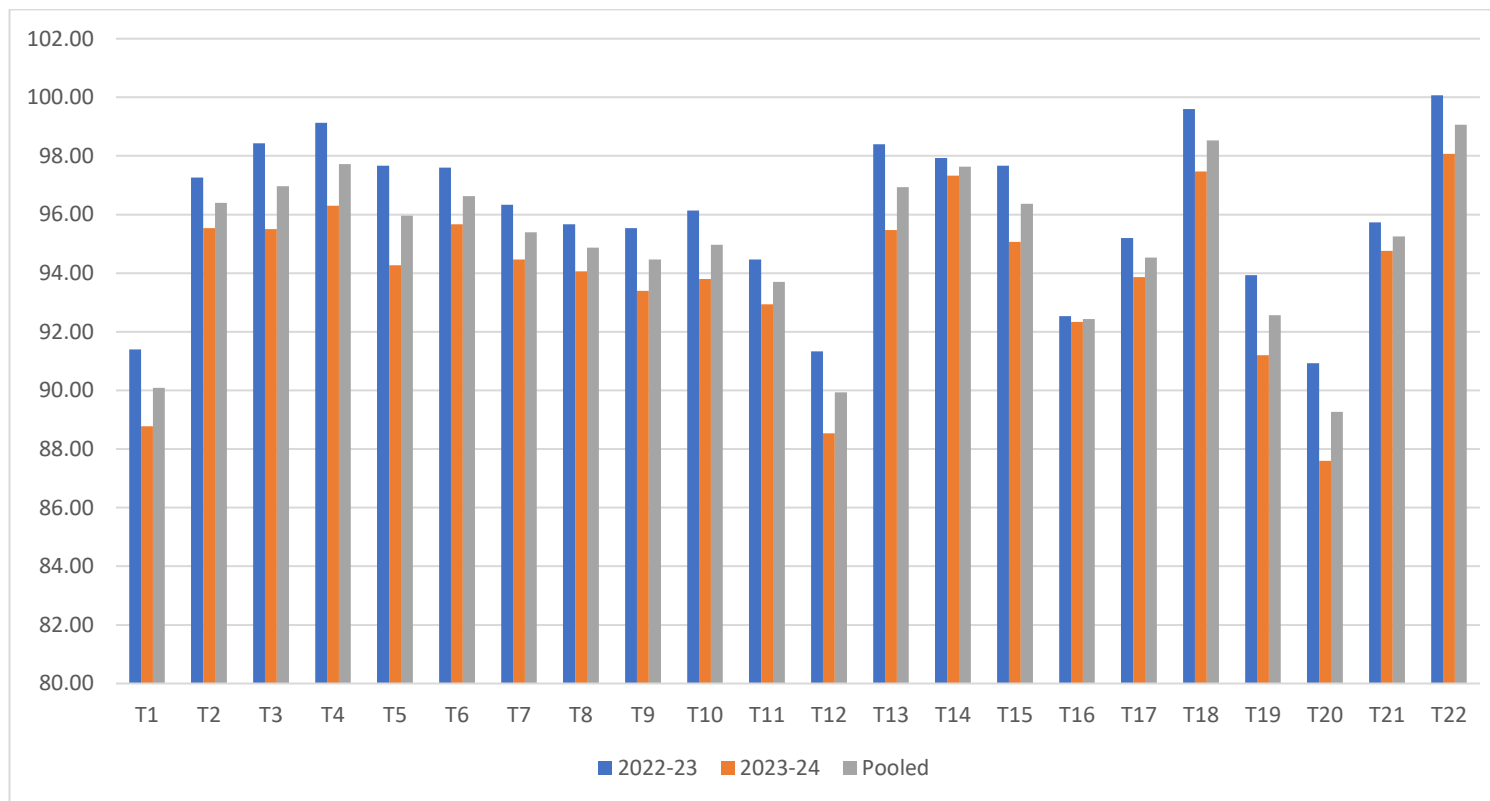


Figure 4.9: Effect of nanofertilizer based INM on days to first female flowering

Table 4.10: Effect of nanofertilizer based INM on days to first male flowering

Sl. no.	Treatment	Days to first male flowering		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	82.13	79.13	80.63
T ₂	Full dose of RDF (N through nano urea)	84.40	82.07	83.23
T ₃	FYM @ 20 t ha ⁻¹	88.33	84.60	86.47
T ₄	VC @ 5 t ha ⁻¹	88.13	87.40	87.77
T ₅	PM @ 10 t ha ⁻¹	86.40	83.53	84.97
T ₆	FYM @ 20 t ha ⁻¹ + MC	87.47	83.73	85.60
T ₇	VC @ 5 t ha ⁻¹ + MC	85.40	85.13	85.27
T ₈	PM @ 10 t ha ⁻¹ + MC	85.07	83.07	84.07
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	85.60	83.27	84.43
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	87.67	85.33	86.50
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	85.13	82.53	83.83
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	81.47	78.73	80.10
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	87.93	84.47	86.20
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	85.67	87.53	86.60
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	85.54	82.13	83.84
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	83.47	79.20	81.33
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	86.07	82.40	84.23
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	84.87	84.20	84.53
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	85.33	80.73	83.03
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	80.60	78.40	79.50
T ₂₁	Farmers practise	86.80	85.73	86.27
T ₂₂	Control	92.47	89.60	91.03
SEm±		1.92	1.74	1.32
CD (P=0.05)		5.48	4.98	3.77

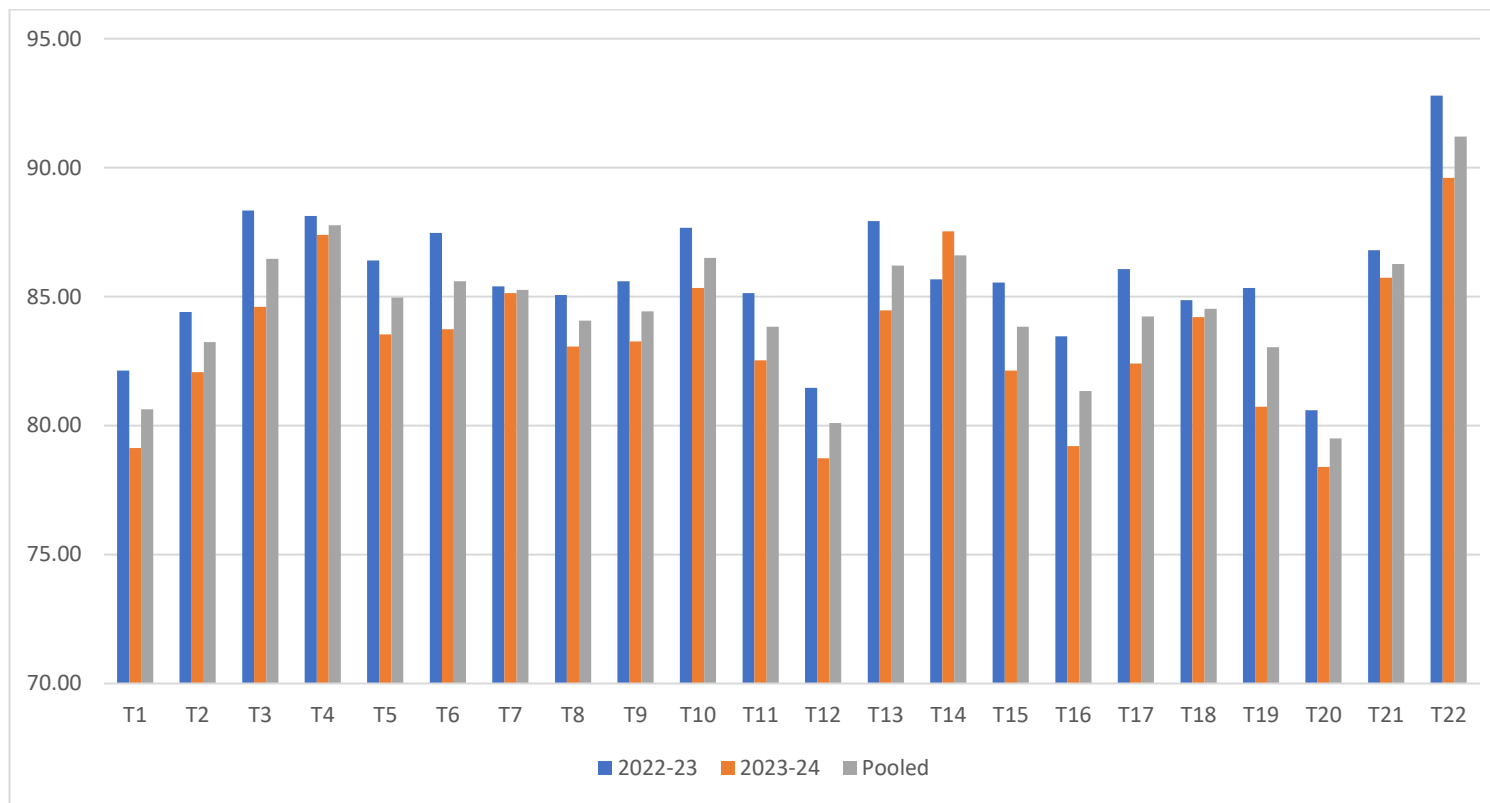


Figure 4.10: Effect of nanofertilizer based INM on days to first male flowering

4.1.11 Days to marketable maturity

The experimental results regarding the influence of nanofertilizers based integrated nutrient management on days to marketable maturity are detailed in Table 4.11 and Figure 4.11. The data shows that there was significant difference between the treatments as demonstrated by one-way ANOVA. Treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] resulted in the earliest marketable maturity at 102.85 days (Pooled). T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₁ [Full dose of RDF (N through urea)] also showed relatively early marketable maturity with an average pooled of 103.86 days and 105.63 days respectively while treatment T₂₂ (control) resulted in the latest marketable maturity with 119.84 days (Pooled) followed subsequently by treatment T₂₁ (Farmer's Practise) and T₁₃ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through urea)] with a mean pooled of 114.29 days and 113.54 days respectively.

4.1.12 Crop duration

The experimental results regarding the impact of nanofertilizers based integrated nutrient management on crop duration are detailed in Table 4.12 and Figure 4.12. The data shows that there was significant difference between the treatments as demonstrated by one-way ANOVA. Treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] exhibited the longest crop duration at 160.41 days (Pooled). Treatment T₁ [Full dose of RDF (N through urea)] had a crop duration of 154.69 days followed subsequently by T₉ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through urea)] relatively showing a longer crop duration of 152.39 days (Pooled). Treatment T₂₂ (control) recorded the shortest crop duration with 144.16 days (Pooled) while Treatment T₂₁ (Farmer's Practise) had a crop duration of 147.30 days.

Table 4.11: Effect of nanofertilizer based INM on days to marketable maturity

Sl. no.	Treatment	Days to marketable maturity		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	106.79	104.47	105.63
T ₂	Full dose of RDF (N through nano urea)	112.07	110.34	111.21
T ₃	FYM @ 20 t ha ⁻¹	109.14	108.41	108.77
T ₄	VC @ 5 t ha ⁻¹	110.17	107.71	108.94
T ₅	PM @ 10 t ha ⁻¹	109.14	108.29	108.72
T ₆	FYM @ 20 t ha ⁻¹ + MC	111.08	109.54	110.31
T ₇	VC @ 5 t ha ⁻¹ + MC	112.12	108.45	110.28
T ₈	PM @ 10 t ha ⁻¹ + MC	112.31	107.68	109.99
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	112.05	111.50	111.78
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	111.52	109.60	110.56
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	109.40	107.47	108.44
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	104.82	102.91	103.86
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	114.65	112.44	113.54
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	112.18	110.40	111.29
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	113.97	110.56	112.27
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	105.25	104.86	105.05
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	111.93	108.64	110.29
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	114.95	111.60	113.27
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	109.55	107.86	108.71
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	103.89	101.82	102.85
T ₂₁	Farmers practise	114.80	113.78	114.29
T ₂₂	Control	120.55	119.12	119.84
SEm±		2.51	2.74	2.06
CD (P=0.05)		7.19	7.84	5.89

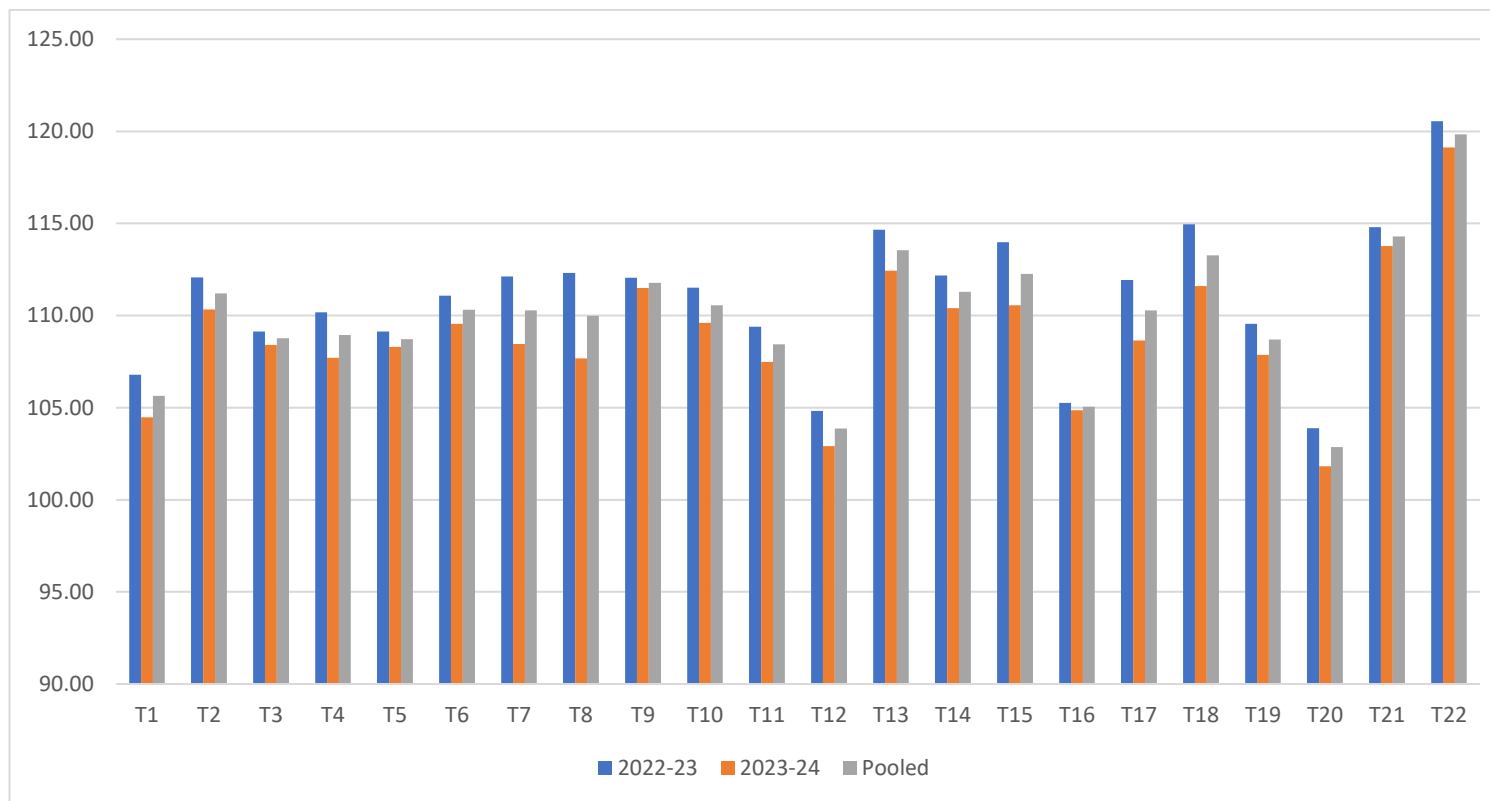


Figure 4.11: Effect of nanofertilizer based INM on days to marketable maturity

Table 4.12: Effect of nanofertilizer based INM on crop duration

Sl. no.	Treatment	Crop duration (days)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	153.18	156.21	154.69
T ₂	Full dose of RDF (N through nano urea)	148.48	149.88	149.18
T ₃	FYM @ 20 t ha ⁻¹	148.18	148.95	148.57
T ₄	VC @ 5 t ha ⁻¹	148.49	147.77	148.13
T ₅	PM @ 10 t ha ⁻¹	145.95	148.12	147.04
T ₆	FYM @ 20 t ha ⁻¹ + MC	148.51	149.37	148.94
T ₇	VC @ 5 t ha ⁻¹ + MC	148.82	149.78	149.30
T ₈	PM @ 10 t ha ⁻¹ + MC	145.46	147.08	146.27
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	151.22	153.55	152.39
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	147.80	149.08	148.44
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	150.75	151.77	151.26
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	149.43	152.44	150.93
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	146.11	148.41	147.26
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	147.48	148.76	148.12
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	148.46	149.89	149.18
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	150.14	153.86	152.00
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	147.25	149.73	148.49
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	146.79	148.27	147.53
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	148.80	149.39	149.09
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	159.43	161.39	160.41
T ₂₁	Farmers practise	146.77	147.83	147.30
T ₂₂	Control	143.56	144.76	144.16
SEm±		2.27	2.39	1.76
CD (P=0.05)		6.47	6.86	5.04

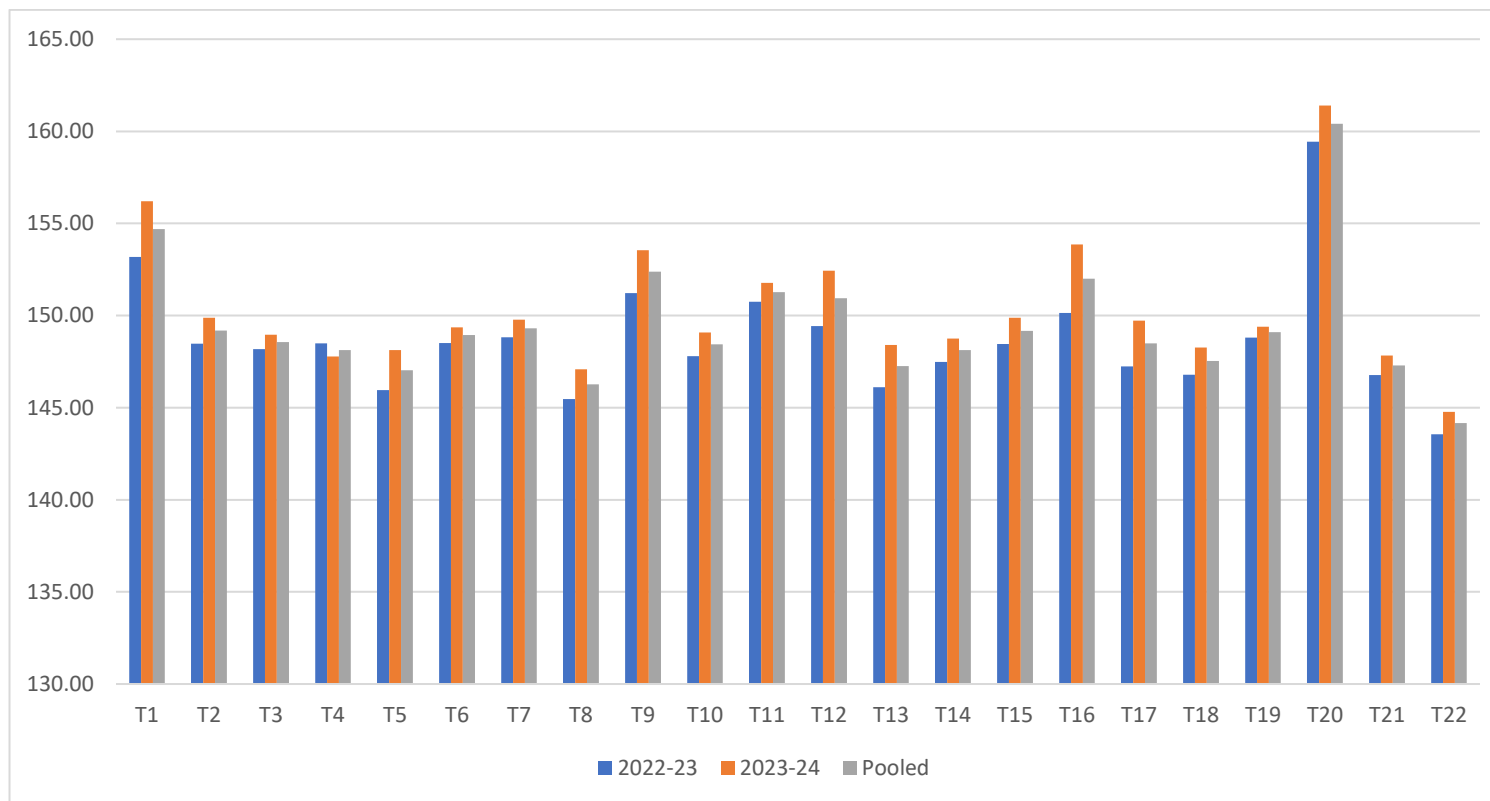


Figure 4.12: Effect of nanofertilizer based INM on crop duration

4.1.13 Vine length

The data on vine length in chow chow and its effect by different sources of nutrients are depicted in Table 4.13 and Figure 4.13. As demonstrated by one way ANOVA, the data indicates that there is variation within the treatments and the CD value at a 5% significance level shows that differences in the vine length greater than 0.39 m (Pooled) across treatments are statistically significant. Treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] had the longest vine length with a Pooled value of 7.01 m while treatment T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₁ [Full dose of RDF (N through urea)] also recorded substantial growth with a vine length of 6.86 m and 6.72 m respectively. The shortest vine length was noted in the treatment T₂₂ (Control) with an average pooled of 4.57 m followed subsequently by treatment T₄ (VC @ 5 t ha⁻¹). Also, the inclusion of microbial consortium typically resulted in longer vine length across treatments. For instance, T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] had the longest vine length at 7.01 m while treatments without microbial consortium, such as T₁₈ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea)] had shorter vine length (5.40 m).

4.1.14 Sex ratio

The data on sex ratio in chow chow and its effect by different sources of nutrients are depicted in Table 4.14 and Figure 4.14. As demonstrated by one way ANOVA, the data indicates that there is variation within the treatments and the CD value at a 5% significance level shows that differences in the vine length greater than 0.94 (Pooled) across treatments are statistically significant. T₂₂ (Control) had the highest sex ratio of 9.09 (pooled), indicating that the control treatment produced significantly more male flowers while, treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] recorded the lowest sex ratio with a mean pooled value of 5.87 and 6.01 respectively.

Table 4.13: Effect of nanofertilizer based INM on vine length

Sl. no.	Treatment	Vine length (m)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	6.63	6.81	6.72
T ₂	Full dose of RDF (N through nano urea)	5.42	5.57	5.50
T ₃	FYM @ 20 t ha ⁻¹	5.29	5.39	5.34
T ₄	VC @ 5 t ha ⁻¹	4.80	4.88	4.84
T ₅	PM @ 10 t ha ⁻¹	4.96	5.06	5.01
T ₆	FYM @ 20 t ha ⁻¹ + MC	5.49	5.57	5.53
T ₇	VC @ 5 t ha ⁻¹ + MC	5.46	5.67	5.57
T ₈	PM @ 10 t ha ⁻¹ + MC	5.39	5.71	5.55
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	5.16	5.49	5.33
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	5.43	5.61	5.52
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	5.38	5.57	5.48
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	6.83	6.90	6.86
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	5.27	5.47	5.37
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	5.23	5.42	5.33
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	5.53	5.64	5.59
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	6.75	6.60	6.68
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	6.32	6.52	6.42
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	5.26	5.55	5.40
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	5.37	5.45	5.41
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	7.17	6.84	7.01
T ₂₁	Farmers practise	5.12	5.21	5.17
T ₂₂	Control	4.48	4.66	4.57
SEm±		0.22	0.18	0.14
CD (P=0.05)		0.64	0.53	0.39

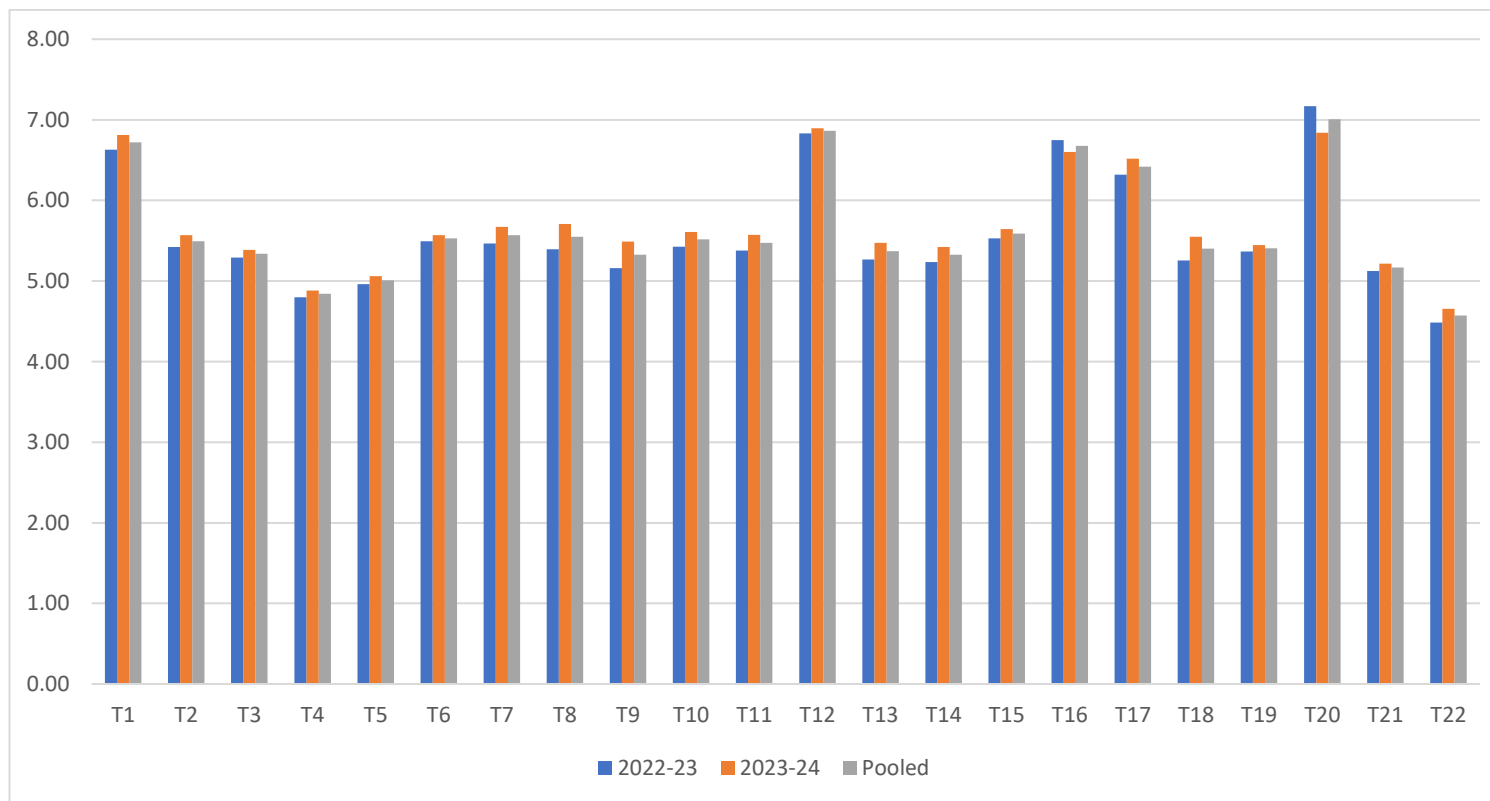


Figure 4.13: Effect of nanofertilizer based INM on vine length

Table 4.14: Effect of nanofertilizer based INM on sex ratio

Sl. no.	Treatment	Sex ratio (M:F)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	6.22	6.09	6.16
T ₂	Full dose of RDF (N through nano urea)	7.51	7.25	7.38
T ₃	FYM @ 20 t ha ⁻¹	8.76	8.65	8.70
T ₄	VC @ 5 t ha ⁻¹	8.77	8.59	8.68
T ₅	PM @ 10 t ha ⁻¹	7.76	7.58	7.67
T ₆	FYM @ 20 t ha ⁻¹ + MC	8.55	8.34	8.44
T ₇	VC @ 5 t ha ⁻¹ + MC	8.33	8.10	8.22
T ₈	PM @ 10 t ha ⁻¹ + MC	7.93	7.68	7.80
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	8.34	8.13	8.24
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	8.67	8.39	8.53
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	7.29	7.03	7.16
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	6.36	6.13	6.25
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	8.39	8.22	8.30
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	6.76	6.52	6.64
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	6.99	6.85	6.92
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	6.09	5.93	6.01
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	8.38	8.21	8.29
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	7.09	6.87	6.98
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	7.60	7.39	7.49
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	5.94	5.81	5.87
T ₂₁	Farmers practise	8.46	8.30	8.38
T ₂₂	Control	9.16	9.03	9.09
SEm±		0.33	0.33	0.33
CD (P=0.05)		0.95	0.94	0.94

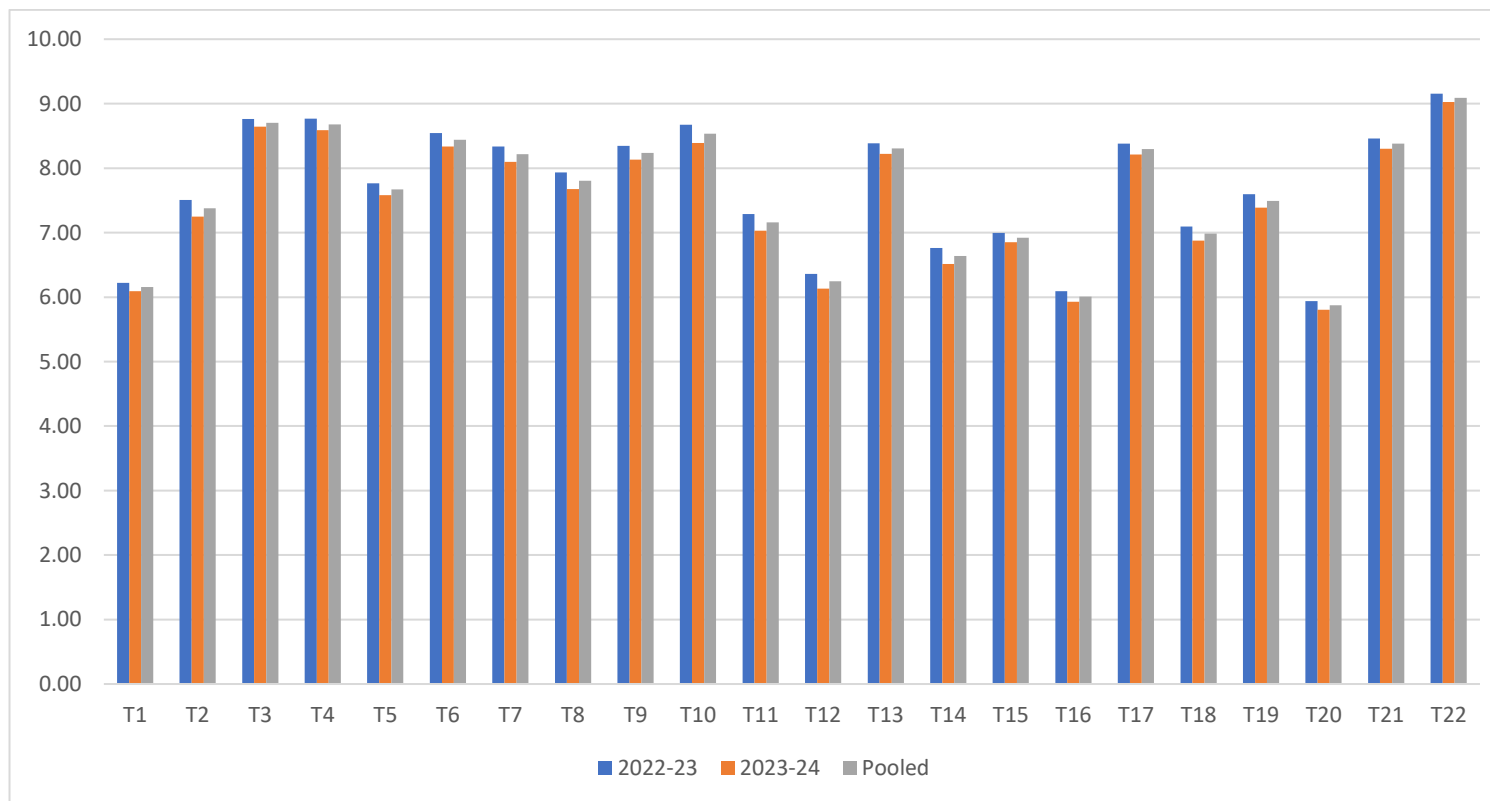


Figure 4.14: Effect of nanofertilizer based INM on sex ratio

The vegetative growth parameters of chow-chow influenced by nanofertilizers based integrated nutrient management were measured in terms of number of leaves per plant, number of primary branches, leaf length (cm), leaf width (cm), leaf area (cm²), internodal length (cm), node at first female flowering, node at first male flowering, days to first female flowering, days to first male flowering, days to marketable maturity (days), crop duration (days), vine length (m), and sex ratio (Male:Female).

The observed higher number of leaves in the treatment incorporated with (T₂₀) PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (as shown in Table 4.1) may possibly be to the sufficient supply of nitrogenous fertilizers which steered to better and enhanced vegetative growth in plants. The timely application of nanofertilizers during critical growth stages and at appropriate concentration ensures efficient utilization of nutrients and consistent nutrient availability throughout the growth and development of the plant. Similar to other nanomaterials, the nutrients of nanofertilizers are also supplied in a controlled way. As the size of the particles being used is very small the surface area is much larger facilitating nutrient use efficiency (Neerugi, 2024). Nitrogen, as a vital component of chlorophyll, plays a crucial role in photosynthesis and supports the overall vegetative growth of plants. Additionally, it is also a basic component of amino acids, which are essential for the production of enzymes that may control different metabolic activities in plants. Poultry manure, being rich in nitrogen, may enhance vegetative growth. Its well-balanced nutrient makeup, which includes micronutrients, potassium, and phosphorus, may further promote leaf development and overall plant health. The microbial consortium which contains nitrogen fixing bacteria, phosphorous solubilising bacteria and potassium mobilising bacteria may help in augmenting nutrient availability, improve in soil health and enhance root growth. These results are in conformity with Merghany *et al.* (2019) in cucumber. Similar results were recorded by Eifediyi and Remison (2010) and Hemavathi (2022).

The maximum number of primary branches (as shown in Table 4.2) was apparent in the treatment that was integrated with PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀). This increase may be due to nitrogen present in nano urea which ensures efficient nutrient supply and assists in promoting vegetative growth by enhancing cell division and cell elongation (Morteza *et al.*, 2013). The controlled

release nature of nano urea may also help in continuous supply of nutrient throughout its growth and development of the plant. Nano urea may also synthesis plant growth regulators which may promotes hormonal balance in plants thereby increase in growth of primary branches. Rathod *et al.* (2022) describes that an increased leaf count may result from the nutrients delivered by foliar application which helps the cell to quickly reach through the stomata or cuts and scrapes in the leaves, which helps to maintain the continuity and speed of delivery of nutrients necessary for plant metabolic activities. Poultry manure significantly improves soil organic matter content, which may enhance the soil's physical structure, water retention capacity, and overall fertility. Additionally, it could also stimulate microbial activity in the soil, promoting the growth and proliferation of beneficial microorganisms. These microbes play a vital role in breaking down organic matter, releasing essential nutrients in forms that can be readily available for plant uptake. The improved nutrient availability may therefore create optimal plant growth conditions and increase vegetative growth. This nutrient-rich environment could foster the initiation of shoots and may also encourage the development of primary branches, thus contributing to better plant structure and productivity (Tripathi *et al.*, 2018). The results are in conformity with Behera (2023) and Baghel *et al.* (2016) in bottle gourd and Singh *et al.* (2018) in cucumber.

The application of nitrogen plays a substantial role in endorsing the vegetative growth. The treatment amended with PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) observed a significant increase in leaf length. This improvement in leaf length could be attributed to the continuous and controlled release of nitrogen by nano urea during critical growth stages, enabling efficient nutrient utilization, minimising loss and maximising nutrient absorption, and thus enhancing leaf elongation (Behera, 2023). Additionally, with the integration of poultry manure and biofertilizers may stimulate the production of plant growth regulators in plants such as auxins, cytokinins, and gibberellins, further contributing to leaf elongation (Aravinda *et al.*, 2022). The synergistic effect of nano urea, poultry manure, and biofertilizers may therefore create an ideal growth environment which may help in ensuring optimal nutrient availability and hormonal regulation, which could further contribute to enhanced leaf length and overall vegetative development (Jagraj *et al.*, 2018). Similar results were obtained by Satish *et al.* (2017) in bottle gourd, Aravinda *et al.* (2022) in muskmelon and Jagraj *et*

al. (2018) in cucumber.

The treatment incorporated with PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) was recorded the longest leaf width. This increase maybe because of the synergistic effect of the poultry manure along with nano urea and biofertilizers which helps to provide nutrients at a consistent and controlled rate and help in the availability of nutrients throughout its growth and development. The added organic manures would have increased its physical, chemical and biological properties which help in nutrient absorption and utilization by the plant resulting better growth (Aravinda *et al.*, 2022). Treatment T₂ [Full dose of RDF (N through nano urea)] did not perform well as compared to T₁. This difference may be for the reason that the lack of nutrient application at the early growth stage of the plant resulted in reduction of vegetative growth. Analogous results were obtained by Satish *et al.* (2017) in bottle gourd, Aravinda *et al.* (2022) in muskmelon and Jagraj *et al.* (2018) in cucumber.

Highest leaf area was perceived in the treatment integrated with PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀). This significant increase may be attributed because of the higher application of nutrients which results in better vegetative growth. Nano urea may application also bring on to an upsurge in leaf area because of its minute size and ability to enter the cell wall of plant cells which allows higher absorption and metabolic activity (Hemavathi, 2022). The combined effect of nano urea alongside with poultry manure and microbial consortium results may lead to an enlargement in both leaf length and leaf width, which could bring about a surge in leaf area. This is in accordance with the work of Al Jabri *et al.* (2020) in okra and Mishra *et al.* (2020) in tomato and Yasser *et al.* (2020).

In cucurbits, generally shorter internodal length is considered as a desirable trait over longer internodal length as it increases the production of leaves and enhanced photosynthetic efficiency (Sahu *et al.*, 2022). The shortest internodal length was noted in the treatment where the treatment was incorporated with FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₂) while there was a significant increase in internodal length in treatment where no additional nutrients were added *i.e.*, treatment control. Integrated application of nano urea beside with organic manures and microbial consortia reduced the internodal length by 2 cm across two growing cycles in chow-chow whereas use of organic manures alone leads to a reduction by 1 cm in internodal

length. This decrease in internodal length may perhaps as a result of balanced application of the nutrients which could result in optimal vegetative growth and reduce excessive elongation of internodes. Identical results were recorded by Behera, (2023) in sponge gourd, Baghel *et al.* (2017) and Patle *et al.* (2018) in bottle gourd and Rathod *et al.* (2018) in ridge gourd.

The node at first female flowering was reflected lowest in the treatment amended with VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₆). Similarly, the integrated application of PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) and FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₂) also recorded the first female flowering at lower node. This may be attribute to the balanced application of fertilizers in combination with organic manures and microbial consortia which may provide an optimal vegetative growth and could encouraged the plants to initiate female flowers without promoting excessive growth and delayed flowering (Kharga *et al.*, 2019). The application of microbial consortia might stimulate plant hormones which may also regulate early flowering in plants. The current findings were in accordance with Thriveni *et al.* (2015) in bitter gourd, Wahocho *et al.* (2016) in cucumber and Thongney *et al.* (2020) in cucumber wherein the rubbing in of balanced nutrients lead to earlier flowering.

The node at first male flowering was perceived lowest across the treatment integrated with VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₆). In contrast the highest node for first male flowering was detailed in the treatment control, with a difference of 5 nodes across the two crop growing cycles. This significant difference may well be owed to the use of balanced fertilization with nano urea in combination with vermicompost and microbial consortium. This integrated approach may not only supply nutrients at a continuous rate but could also stimulate growth hormones, which are essential for the primordial development of flowers and may allow the plant to initiate early flowering the control treatment, where no additional inputs were added, may suffer nutrient limitation which might allow the plant to push the male flowering to a higher node. These are validated by the findings of Thriveni *et al.* (2015) in bitter gourd, Wahocho *et al.* (2016) in cucumber and Behera (2023) in sponge gourd.

The efficacy of the treatment PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea)

+ MC (T₂₀) was reflected in the fact of the earlier flowering of the females in chow-chow in comparison with the control and even with the use of chemical fertilizers or organic manures only. This may be because of the integration of quick-release fertilizers, slow-release organic sources and controlled-released nano urea which might allow a steady supply of nutrients, thus preventing vegetative overgrowth and may initiate early flowering. The addition of organic amendments and microbial consortia may also allow the plant to increase the production of growth hormones, which could initiate early flowering. The utilization of both the synthetic fertilizers and organic manures together may also reduce the nutrient deficiency in the plants and therefore may prevent stress in the plant; hence, delay in flowering may be minimized. Another cause for earliness in flowering may also be put down to better translocation of nutrients (Tripathi *et al.*, 2018). Corresponding results were also documented by Baghel *et al.* (2017) in bottle gourd, Singh *et al.* (2017) in cucumber and Behera (2023) in sponge gourd.

The interaction of PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) recorded the earliest male flowering in chow-chow compared to the control or the expend of chemical fertilizers alone or organic manures alone. This could be accredited to the fact that the use of integrated sources of nutrients from chemical fertilizers, organic manures and microbial consortia permits the plant to reduce nutrient-related stress, which in turn may allocate the plant to develop steadily with an optimal supply of nutrients and increase in the early initiation of male flower. The control treatment along with the treatment that uses solely organic sources, recorded the most delayed male flowering. This delay in flowering may be due to lack of readily available nutrients in the control treatment and the slow nutrient release from organic sources when used alone which may not meet the plant nutritional demand during the critical growth stages consequently leading to delay in initiation of male flowering. These results are in accordance with Baghel *et al.* (2017) in bottle gourd, Singh *et al.* (2017) in cucumber and Behera (2023) in sponge gourd.

The earliest marketable maturity was obtained in the treatment which was amended with PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) as equated to the control treatment where delay in marketable maturity was observed. This significant difference is ascribed to the use of balanced nutrients and nano urea

apparently leading to different marketable maturity. Nano urea contains nitrogen, which is an indispensable component of chlorophyll, and therefore the photosynthesis rate might be enhanced by the application of nano urea. This could provide the energy for forming stimuli to set the fruits, their development and ripening at a faster rate. The use of the organic amendments and the microbial consortium may offer a complete nutrient package including micronutrients and therefore will lead to faster maturity rates. The combined use of chemical fertilizer with organic manures and microbial consortia may also affect plant hormones that may induce early fruit development and ripening. The control treatment where no nutrients were added may not have available nutrients to complement the plant which may lead to a delay in market maturity. Sahu *et al.* (2020) described that the early maturity in cucumber may be due to better translocation of nutrients to the aerial parts. Similar results were recorded by Singh *et al.* (2017) in cucumber and Behera (2023) in sponge gourd.

The longest crop duration was observed in the treatment where PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) was integrated whereas the shortest crop duration was recorded in the treatment control. This longer time for crop growth can however be explained by the impacts that arise from the implementation of the INM approach. Organic matter that was obtained from poultry manure may enhance soil structure by providing nutrients in a slow, constant and balanced manner for the growing crops. The use of nano urea may allow for a steady release of nitrogen which might be essential for vegetative and reproductive growth. Moreover, the use of microbial consortia might enhance nutrient solubilization and formulate the synthesis of the plant growth regulators including auxin and cytokinin. These hormones may prolong the duration of active growth and fruit development periods. The control treatment, however, which did not contain such inputs may not furnish the plants with nutrient requirements or the ideal environmental requirements needed for growth. As such, the duration in plants under the control treatment was observed to be shorter. Behera (2023) describe that observe longer crop duration in sponge gourd on treatments amended by nano urea may be as a consequence of prolonged accessibility of nitrogen throughout the crop growth stages as the unused nano urea particles are stored in vacuoles of the cells and released as and when required by the plant. Similar findings were reported by Prasad *et al.* (2016) in bottle gourd and Wahocho *et al.* (2017) in

muskmelon.

The treatment which was amended with PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) was observed the longest vine length. This may possibly be due to the integration of chemical inputs alongside with organic sources of nutrients and microbial consortia which might allow an optimal and balanced supply of nutrients (Benzon *et al.*, 2015). The incorporation of nano urea could enhance nitrogen availability which may promote cell elongation and division and further lead to an increase in vine length (Ghormade *et al.*, 2011). Also, the gradual release of nitrogen from nano urea may ensure supply of nitrogen throughout its critical growth stage which may mitigate nitrogen related stress. Microbial consortia, which contain beneficial microorganisms might increase the organic matter decomposition and may also enhance soil health by improving the soil structure, water retention and increase in microbial activity in the soil which may create favourable condition for the roots and further allow the root to absorb nutrient efficiently, thus encouraging vine length. The outcomes of this experiment validate with results of Tripathi *et al.* (2018) in Behera (2023) in sponge gourd, Baghel *et al.* (2017) in bottle gourd and Singh *et al.* (2017) in cucumber.

The sex ratio (M:F), particularly in cucurbitaceous vegetables is important to determine yield as the female flower directly influences the production of the fruits. The treatment which was incorporated with PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) and VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₆) recorded the lowest sex ratio as compared to the treatment control which was recorded the highest. The lower sex ratio may possibly be due to the production of equal number of female flowers as that of male flower (Anjanappa *et al.*, 2008). The significant difference in sex ratio (M:F) maybe because of the balanced fertilization of the nutrients which may influence in maintaining a favourable sex ratio. The combined application of inorganic fertilizers, organic manures and microbial consortium may provide a stable supply of nutrients which may prevent excessive vegetative growth and may encourage the development of female flowers. Also, the application of nano urea which allows the nutrient to release in controlled form helps in balancing male to female flower ratio as excess nitrogen may favor the production of higher male flowers. The application of microbial consortium which helps in stimulation of plant growth

hormones such as auxin and gibberellin, may promote development of more female flowers and might maintain the balance of auxin and ethylene as higher ethylene leads to formation of additional female flowers. The outcomes are in compliance with the findings of Anjanappa *et al.* (2012) in cucumber and Jagraj *et al.* (2018) in cucumber.

4.2 Yield parameters

4.2.1 Number of fruits per plant

The data on the number of fruits per plant and it's influenced by different sources of nutrients is detailed on Table 4.15 and Figure 4.15. Table 4.15 shows that there were significant differences between the treatments as demonstrated by one-way ANOVA. Treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] recorded the highest number of fruits per plant with a pooled average of 15.65, followed closely by T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] with a pooled value of 15.47 and 15.37 fruits per plant respectively. Treatment incorporated with microbial consortium were recorded as intermediate performers. For instance, treatment T₁₁ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through urea) + MC], T₁₅ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through urea) + MC] and T₁₉ [PM @ 5 t ha⁻¹ + ½ of RDF (N through urea) + MC] resulted in 13.97, 14.20 and 14.13 fruits per plant respectively while treatment control (T₂₂) recorded the lowest number of fruits per plant with a pooled average of 10.37.

4.2.2 Fruit length

The data on the fruit length and it's influenced by different sources of nutrients is detailed on Table 4.16 and Figure 4.16. Table 4.16 shows that there were significant differences between the treatments as demonstrated by one-way ANOVA. Treatment T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] recorded the longest fruits with a pooled length of 13.40 and 13.29 cm respectively while treatment T₁ (control) recorded the shortest fruit length with an average of 8.68 cm. Treatment T₂₁ (Farmers practice) produced fruit length of 10.20 cm, which is moderately good but lower than integrated treatments involving microbial consortium and nano urea.

Table 4.15: Effect of nanofertilizer based INM on number of fruits per plant

Sl. no.	Treatment	Number of fruits per plant		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	15.27	15.07	15.17
T ₂	Full dose of RDF (N through nano urea)	11.33	11.40	11.37
T ₃	FYM @ 20 t ha ⁻¹	10.93	11.07	11.01
T ₄	VC @ 5 t ha ⁻¹	10.33	10.47	10.40
T ₅	PM @ 10 t ha ⁻¹	12.13	12.20	12.17
T ₆	FYM @ 20 t ha ⁻¹ + MC	11.87	11.93	11.90
T ₇	VC @ 5 t ha ⁻¹ + MC	11.33	11.47	11.40
T ₈	PM @ 10 t ha ⁻¹ + MC	11.40	11.53	11.47
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	12.20	12.33	12.27
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	12.60	12.73	12.67
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	13.87	14.07	13.97
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	15.33	15.40	15.37
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	13.13	13.27	13.20
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	13.60	13.67	13.63
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	14.13	14.27	14.20
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	15.40	15.53	15.47
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	13.40	13.33	13.37
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	12.87	12.73	12.80
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	14.07	14.20	14.13
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	15.60	15.70	15.65
T ₂₁	Farmers practise	13.33	13.40	13.37
T ₂₂	Control	10.40	10.33	10.37
SEm±		0.34	0.34	0.33
CD (P=0.05)		0.98	0.97	0.95

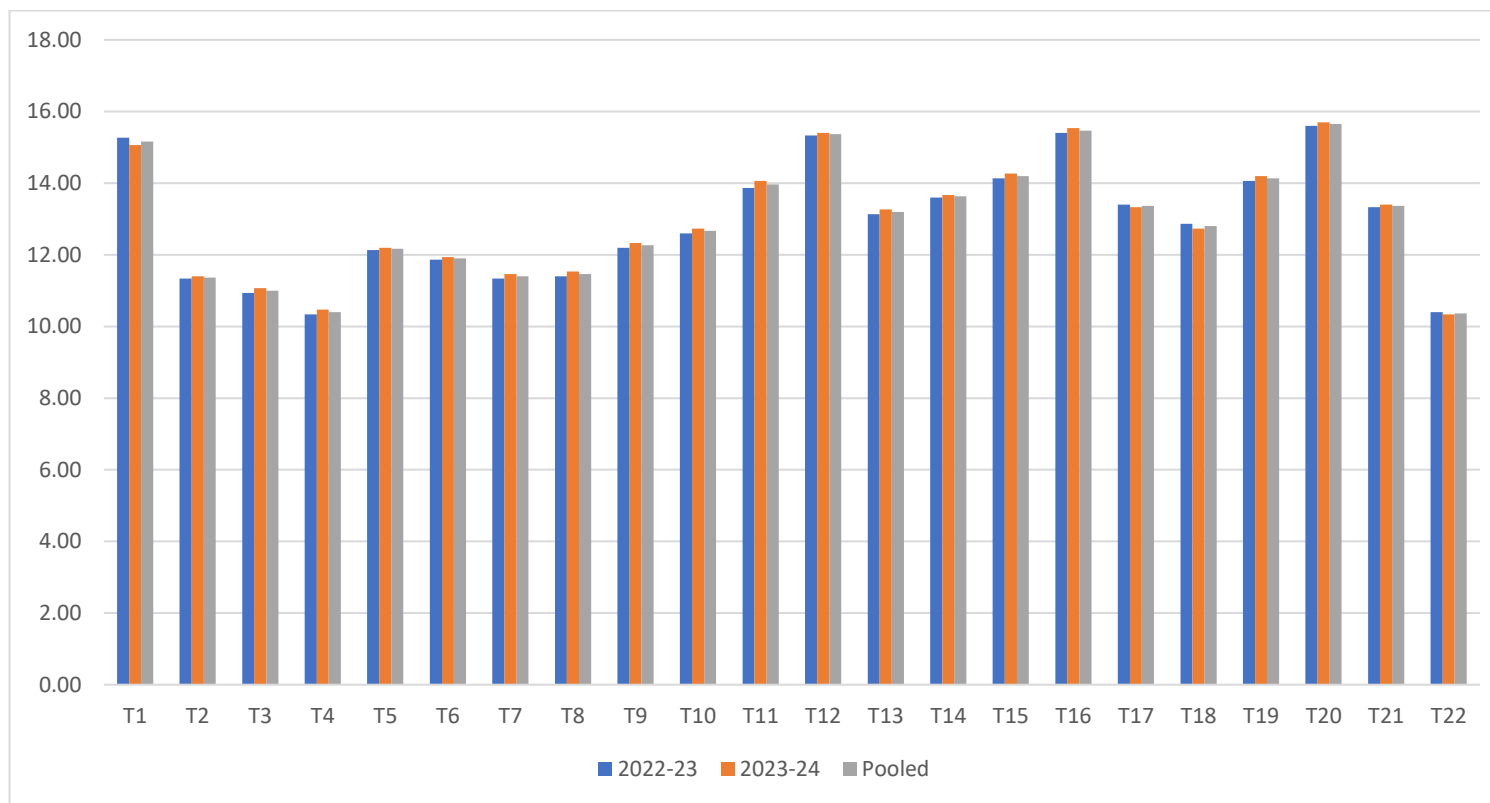


Figure 4.15: Effect of nanofertilizer based INM on number of fruits per plant

Table 4.16: Effect of nanofertilizer based INM on fruit length

Sl. no.	Treatment	Fruit length (cm)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	12.06	12.08	12.07
T ₂	Full dose of RDF (N through nano urea)	9.59	9.51	9.55
T ₃	FYM @ 20 t ha ⁻¹	11.07	11.21	11.14
T ₄	VC @ 5 t ha ⁻¹	10.95	11.95	11.45
T ₅	PM @ 10 t ha ⁻¹	10.49	11.42	10.96
T ₆	FYM @ 20 t ha ⁻¹ + MC	11.15	11.73	11.44
T ₇	VC @ 5 t ha ⁻¹ + MC	10.20	10.75	10.48
T ₈	PM @ 10 t ha ⁻¹ + MC	11.40	11.74	11.57
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	9.45	10.07	9.76
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	10.77	11.37	11.07
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	11.21	11.10	11.16
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	13.03	13.76	13.40
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	10.25	10.90	10.58
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	9.57	9.75	9.66
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	10.36	10.91	10.64
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	11.53	11.85	11.69
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	9.92	10.64	10.28
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	10.66	11.38	11.02
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	10.83	10.87	10.85
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	12.97	13.62	13.29
T ₂₁	Farmers practise	10.03	10.37	10.20
T ₂₂	Control	8.59	8.78	8.68
SEm±		0.26	0.37	0.23
CD (P=0.05)		0.74	0.96	0.66

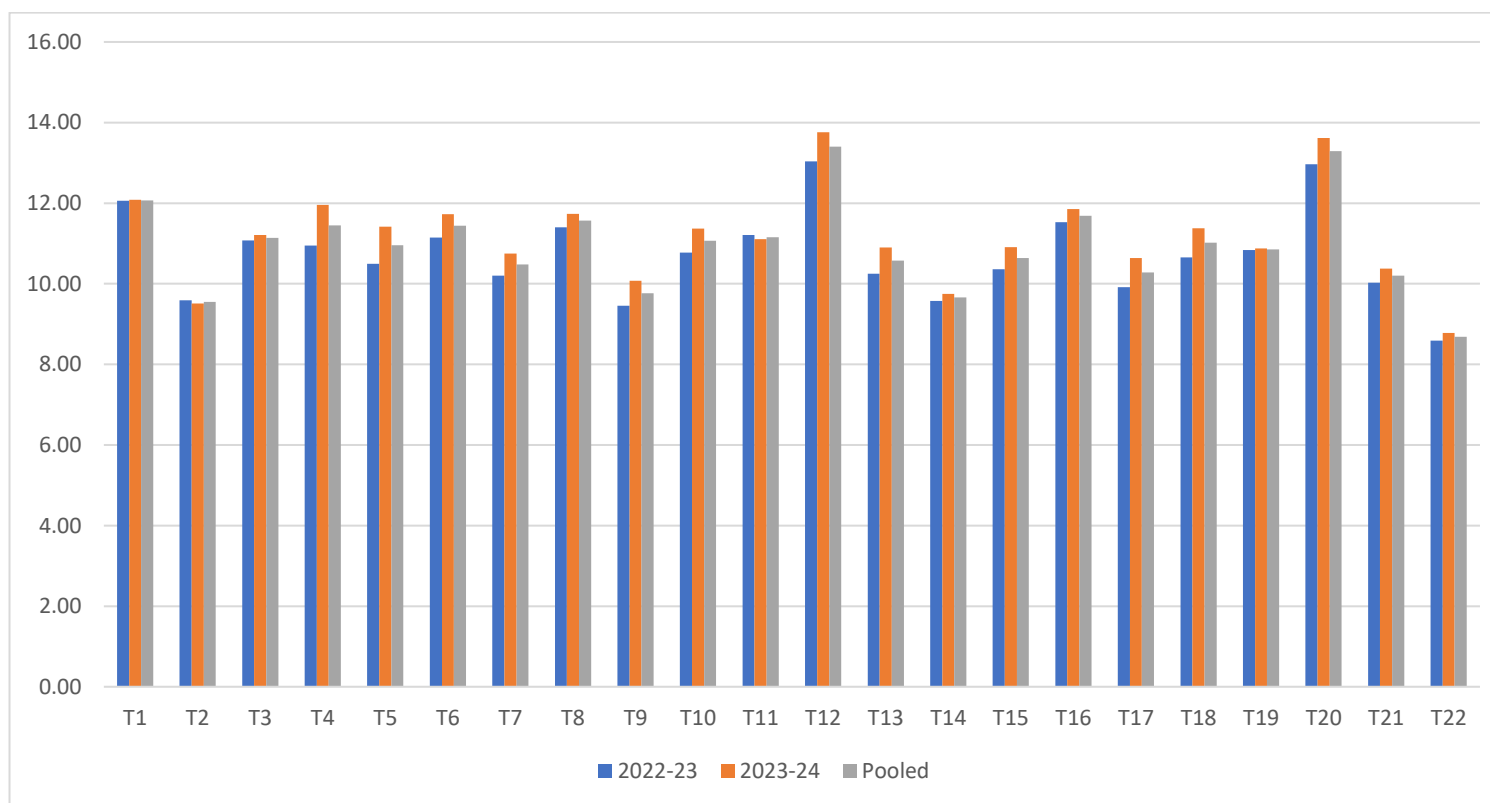


Figure 4.16: Effect of nanofertilizer based INM on fruit length

4.2.3 Fruit diameter

The experimental results regarding the influence of nanofertilizers based integrated nutrient management on fruit diameter are detailed in Table 4.17 and Figure 4.17. The data shows that there was significant difference between the treatments as demonstrated by one-way ANOVA. Treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] exhibited the largest fruit diameter with a pooled value of 8.98 cm followed by T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] with a pooled average of 8.91 cm and 8.50 cm respectively. T₂ [Full dose of RDF (N through nano urea)] recorded the lowest average fruit diameter at 6.62 cm (pooled) just behind the treatment control (T₂₂) with 6.71 cm (pooled).

4.2.4 Average weight of fruit

The experimental results regarding the influence of nanofertilizers based integrated nutrient management on the average weight of the fruit are detailed in Table 4.18 and Figure 4.18. The data shows that there was significant difference between the treatments as demonstrated by one-way ANOVA. The treatment with the highest pooled average weight of fruit was documented in the treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] with 482.40 g. Treatment T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] was statistically on parity with treatment T₂₀ with an average weight of 450.42 g (pooled). Treatment control (T₂₂) recorded the lowest average weight of fruit with a pooled value of 297.11 g.

Table 4.17: Effect of nanofertilizer based INM on fruit diameter

Sl. no.	Treatment	Fruit diameter (cm)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	8.06	8.16	8.11
T ₂	Full dose of RDF (N through nano urea)	6.56	6.69	6.62
T ₃	FYM @ 20 t ha ⁻¹	7.10	7.29	7.20
T ₄	VC @ 5 t ha ⁻¹	7.18	7.30	7.24
T ₅	PM @ 10 t ha ⁻¹	7.81	8.10	7.96
T ₆	FYM @ 20 t ha ⁻¹ + MC	7.75	7.95	7.85
T ₇	VC @ 5 t ha ⁻¹ + MC	7.66	7.69	7.67
T ₈	PM @ 10 t ha ⁻¹ + MC	7.46	7.60	7.53
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	7.59	7.76	7.68
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	8.13	8.35	8.24
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	7.81	8.22	8.02
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	8.82	9.01	8.91
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	7.89	8.05	7.97
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	7.26	7.50	7.38
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	6.99	7.12	7.06
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	8.41	8.59	8.50
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	6.97	7.05	7.01
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	7.35	7.47	7.41
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	6.99	7.15	7.07
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	8.86	9.09	8.98
T ₂₁	Farmers practise	7.05	7.12	7.09
T ₂₂	Control	6.75	6.66	6.71
SEm±		0.16	0.31	0.21
CD (P=0.05)		0.48	0.88	0.57

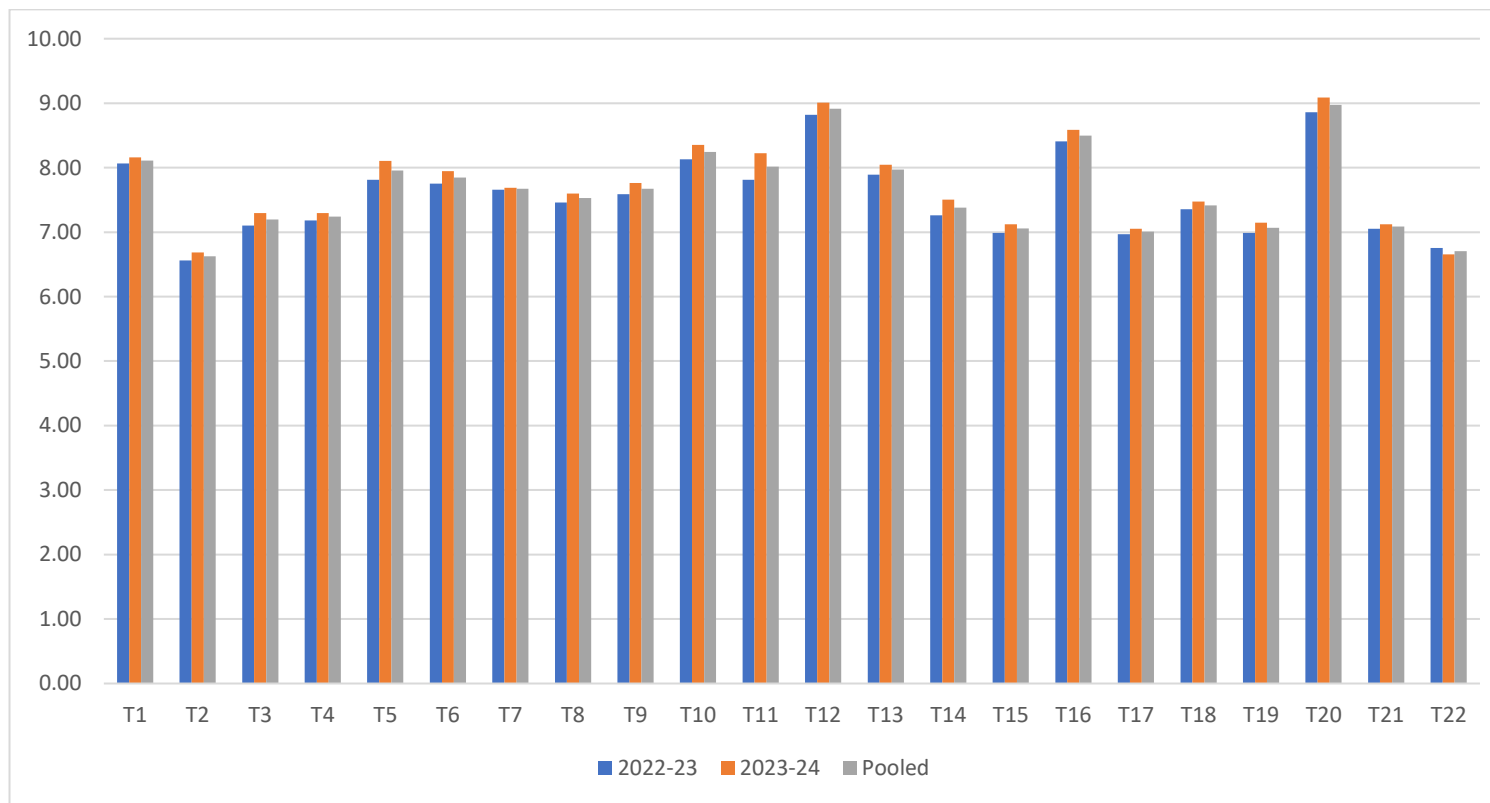


Figure 4.17: Effect of nanofertilizer based INM on fruit diameter

Table 4.18: Effect of nanofertilizer based INM on average weight of fruit

Sl. no.	Treatment	Average weight of fruit (g)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	415.52	418.56	417.04
T ₂	Full dose of RDF (N through nano urea)	312.85	315.13	313.99
T ₃	FYM @ 20 t ha ⁻¹	352.52	357.30	354.91
T ₄	VC @ 5 t ha ⁻¹	325.48	329.98	327.73
T ₅	PM @ 10 t ha ⁻¹	303.59	309.63	306.61
T ₆	FYM @ 20 t ha ⁻¹ + MC	403.32	406.45	404.89
T ₇	VC @ 5 t ha ⁻¹ + MC	335.26	338.88	337.07
T ₈	PM @ 10 t ha ⁻¹ + MC	314.93	312.71	313.82
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	309.61	312.86	311.23
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	381.41	376.45	378.93
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	354.90	357.64	356.27
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	448.82	452.02	450.42
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	305.58	308.25	306.92
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	306.90	308.57	307.74
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	363.18	367.23	365.21
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	431.43	425.14	428.28
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	301.41	304.27	302.84
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	302.55	303.10	302.82
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	358.77	361.57	360.17
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	480.28	484.52	482.40
T ₂₁	Farmers practise	328.71	330.19	329.45
T ₂₂	Control	299.86	294.36	297.11
SEm±		17.58	29.71	17.71
CD (P=0.05)		50.35	85.08	50.71

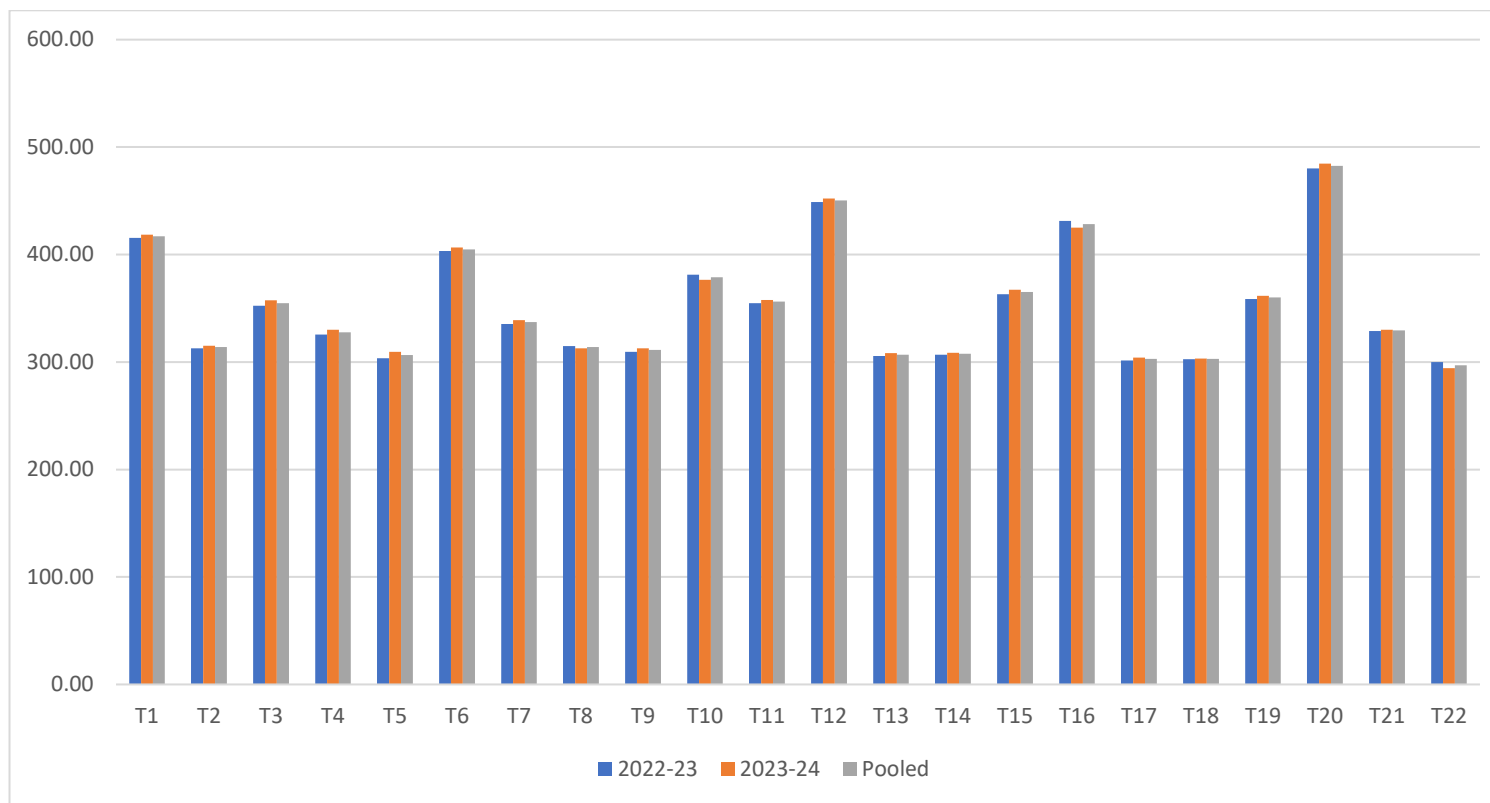


Figure 4.18: Effect of nanofertilizer based INM on average weight of fruit

4.2.5 Yield per plant

The data portrayed in Table 4.19 and Figure 4.19 show the outcome of different sources of nutrients on the yield per plant in chow-chow. As demonstrated by one-way ANOVA, the data indicates that there is variation within the treatments and the CD value at a 5% significance level shows that differences greater than 0.86 kg (Pooled) across treatments are statistically significant. Treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] detailed the highest yield per plant with a pooled average of 7.57 kg plant⁻¹. T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + Microbial consortium] and T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] also performed well with an average pooled yield of 6.93 kg plant⁻¹ and 6.62 kg plant⁻¹ respectively. Treatment control (T₂₂) was recorded with the lowest yield with an average of 3.08 kg plant⁻¹.

4.2.6 Yield per ha

The data portrayed in Table 4.20 and Figure 4.20 show the effect of different sources of nutrients on the yield per ha in chow-chow. As demonstrated by one-way ANOVA, the data indicates that there is variation within the treatments and the CD value at a 5% significance level shows that differences greater than 74.04 q (Pooled) across treatments are statistically significant. Treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] documented the highest yield per ha with a pooled yield of 681.40 q ha⁻¹. The second highest yield was perceived in the treatment T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] with pooled yield of 676.88 q ha⁻¹, followed by T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] with 662.32 q ha⁻¹. Treatment control (T₂₂) recorded the lowest yield with a pooled average of 339.99 q ha⁻¹.

Table 4.19: Effect of nanofertilizer based INM on yield per plant

Sl. no.	Treatment	Yield per plant (kg)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	6.34	6.31	6.33
T ₂	Full dose of RDF (N through nano urea)	3.55	3.59	3.57
T ₃	FYM @ 20 t ha ⁻¹	3.86	3.95	3.91
T ₄	VC @ 5 t ha ⁻¹	3.36	3.45	3.41
T ₅	PM @ 10 t ha ⁻¹	3.69	3.78	3.73
T ₆	FYM @ 20 t ha ⁻¹ + MC	4.78	4.85	4.81
T ₇	VC @ 5 t ha ⁻¹ + MC	3.79	3.89	3.84
T ₈	PM @ 10 t ha ⁻¹ + MC	3.58	3.61	3.59
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	3.77	3.86	3.82
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	4.80	4.79	4.80
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	4.93	5.03	4.98
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	6.89	6.96	6.93
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	4.01	4.09	4.05
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	4.18	4.22	4.20
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	5.13	5.24	5.19
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	6.64	6.60	6.62
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	4.04	4.06	4.05
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	3.91	3.86	3.88
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	5.05	5.13	5.09
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	7.54	7.61	7.57
T ₂₁	Farmers practise	4.40	4.42	4.41
T ₂₂	Control	3.12	3.04	3.08
SEm±		0.26	0.46	0.31
CD (P=0.05)		0.75	1.32	0.86

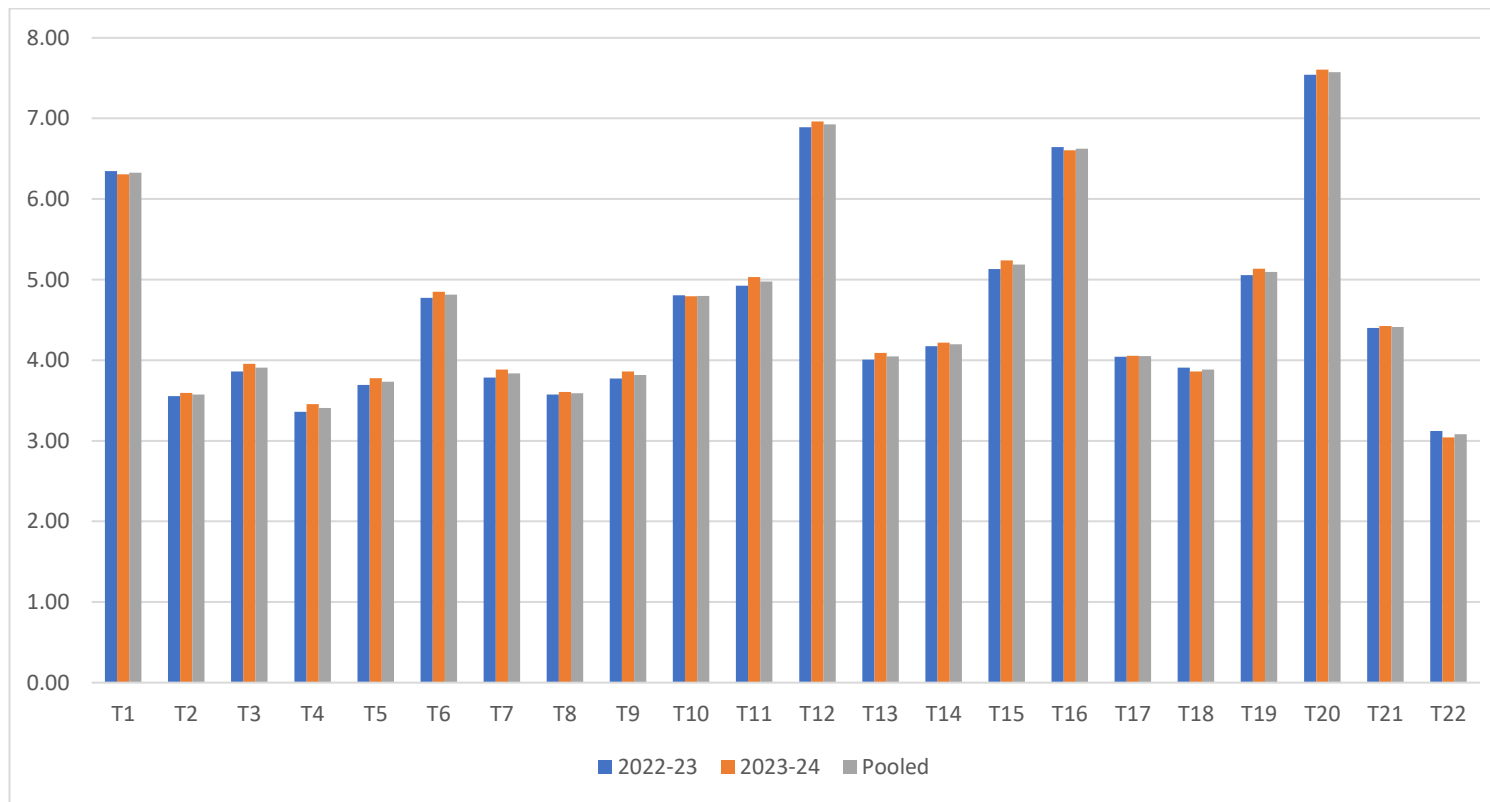


Figure 4.19: Effect of nanofertilizer based INM on yield per plant

Table 4.20: Effect of nanofertilizer based INM on yield per ha

Sl. no.	Treatment	Yield per ha (q)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	604.48	606.65	605.56
T ₂	Full dose of RDF (N through nano urea)	455.49	458.37	456.93
T ₃	FYM @ 20 t ha ⁻¹	386.01	396.37	391.19
T ₄	VC @ 5 t ha ⁻¹	370.68	371.11	370.90
T ₅	PM @ 10 t ha ⁻¹	380.90	381.82	381.36
T ₆	FYM @ 20 t ha ⁻¹ + MC	477.55	482.10	479.83
T ₇	VC @ 5 t ha ⁻¹ + MC	378.60	393.22	385.91
T ₈	PM @ 10 t ha ⁻¹ + MC	357.62	362.68	360.15
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	381.42	385.72	383.57
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	479.48	480.46	479.97
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	502.51	505.27	503.89
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	675.64	678.13	676.88
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	400.85	409.97	405.41
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	417.52	421.23	419.37
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	513.26	524.06	518.66
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	664.29	660.36	662.32
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	404.14	403.47	403.80
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	390.85	387.84	389.34
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	505.40	513.87	509.63
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	680.76	682.04	681.40
T ₂₁	Farmers practise	439.95	444.93	442.44
T ₂₂	Control	336.08	343.90	339.99
SEm±		22.45	38.87	25.85
CD (P=0.05)		72.91	111.33	74.04

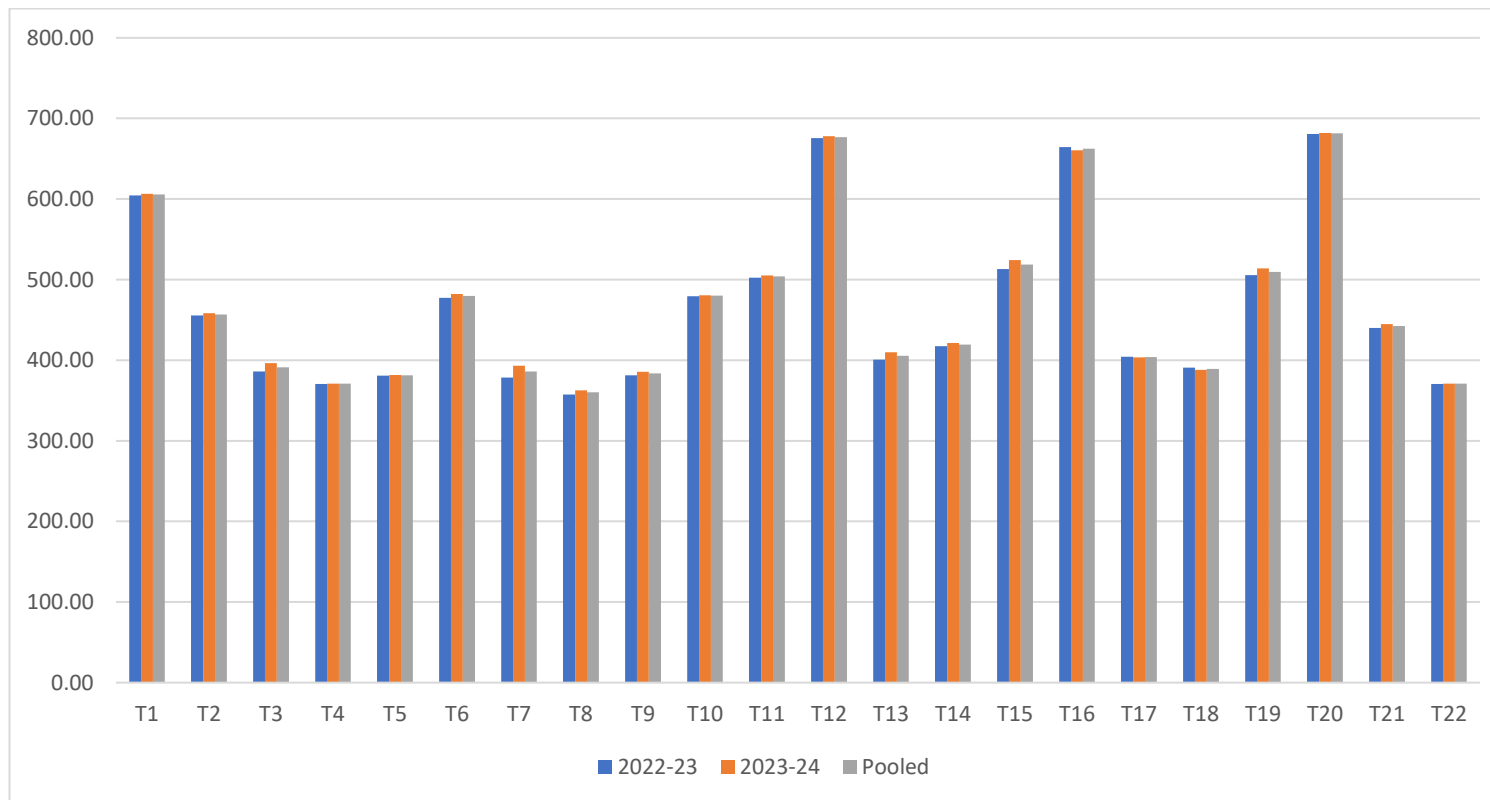


Figure 4.20: Effect of nanofertilizer based INM on yield per ha

The application of nano urea-based Integrated Nutrient Management (INM) had a profound influence on the number of fruits per plant, with the maximum fruit count observed in the treatment amended with PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀). This large increment in the production of fruits can be attributed to the use of nano-urea which is an effective nutrient delivery agent. Nano urea slowly releases nitrogen at a constant rate hence maintaining a balanced nutrient supply from the planting stage to the maturity stage. This limited nutrient mobilization may help strong vegetation development and could positively influence the reproductive phase such as flowering and fruiting. Nano urea can therefore ensure an instructive nitrogen balance to generate more female flower which are much critical to fruit yield. It may further contribute to this increase, because of the balanced nutrient supply which is obtained by the amalgamated management of inorganic fertilizers, organic manures, and microbial consortia (Choudhary, 2020). Behera (2023) stated that the proliferation in yield may also be due to the harmonious effect of nano urea on the practicality of conventional urea to enhance nutrient fascination by plant cells, resulting in optimal growth of plant parts and metabolic processes, such as photosynthesis, which translates to greater accumulation of photosynthates and their translocation to the economically important parts, resulting in surge in the number of fruits with greater length and diameter. The poultry manure may increase the organic matter content of the soil, increase microbial activities, and supply slow release of nutrients; the microbial consortia may increase nutrient absorption, and plant growth regulators such as auxin, cytokine and gibberellin. These hormones are involved with flower initiation, fruiting development and fruit maturation for better and enhanced production rates (Kharga *et al.*, 2020). Further, by applying the integrated nutrient management the flower and fruit drop might be reduced as the plant is given constant nutrients to support its growth process. This may also decrease nutrient stress, normalize hormonal processes, and enhance the general plant hardiness of flowers and fruits resulting to a much higher yield per plant. These results are consistent with Thriveni *et al.* (2015) in bitter gourd, Jagraj *et al.* (2018) in cucumber, Choudhary (2020) in ridge gourd and Behera (2023) in cucumber.

The application of nano urea based INM had a significant effect on the fruit length with the longest fruit recorded in the treatment which was incorporated with

FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₂) and PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀). This notable increase in fruit length can be attributed to the application of nano urea which may provide nitrogen in a consistent and targeted approach leading to cell elongation and better fruit development (Enigi, 2022). The compound application of chemical fertilizers, organic manures and microbial consortia may ensure a balanced supply of nutrients throughout the plant's growth and development, reducing nutrient imbalance in the plant which may limit fruit growth. The addition of organic manures and microbial consortia may also help in more desirable soil microbial activity which may indirectly influence cell elongation by leading to better nutrient uptake. Sharma (2019) stated that the enlargement in fruit length is due to the better efficiency of combined use of inorganic fertilizers along with organic manures which have provided micronutrients and increased the plant metabolic activities. These conclusion are in agreement with Jagraj *et al.* (2018) in cucumber, Sharma (2019) In cucumber, Choudhary (2020) in ridge gourd and Behera (2023) in cucumber.

The treatment incorporated with PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) recorded the highest fruit diameter. Similarly, significant results were observed in treatment integrated with FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₂) and VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₆). This increase in the fruit diameter may possibly be due to the combination use of chemical fertilizers, organic manures and microbial consortium as these allow a continuous and uniform supply of nutrients which helps in cellular expansion of cells and thereby increase in fruit diameter (Hemavathi, 2022). The application of nano urea which contains nitrogen may also help in cell enlargement which directly influences increased fruit diameter. The lowest average fruit that was observed in the treatment control and treatment incorporated with a full dose of RDF (N through nano urea) likely based because of the limitations of nutrient availability in the control treatment and inadequate nitrogen available during the initial growing stage as nano urea was applied only during the vegetative stage which might have hamper the vegetative growth leading to nutrient stress. Similar results are recorded by Jagraj *et al.* (2018) in cucumber, Sharma (2019) in cucumber, Choudhary (2020) in ridge gourd and Behera (2023) in cucumber.

The use of nano urea based INM had a notable effect on the average weight of fruit with the highest average fruit weight recorded in the treatment incorporated with PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀). Similarly, statistically par treatment was recorded in FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₂). This increase is likely to the application of nano urea which contains nitrogen and nitrogen is vital for cell division and expansion which may assist in an increase in fruit size and weight (Neeruggi, 2024). Nano urea may also help in increase in photosynthetic activity which may aid in better production of energy and carbohydrates for fruit development resulting in increase in fruit size (Heemavathi, 2022). The compound application of organic inputs, chemical fertilizers and microbial consortium also leads to the availability of nutrients throughout its growth stage which may help in increase in fruit weight. Treatment control was recorded with lower fruit weight. This may possibly be due to the limited nutrient accessibility within the soil, for which treatment control may not be able to suffice the crop nutritional requirements and there may well be a reduction in the fruit size further leading to a decrease in fruit weight. This finding related to the average fruit weight is in harmony with the results of Merghany *et al.* (2019) in cucumber, Sharma, (2019) in cucumber, Choudhary, (2020) in ridge gourd and Behera, (2023) in cucumber.

The average yield per plant was documented maximum in the treatment integrated with PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) whereas the minimum yield per plant (average) was perceived in the treatment control. This growth can result from the use of nano urea which assist in the proliferation in vegetative growth, increase in the quantity of leaves, flowering and fruit set which directly influence the yield per plant. Further the buildup in fruit weight and greater number of female flowers may also result in improved yield per plant (Neeruggi, 2024). The balanced nutrient supply by the combination use of inorganic fertilizer, organic manures and microbial consortium may also directly influence yield per plant by optimizing vegetative growth and inducing the reproductive phase (Sharma, 2019). The organic inputs *i.e.*, manures and microbial consortium may also enhance microbial population in the soil which may enhance root development in the soil and improve nutrient uptake of the plant. The lower yield per plant in the treatment control may be due to having a lower fruit set and a lower fruit size as observed in the previous

parameters. This could be ascribed to the limitation of nutrient supply in the treatment control which could not meet its nutrient requirements. Behera, (2023) stated that improvement in the production of female flowers will lead to an increased synthesis of carbohydrates and transport of sugar from the source to sink where they are needed during the reproductive phase, which brings about greater quantity of fruits per plant. This result is in harmony with the verdicts of Heemavathi, (2022), Kharga *et al.* (2020), Jagraj *et al.* (2018) and Thriveni *et al.* (2015).

The maximum yield per ha was accounted for the treatment that was pertained with PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀). The reason for this could be the synergistic effect of the treatment which offers a balanced fertilization to the plant leading to continuous distribution of nutrients all over its growth and development. The utilization of poultry manure, which is a slow release in nature, may guarantee a sturdy nutrient supply. Poultry manure also promotes higher soil activity and improves soil fertility (Baghel *et al.*, 2016). The combination application of nano urea, organic manures and microbial consortium may also improve tolerance to plant abiotic and biotic stress which may result in increase in productivity. Similarly, treatment T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] also observed statistically on par and this could be brought about by the use of FYM and VC as this improves the soil biological, chemical and physical properties which enhance higher activity in the soil, improve water holding capacity and also increase cation exchange capacity (CEC). Behera, (2023) described that an increase in yield of sponge gourd may be due to the application of nano urea which enhance higher photosynthetic activities leading to stimulation of root and shoot growth which may result in higher production of fruits per unit. The control treatment recorded the lowest yield per ha because of the limited availability of nutrients which resulted in restricted growth and development and ultimately a further decrease in productivity. The farmers treatment (T₂₁) recorded a higher yield per ha than the control treatment. This is attributable to the fact that nutrient inputs were applied in the treatment and these might have provided for its nutrient requirement to some extent. However, a significant difference has been observed in farmers treatment compared to treatment PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀). This may probably be due to inadequate nutrients

introduced in the soil which could not support the nutrient needs of the crop. Similar results were recorded by Aravinda *et al.* (2022), Heemavathi, (2022), Kharga *et al.* (2020), Jagraj *et al.* (2018) and Thriveni *et al.* (2015).

4.3 Quality parameters

4.3.1 TSS

The experimental results regarding the influence of nanofertilizers based integrated nutrient management on TSS content in the fruit are detailed in Table 4.21 and Figure 4.21. The data shows that there was a significant difference between the treatments as demonstrated by one-way ANOVA. Treatment T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] recorded the highest pooled TSS with 4.66 °B, followed by treatment T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₁₅ [VC @ 2.55 t ha⁻¹ + ½ of RDF (N through urea) + MC] with 4.54 °B and 4.45°B respectively. The lowest pooled TSS was evident in the treatment control (T₂₂) with 2.75 °B.

4.3.2 Crude protein content

The experimental results regarding the influence of nanofertilizers based integrated nutrient management on crude protein content in the fruit are detailed in Table 4.22 and Figure 4.22. The data reveals that there was a significant difference between the treatments as demonstrated by one-way ANOVA. The highest average content of crude protein was evident in the treatment amended with FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₂) with 0.66% followed by treatment T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] with 0.64%. As per the pooled data, the lowest protein content was observed in the treatment control (T₂₂) with 0.39%.

Table 4.21: Effect of nanofertilizer based INM on TSS of the fruit

Sl. no.	Treatment	TSS (°B)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	4.06	4.11	4.09
T ₂	Full dose of RDF (N through nano urea)	3.07	3.15	3.11
T ₃	FYM @ 20 t ha ⁻¹	3.01	2.89	2.95
T ₄	VC @ 5 t ha ⁻¹	2.96	2.99	2.97
T ₅	PM @ 10 t ha ⁻¹	3.48	3.64	3.56
T ₆	FYM @ 20 t ha ⁻¹ + MC	2.79	2.95	2.87
T ₇	VC @ 5 t ha ⁻¹ + MC	2.82	2.97	2.90
T ₈	PM @ 10 t ha ⁻¹ + MC	3.05	2.88	2.96
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	2.90	3.01	2.95
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	3.34	3.55	3.44
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	4.32	4.43	4.38
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	4.48	4.59	4.54
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	2.63	2.87	2.75
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	3.04	3.23	3.13
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	4.33	4.57	4.45
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	4.60	4.71	4.66
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	3.53	3.68	3.61
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	3.84	3.46	3.65
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	3.67	3.96	3.82
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	4.47	4.31	4.39
T ₂₁	Farmers practise	3.36	3.13	3.25
T ₂₂	Control	2.78	2.72	2.75
SEm±		0.13	0.15	0.13
CD (P=0.05)		0.38	0.43	0.36

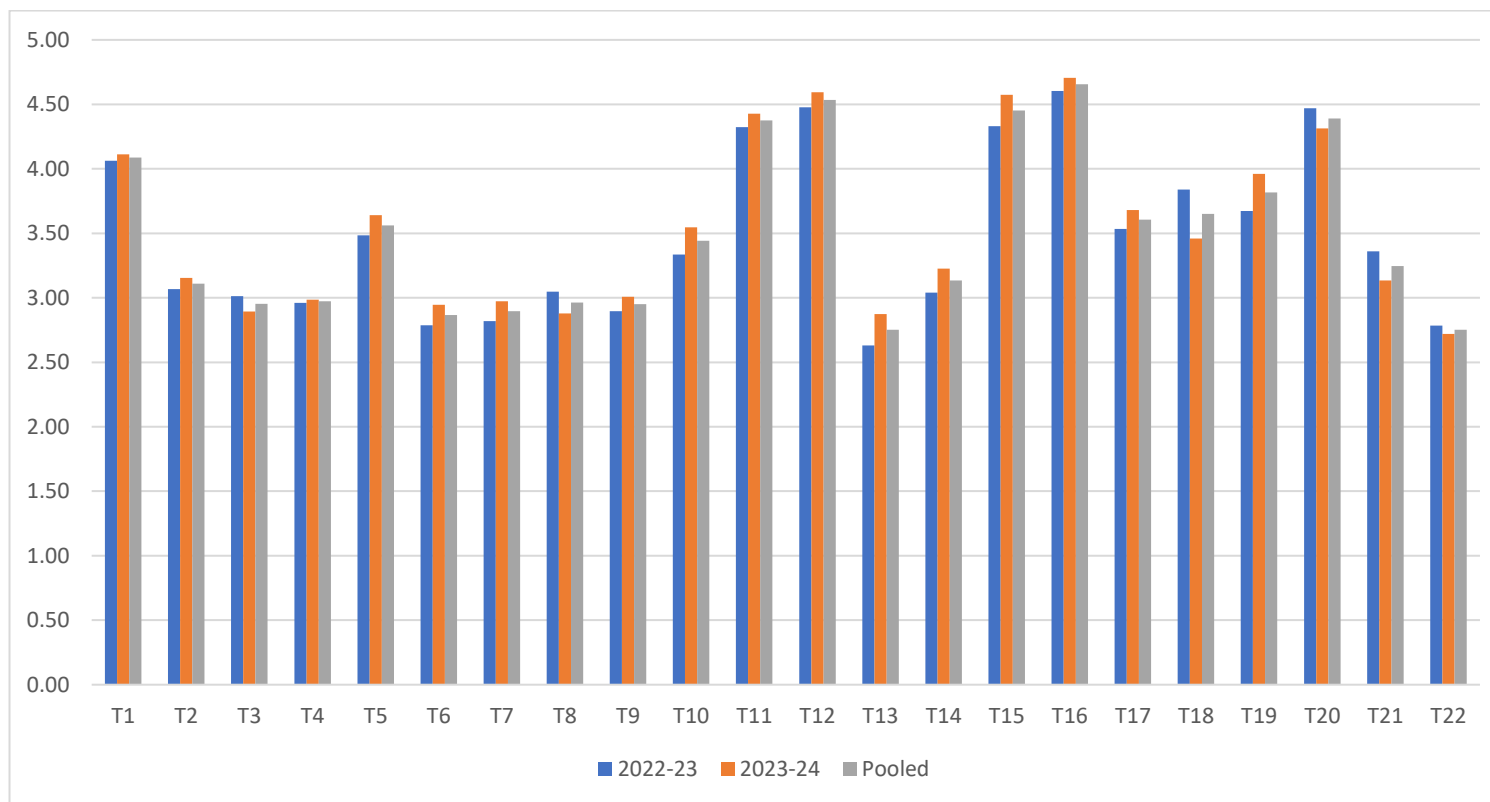


Figure 4.21: Effect of nanofertilizer based INM on TSS content of the fruit

Table 4.22: Effect of nanofertilizer based INM on crude protein content of the fruit

Sl. no.	Treatment	Crude protein (%)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	0.62	0.64	0.63
T ₂	Full dose of RDF (N through nano urea)	0.51	0.54	0.52
T ₃	FYM @ 20 t ha ⁻¹	0.45	0.48	0.46
T ₄	VC @ 5 t ha ⁻¹	0.39	0.41	0.4
T ₅	PM @ 10 t ha ⁻¹	0.49	0.52	0.51
T ₆	FYM @ 20 t ha ⁻¹ + MC	0.51	0.54	0.52
T ₇	VC @ 5 t ha ⁻¹ + MC	0.48	0.51	0.5
T ₈	PM @ 10 t ha ⁻¹ + MC	0.45	0.47	0.46
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	0.42	0.44	0.43
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	0.46	0.48	0.47
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	0.6	0.61	0.61
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	0.64	0.68	0.66
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	0.48	0.47	0.47
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	0.51	0.53	0.52
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	0.58	0.61	0.59
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	0.63	0.65	0.64
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	0.42	0.45	0.43
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	0.5	0.52	0.51
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	0.55	0.57	0.56
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	0.6	0.62	0.61
T ₂₁	Farmers practise	0.45	0.46	0.46
T ₂₂	Control	0.38	0.39	0.39
SEm±		0.031	0.029	0.029
CD (P=0.05)		0.086	0.084	0.084

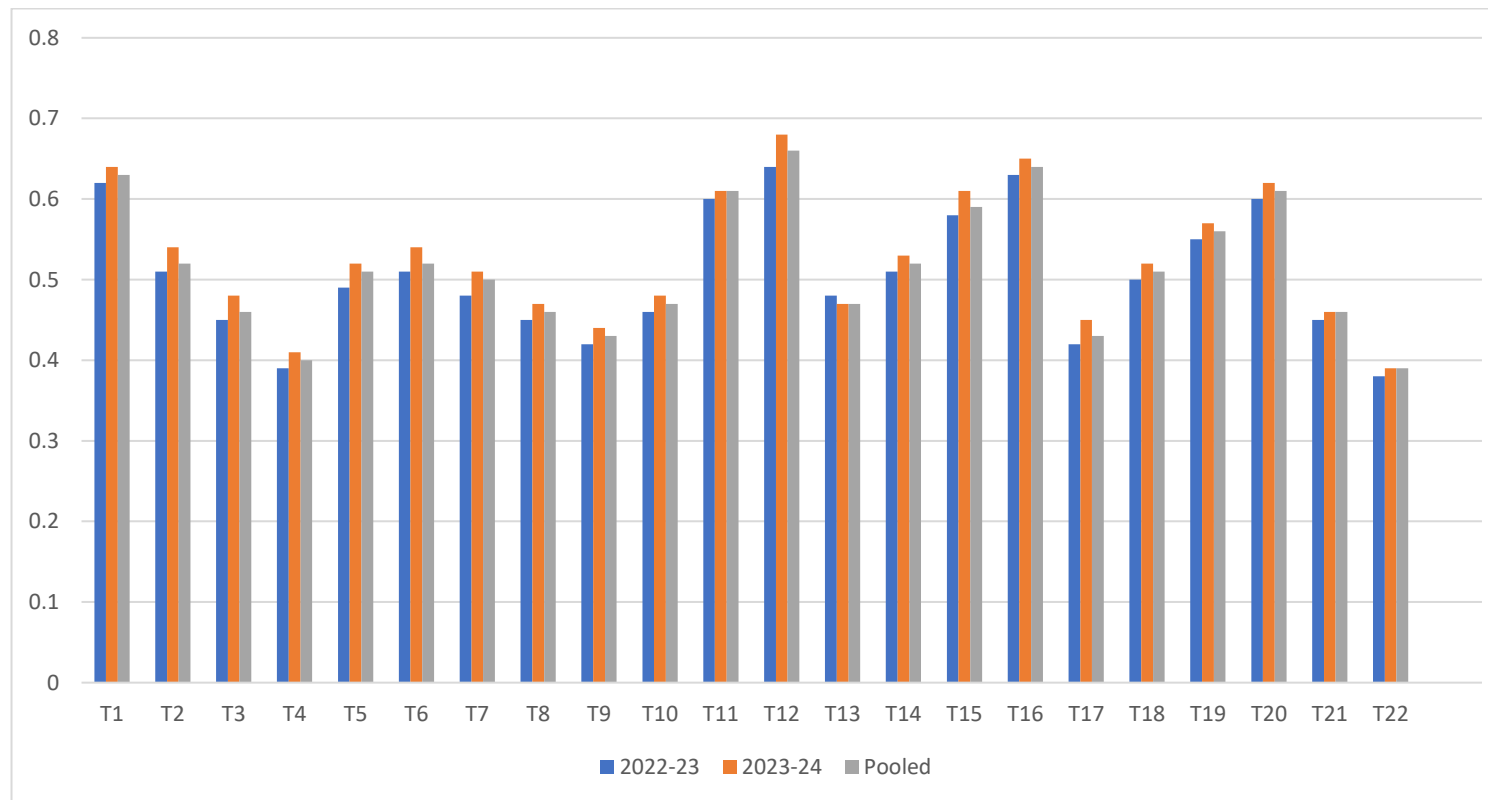


Figure 4.22: Effect of nanofertilizer based INM on crude protein content of the fruit

4.3.3 Total chlorophyll content

The data on total chlorophyll content in chayote fruit are detailed in Table 4.23 and Figure. 4.23. The data reveals that there was a significant difference between the treatments as demonstrated by one-way ANOVA. Treatment T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] recorded the highest pooled total chlorophyll content at 0.289 mg g⁻¹. Statistically similar data on total chlorophyll content was recorded in treatment T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] at 0.272 mg g⁻¹. The lowest total chlorophyll content was observed in the treatment control (T₂₂) with a pooled average of 0.143 mg g⁻¹. Treatment like T₁₁ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through urea) + MC], T₁₅ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through urea) + MC] and T₁₉ [PM @ 5 t ha⁻¹ + ½ of RDF (N through urea) + MC] which was incorporated with conventional urea also recorded higher chlorophyll content with 0.246 mg g⁻¹, 0.221mg g⁻¹ and 0.217 mg g⁻¹ respectively.

4.3.4 Vitamin C content

The data on total vitamin C content in chayote fruit are illustrated in Table 4.24 and Figure. 4.24. The data illuminates that there was a significant difference between the treatments as demonstrated by one-way ANOVA. Treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] recorded the highest vitamin C content with an average pooled data of 4.99 mg g⁻¹ and 5.00 mg g⁻¹ respectively. Treatment control recorded the lowest vitamin C content with 3.35 mg g⁻¹. Treatment T₂₁ (Farmers practice) also recorded relatively less vitamin C content (3.70 mg g⁻¹) as compared to treatments incorporated with fertilizers, manures and biofertilizers.

Table 4.23: Effect of nanofertilizer based INM on total chlorophyll content of the fruit

Sl. no.	Treatment	Total chlorophyll (mg g ⁻¹)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	0.191	0.194	0.192
T ₂	Full dose of RDF (N through nano urea)	0.217	0.219	0.218
T ₃	FYM @ 20 t ha ⁻¹	0.208	0.210	0.209
T ₄	VC @ 5 t ha ⁻¹	0.185	0.188	0.186
T ₅	PM @ 10 t ha ⁻¹	0.165	0.168	0.166
T ₆	FYM @ 20 t ha ⁻¹ + MC	0.203	0.206	0.204
T ₇	VC @ 5 t ha ⁻¹ + MC	0.154	0.156	0.155
T ₈	PM @ 10 t ha ⁻¹ + MC	0.193	0.195	0.194
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	0.222	0.224	0.223
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	0.188	0.191	0.189
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	0.245	0.247	0.246
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	0.271	0.274	0.272
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	0.181	0.183	0.182
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	0.206	0.208	0.207
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	0.220	0.222	0.221
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	0.288	0.290	0.289
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	0.213	0.216	0.214
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	0.176	0.178	0.177
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	0.216	0.218	0.217
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	0.209	0.211	0.210
T ₂₁	Farmers practise	0.190	0.192	0.191
T ₂₂	Control	0.142	0.144	0.143
SEm±		0.02	0.02	0.016
CD (P=0.05)		0.04	0.05	0.045

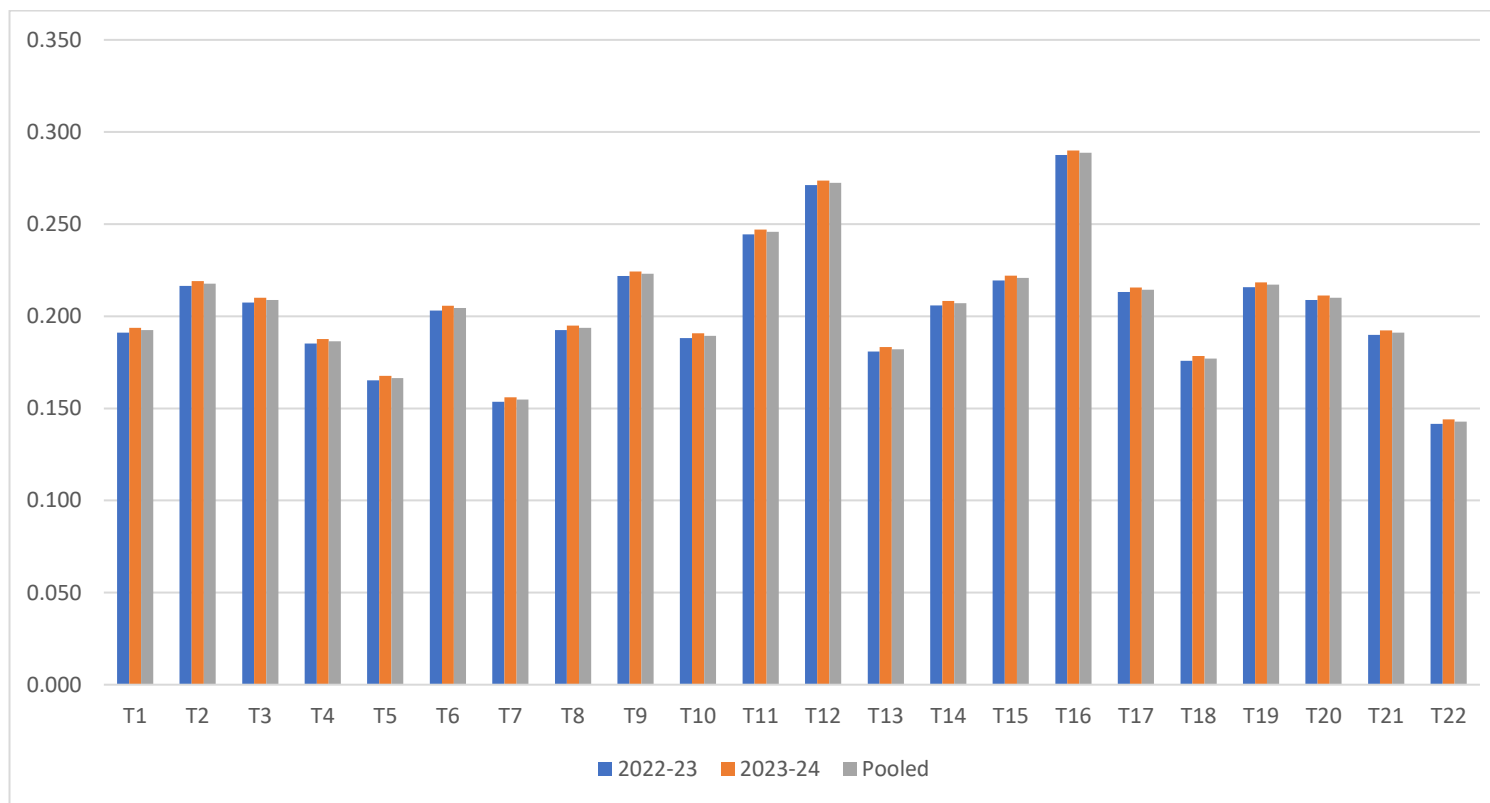


Figure 4.23: Effect of nanofertilizer based INM on total chlorophyll content of the fruit

Table 4.24: Effect of nanofertilizer based INM on vitamin C content of the fruit

Sl. no.	Treatment	Vitamin C (mg g ⁻¹)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	4.66	4.81	4.74
T ₂	Full dose of RDF (N through nano urea)	4.11	4.26	4.19
T ₃	FYM @ 20 t ha ⁻¹	3.50	3.65	3.57
T ₄	VC @ 5 t ha ⁻¹	4.19	4.05	4.12
T ₅	PM @ 10 t ha ⁻¹	3.97	4.11	4.04
T ₆	FYM @ 20 t ha ⁻¹ + MC	3.85	3.92	3.88
T ₇	VC @ 5 t ha ⁻¹ + MC	4.29	4.15	4.22
T ₈	PM @ 10 t ha ⁻¹ + MC	3.76	3.84	3.80
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	3.80	4.03	3.92
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	3.55	3.77	3.66
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	4.04	4.27	4.16
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	4.80	4.93	4.86
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	3.56	3.74	3.65
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	4.38	4.51	4.45
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	4.01	4.16	4.08
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	4.87	5.13	5.00
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	3.53	3.71	3.62
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	3.75	3.97	3.86
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	4.17	4.43	4.30
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	4.94	5.04	4.99
T ₂₁	Farmers practise	3.74	3.67	3.70
T ₂₂	Control	3.44	3.25	3.35
SEm±		0.21	0.21	0.21
CD (P=0.05)		0.61	0.60	0.58

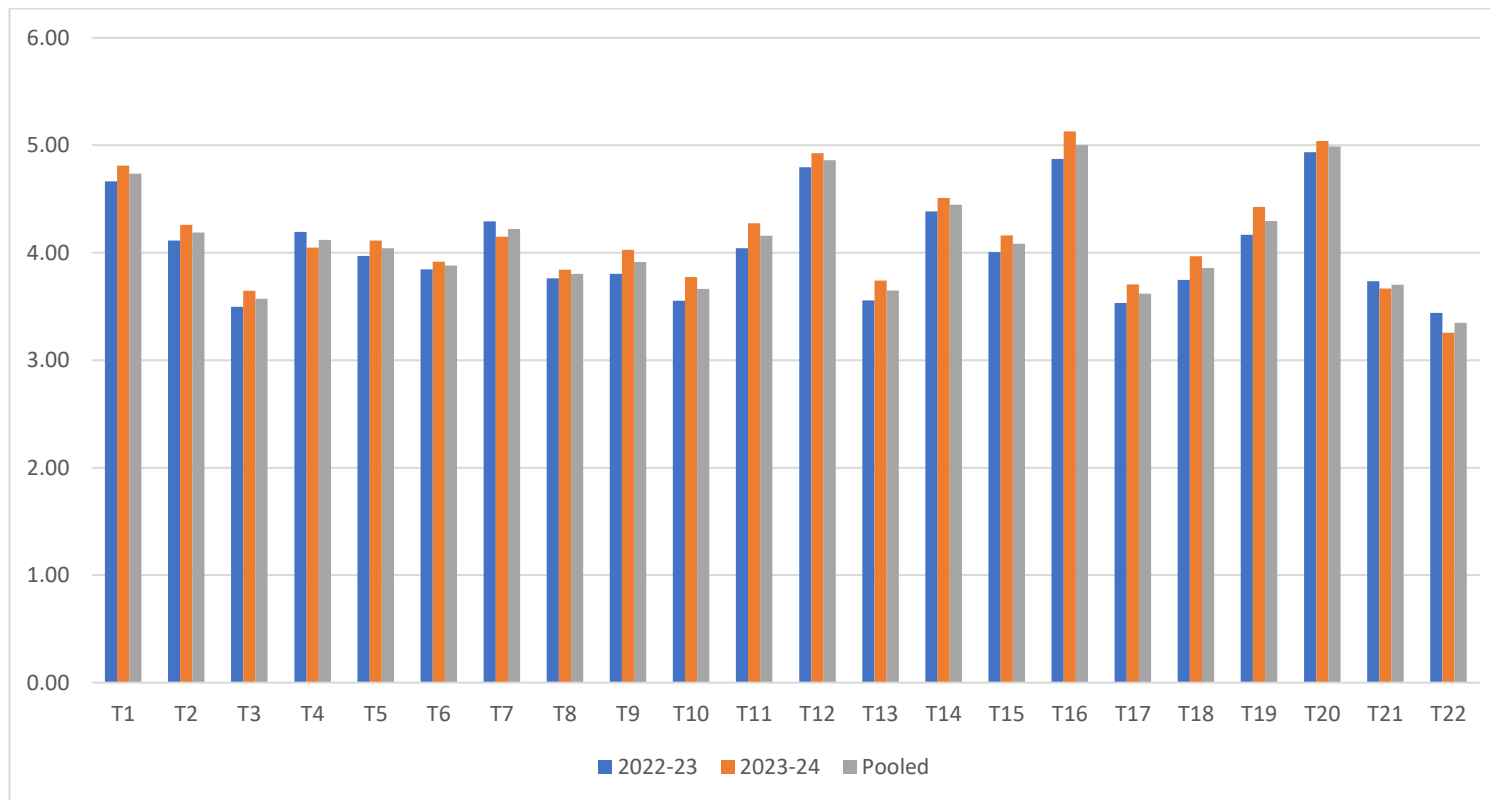


Figure 4.24: Effect of nanofertilizer based INM on vitamin C content of the fruit

4.3.5 Total carbohydrate content

Table 4.25 and Figure. 4.25 describes the data on total carbohydrate content in chow-chow fruit. The data displays that there was a significant difference between the treatments as demonstrated by one-way ANOVA. The highest average total carbohydrate content was recorded in the treatment T₁ [Full dose of RDF (N through urea)] with a pooled data of 3.83%. Treatment T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] recorded relatively high content of total carbohydrate with 3.75% and 3.79% respectively and the outcome was statistically on par with treatment T₁. The lowest average total carbohydrate content was observed in the treatment control (T₂₂) at 2.90% (pooled).

4.3.6 Fibre content

Table 4.26 and Figure. 4.26 describes the data on total fibre content in chow-chow fruit. The data specify that there was a significant difference between the treatments as demonstrated by one-way ANOVA. Treatment T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] recorded the highest pooled fibre content of 0.209 % followed by treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] with 0.200 % while treatment T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₁₅ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through urea) + MC] performed moderately as compared to treatment control with 0.190% and 0.180% respectively. Treatment T₂₂ (control) recorded the lowest pooled fibre content with 0.145%.

Table 4.25: Effect of nanofertilizer based INM on total carbohydrate content of the fruit

Sl. no.	Treatment	Total carbohydrate (%)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	3.74	3.93	3.83
T ₂	Full dose of RDF (N through nano urea)	3.03	3.11	3.07
T ₃	FYM @ 20 t ha ⁻¹	3.11	3.02	3.06
T ₄	VC @ 5 t ha ⁻¹	3.14	3.25	3.19
T ₅	PM @ 10 t ha ⁻¹	3.05	3.23	3.14
T ₆	FYM @ 20 t ha ⁻¹ + MC	3.07	3.14	3.11
T ₇	VC @ 5 t ha ⁻¹ + MC	3.08	3.29	3.19
T ₈	PM @ 10 t ha ⁻¹ + MC	3.21	3.38	3.30
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	2.96	3.04	3.00
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	3.32	3.40	3.36
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	3.23	3.36	3.29
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	3.54	3.79	3.67
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	3.06	3.20	3.13
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	3.50	3.69	3.59
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	3.31	3.48	3.40
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	3.69	3.81	3.75
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	3.13	3.26	3.19
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	3.39	3.55	3.47
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	3.63	3.71	3.67
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	3.71	3.86	3.79
T ₂₁	Farmers practise	3.24	3.37	3.31
T ₂₂	Control	2.88	2.92	2.90
SEm±		0.08	0.07	0.06
CD (P=0.05)		0.24	0.21	0.18

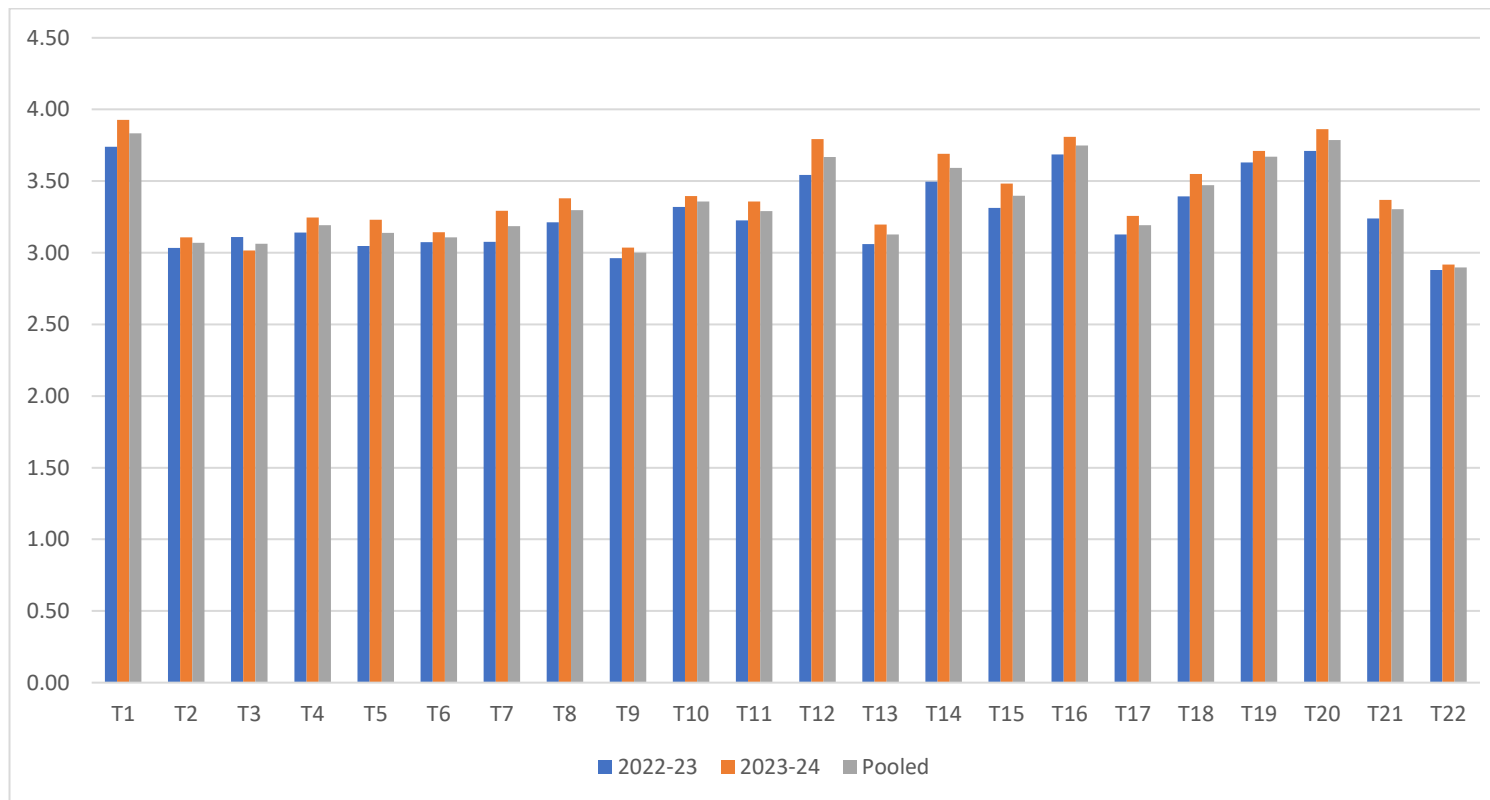


Figure 4.25: Effect of nanofertilizer based INM on total carbohydrate content of the fruit

Table 4.26: Effect of nanofertilizer based INM on fibre content of the fruit

Sl. no.	Treatment	Fibre (%)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	0.191	0.199	0.195
T ₂	Full dose of RDF (N through nano urea)	0.169	0.174	0.171
T ₃	FYM @ 20 t ha ⁻¹	0.156	0.160	0.158
T ₄	VC @ 5 t ha ⁻¹	0.144	0.148	0.146
T ₅	PM @ 10 t ha ⁻¹	0.153	0.158	0.156
T ₆	FYM @ 20 t ha ⁻¹ + MC	0.155	0.161	0.158
T ₇	VC @ 5 t ha ⁻¹ + MC	0.172	0.165	0.169
T ₈	PM @ 10 t ha ⁻¹ + MC	0.152	0.157	0.154
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	0.163	0.167	0.165
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	0.166	0.174	0.170
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	0.169	0.177	0.173
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	0.189	0.190	0.190
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	0.174	0.178	0.176
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	0.162	0.168	0.165
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	0.177	0.182	0.180
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	0.206	0.213	0.209
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	0.167	0.170	0.169
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	0.158	0.162	0.160
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	0.177	0.184	0.180
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	0.198	0.202	0.200
T ₂₁	Farmers practise	0.155	0.159	0.157
T ₂₂	Control	0.143	0.146	0.145
SEm±		0.005	0.005	0.005
CD (P=0.05)		0.013	0.014	0.013

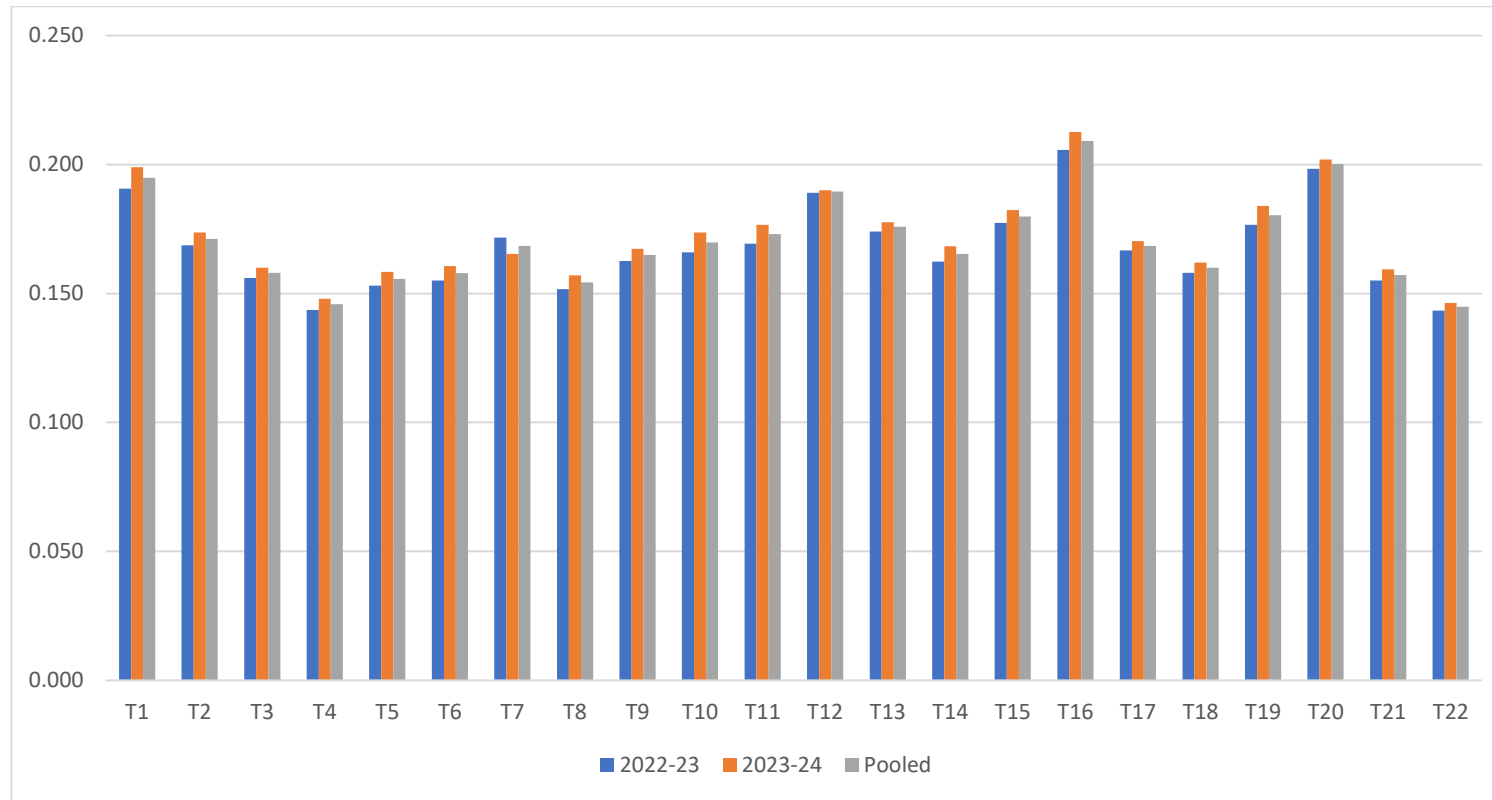


Figure 4.26: Effect of nanofertilizer based INM on fibre content of the fruit

4.3.7 Calcium content

The data presented in Table 4.27 and Figure 4.27 shows the effect of different sources of nutrients on the calcium content in chow chow. As demonstrated by one way ANOVA, the data indicates that there is variation within the treatments and the CD value at a 5% significance level shows that differences greater than 0.39% (Pooled) across treatments are statistically significant. The highest calcium content in chow-chow fruit was noted in the treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] with 13.29 mg 100 g⁻¹ followed by T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC]. Treatment T₅ (PM @ 10 t ha⁻¹) and T₂₂ (Control) recorded the lowest pooled calcium content with 11.62 mg 100 g⁻¹ and 11.75 mg 100 g⁻¹ respectively.

4.5.8 Total phenolic content (mg g⁻¹)

The data presented in Table 4.28 and Figure 4.28 shows the effect of different sources of nutrients on the total phenolic content in chow chow. As demonstrated by one-way ANOVA, the data indicates that there is variation within the treatments and the CD value at a 5% significance level shows that differences greater than 0.092 mg g⁻¹ (Pooled) across treatments are statistically significant. Treatments T₁₅ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through urea) + MC], T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₁ (Full dose of RDF through urea) recorded the highest total phenolic content with 1.77 mg g⁻¹, 1.73 mg g⁻¹ and 1.71 mg g⁻¹. The lowest total phenolic content was observed in the treatment control (T₂₂) with 1.31 mg g⁻¹ (Pooled).

Table 4.27: Effect of nanofertilizer based INM on calcium content of the fruit

Sl. no.	Treatment	Calcium (mg 100 g ⁻¹)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	12.56	12.87	12.72
T ₂	Full dose of RDF (N through nano urea)	12.54	12.65	12.60
T ₃	FYM @ 20 t ha ⁻¹	11.94	12.06	12.00
T ₄	VC @ 5 t ha ⁻¹	12.07	12.24	12.16
T ₅	PM @ 10 t ha ⁻¹	11.57	11.66	11.62
T ₆	FYM @ 20 t ha ⁻¹ + MC	12.04	12.21	12.13
T ₇	VC @ 5 t ha ⁻¹ + MC	11.89	12.04	11.97
T ₈	PM @ 10 t ha ⁻¹ + MC	12.07	12.23	12.15
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	12.55	12.65	12.60
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	12.17	12.03	12.10
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	12.69	12.81	12.75
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	12.97	13.11	13.04
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	12.04	12.21	12.13
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	12.15	12.31	12.23
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	12.70	12.85	12.78
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	12.85	13.00	12.93
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	11.96	12.16	12.06
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	12.14	12.40	12.27
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	12.63	12.80	12.72
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	13.22	13.36	13.29
T ₂₁	Farmers practise	12.45	12.61	12.53
T ₂₂	Control	11.68	11.82	11.75
SEm±		0.13	0.14	0.14
CD (P=0.05)		0.39	0.41	0.39

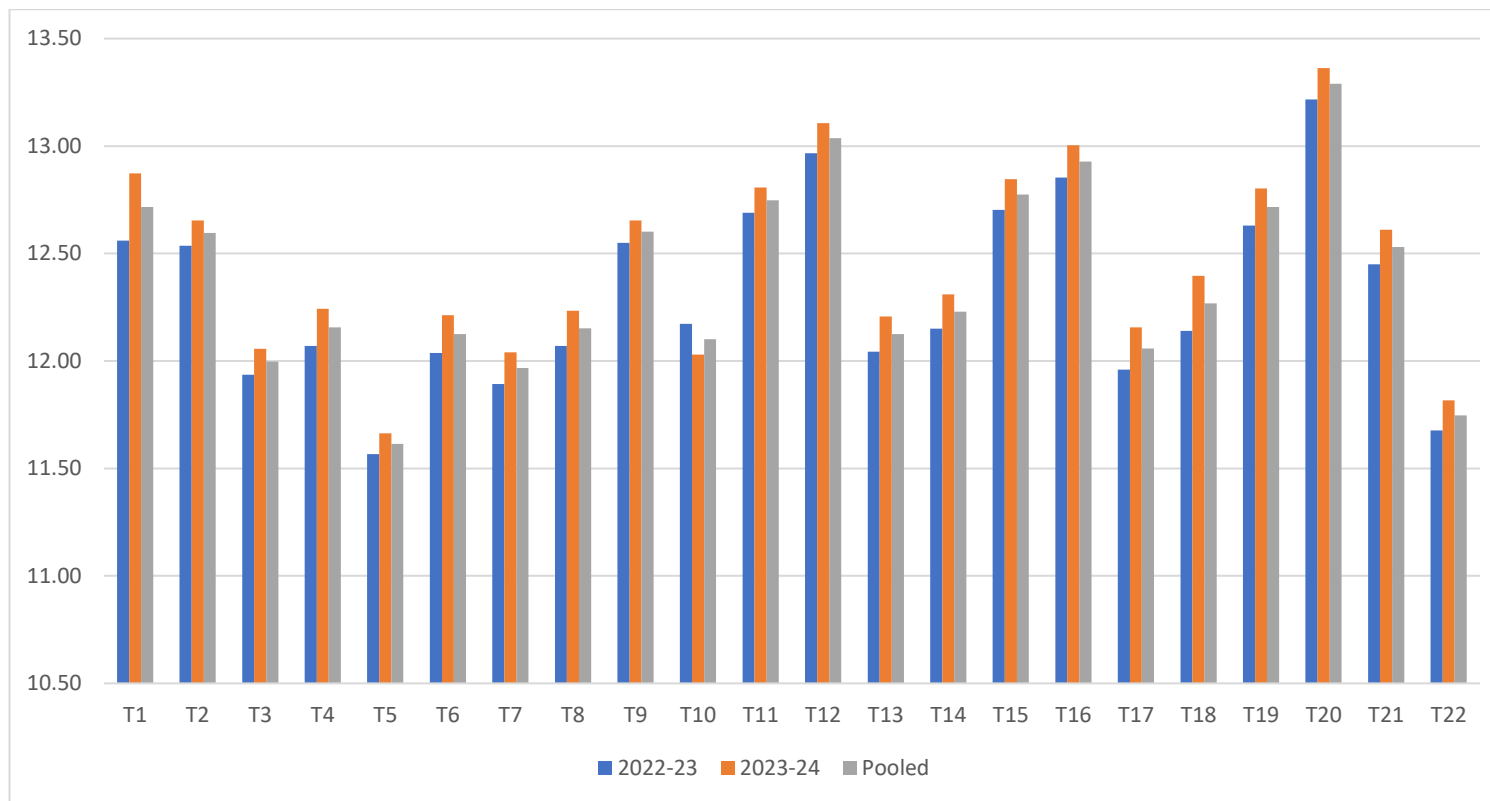


Figure 4.27: Effect of nanofertilizer based INM on calcium content of the fruit

Table 4.28: Effect of nanofertilizer based INM on total phenolic content of the fruit

Sl. no.	Treatment	Total Phenolic content(mg g ⁻¹)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	1.69	1.73	1.71
T ₂	Full dose of RDF (N through nano urea)	1.62	1.69	1.65
T ₃	FYM @ 20 t ha ⁻¹	1.41	1.46	1.44
T ₄	VC @ 5 t ha ⁻¹	1.43	1.49	1.46
T ₅	PM @ 10 t ha ⁻¹	1.29	1.33	1.31
T ₆	FYM @ 20 t ha ⁻¹ + MC	1.31	1.36	1.34
T ₇	VC @ 5 t ha ⁻¹ + MC	1.43	1.47	1.45
T ₈	PM @ 10 t ha ⁻¹ + MC	1.44	1.49	1.46
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	1.56	1.62	1.59
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	1.49	1.53	1.51
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	1.47	1.51	1.49
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	1.66	1.72	1.69
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	1.48	1.51	1.49
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	1.58	1.62	1.60
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	1.76	1.78	1.77
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	1.72	1.74	1.73
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	1.61	1.64	1.63
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	1.45	1.48	1.46
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	1.62	1.65	1.63
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	1.66	1.69	1.68
T ₂₁	Farmers practise	1.55	1.59	1.57
T ₂₂	Control	1.30	1.32	1.31
SEm±		0.032	0.034	0.032
CD (P=0.05)		0.092	0.098	0.092

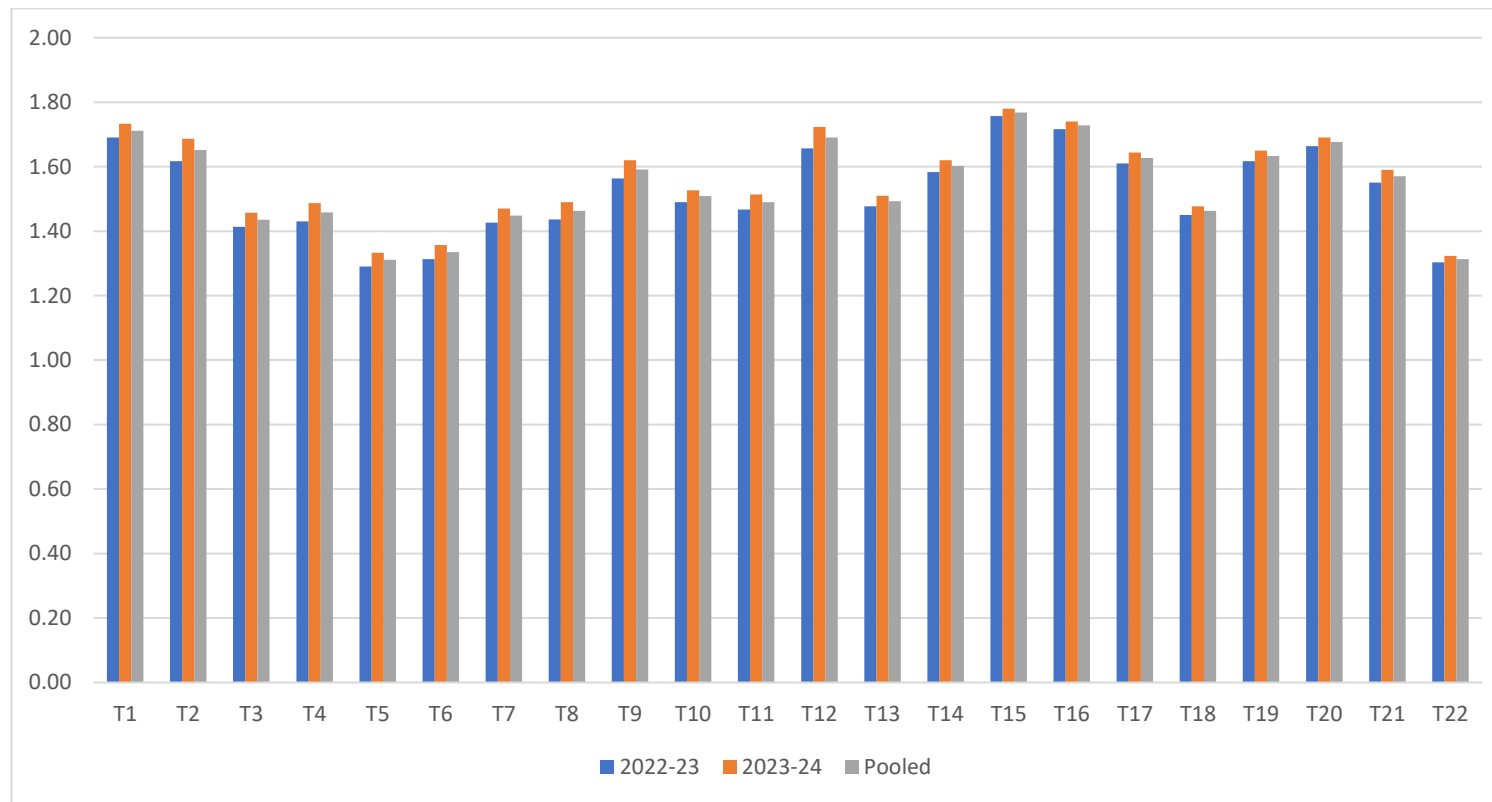


Figure 4.28: Effect of nanofertilizer based INM on total phenolic content of the fruit

4.3.9 Shelf life

The experimental results regarding the influence of nanofertilizers based integrated nutrient management on the shelf life of the fruit are detailed in Table 4.29 and Figure 4.29. The data reveal that there was significant difference between the treatments as demonstrated by one-way ANOVA. Treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] recorded the longest shelf life of the fruit with 31.40 days followed by T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] with 30.57 days and 29.80 days respectively. The shortest shelf life was detailed in the treatment T₂₂ (control) with a pooled average of 26.37 days.

Table 4.29: Effect of nanofertilizer based INM on the shelf life of the fruit

Sl. no.	Treatment	Shelf life (days)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	29.13	28.87	29.00
T ₂	Full dose of RDF (N through nano urea)	26.81	26.40	26.60
T ₃	FYM @ 20 t ha ⁻¹	27.60	27.73	27.67
T ₄	VC @ 5 t ha ⁻¹	26.27	26.53	26.40
T ₅	PM @ 10 t ha ⁻¹	27.53	27.80	27.67
T ₆	FYM @ 20 t ha ⁻¹ + MC	25.87	26.20	26.03
T ₇	VC @ 5 t ha ⁻¹ + MC	26.47	26.93	26.70
T ₈	PM @ 10 t ha ⁻¹ + MC	26.07	25.67	25.87
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	27.87	28.07	27.97
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	26.73	27.00	26.87
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	28.20	28.40	28.30
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	29.53	30.07	29.80
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	28.27	28.13	28.20
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	28.47	28.73	28.60
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	29.20	29.47	29.33
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	30.40	30.73	30.57
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	26.87	27.27	27.07
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	29.07	29.33	29.20
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	27.40	27.67	27.53
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	31.33	31.47	31.40
T ₂₁	Farmers practise	28.07	28.40	28.23
T ₂₂	Control	26.27	26.47	26.37
SEm±		0.77	0.84	0.79
CD (P=0.05)		2.22	2.42	2.27

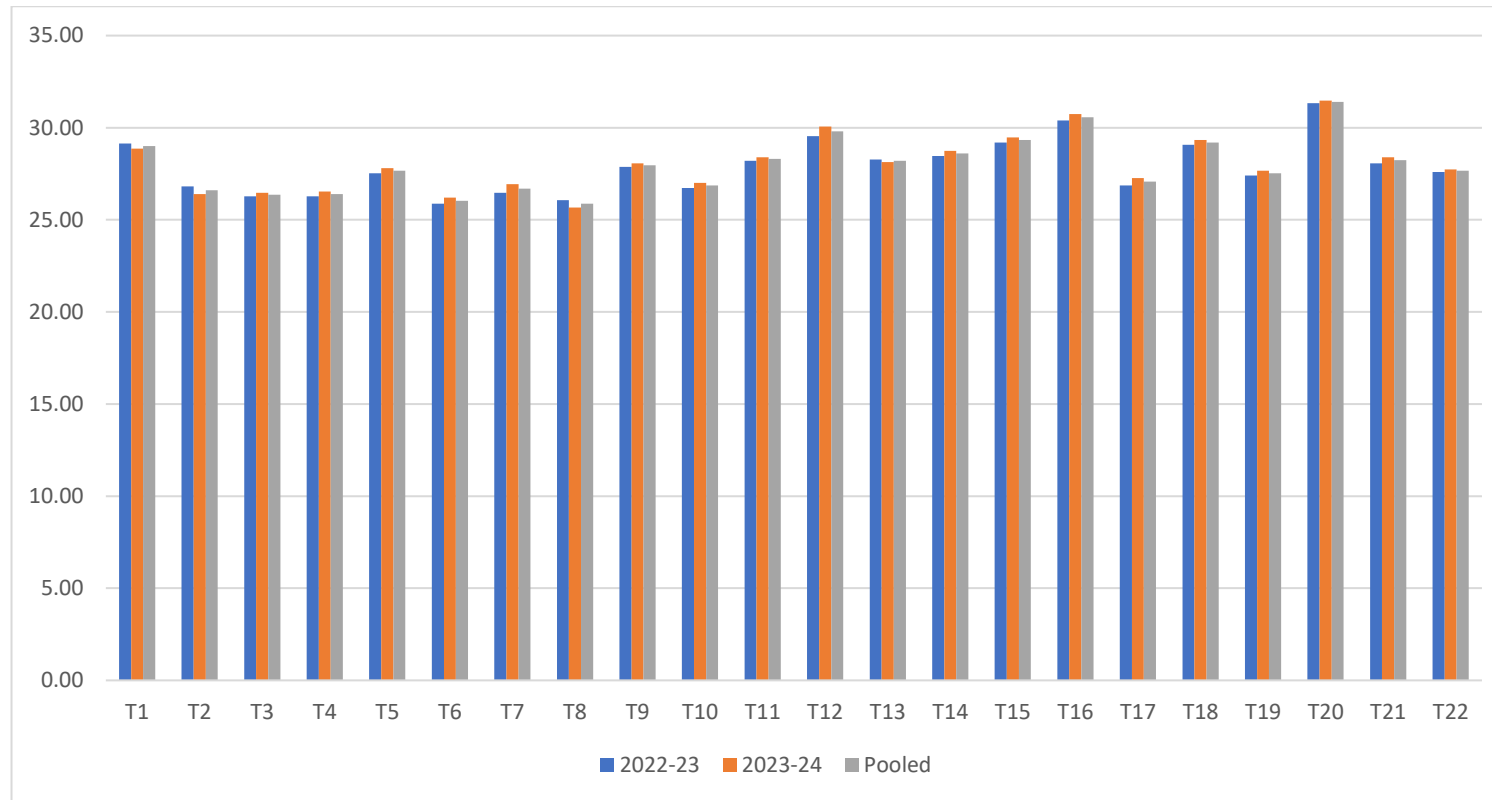


Figure 4.29: Effect of nanofertilizer based INM on shelf life of the fruit

The highest TSS in fruit was observed in the treatment incorporated with VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₆). Similarly, high TSS was also recorded in the treatment amended with FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀). These differences observed in the TSS content of the fruit amongst the treatments suggest that the TSS value might be influenced by the application of inputs. The fruits that received those treatments which were enriched with nano urea registered higher TSS content in their fruits. This difference can be explained by nano urea as this increases nitrogen use efficiency and increases chlorophyll content in plants which in turn increases photosynthesis and in turn, the accumulation of carbohydrates (Behera, 2023). Increase in TSS may also be attributed to a higher accumulation of carbohydrates, proteins and captured energy by the ample supply of nitrogen, phosphorus and potassium through inorganic sources and organic sources of nutrients (Aravinda *et al.*, 2022). Singh *et al.* (2017) stated that the exertion of microbial consortia can enhance the nutrients availability and growth promoting substances which in turn will increase the TSS of the fruit. These findings are in conformity with Piruthiga *et al.* (2024) Sahu *et al.* (2022) and Sharma (2019).

It was observed that the exertion of vermicompost outperforms all the treatments in terms of protein content in chow-chow fruit over the two years. This significant increase can be ascribed to the application of vermicompost, as vermicompost is rich in primary nutrients and micronutrients especially nitrogen which helps in protein synthesis and enhances the protein content in fruit. Vermicompost also contains beneficial microorganisms which improve soil health and nitrogen fixation and may help in better uptake of nutrients which may be necessary for protein formation in plants. Similarly, the application of poultry manures also thrived well in the present study as per the analysis. This increase may be due to the higher content of primary nutrients as contrary to other sources of nutrients which might augment the plant growth and help in continuous supply of nutrients throughout its growth cycle (Pranali *et al.*, 2018). The low content of protein in the treatment control may be due to its inability to meet the plant nutrient demand which limits the production of amino acid and may thus decrease its protein content in the fruit. Similar results were perceived by Thriveni *et al.* (2015), Pathak *et al.* (2017) and Behera (2023).

The effect of nano urea-based INM on the total chlorophyll content of fruits had

a significant effect in which the treatment integrated with VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₆) recorded the highest chlorophyll content. Similarly, statistically on par data were recorded in treatment T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC and T₂₀ PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC. This may be explained by the use of nano urea as it enhances the manufacture of chlorophyll owing to a uniform supply of nitrogen. The enhancement in chlorophyll synthesis could enhance photosynthate accumulation in the fruits which could enhance the chlorophyll content of the leaves. The high chlorophyll content in treatment incorporated with conventional urea, organic manures and microbial consortia {T₁₁, [FYM @ 10 t ha⁻¹ + ½ of RDF (N through urea) + MC], T₁₅ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through urea) + MC] and T₁₉ [PM @ 5 t ha⁻¹ + ½ of RDF (N through urea) + MC]} maybe clarified by the application of urea, which has high nitrogen content and it might have helped in increased in the synthesis of chlorophyll pigment. Similarly, the application of poultry manures also thrived well in the present study as per the analysis. This increase is because of the higher content of primary nutrients as contrast to other sources of nutrients which might augment the plant growth and help in a continuous supply of nutrients throughout its growth cycle (Pranali *et al.*, 2018). The low content of protein in the treatment control may be due to its inability to meet the plant nutrient demand which limits the stimulation of amino acid and may thus decrease its protein content in the fruit. Kharga *et al.* (2020) stated that the rise in the chlorophyll content can be explained by the increase in the efficacy of biofertilizers to fix atmospheric nitrogen and phosphorus solubilization when used in combination with organic manures and inorganic fertilizers which has resulted in the creation of suitable microclimatic condition and better uptake of nutrient and further accelerating the rate of chlorophyll synthesis. Similar findings regarding the increased in chlorophyll content were reported by Enigi (2022), Dudhat and Patel (2020), Merghany *et al.* (2019) and Triveni *et al.* (2015)

Those treatments integrated with nano urea, organic manures and microbial consortium *i.e.*, {T₁₂, [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC], T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC]} recorded higher vitamin C content as compared to other treatments. The joint effects of the combined treatments explained

the enhanced vitamin C content possibly because the treatments delivered balanced nutrients along with micronutrients through manures throughout the growth and development stages of the plants. These combined treatments apparently provide continuous nutrient supplies leading to elevated antioxidant properties along with phytochemical production thus enhancing vitamin C levels in fruits. Sahu *et al.* (2022) reported that application of integrated application of inorganic chemical fertilizers, organic manures (FYM/VC) with soil inoculation of biofertilizer consortia significantly enhanced the cucumber fruit quality with high ascorbic acid content which is due to steady and continuous supply of plant nutrient both nitrogen and potassium along with other important micro nutrients. Similar results are recorded by Thriveni *et al.* (2015), Singh *et al.* (2017) and Vennela *et al.* (2021).

The highest total carbohydrate content was recorded in the treatment T₁ [Full dose of RDF (N through urea)]. This may be accredited to the application of the recommended dose of fertilizers which ensure optimal availability of nutrients to the plants enhance synthesis of amino acids, protein and increase the rate of cell division which may further increase the chlorophyll content in leaves following in the production of more photosynthates and total carbohydrate through the means of photosynthesis (Kharga *et al.*, 2020). The application of potassium may also help in the translocation of sugar from leaves to fruits which might increase the carbohydrate content of the fruit. Statistically par data recorded on the treatments integrated with nano urea, organic manures and microbial consortium *i.e.*, {T₁₂, [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC], T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] maybe due to the combined effect of the treatments which provide a balanced supply of nutrients and thus increase in carbohydrate content of the fruit. The above finding is in accordance with Nayak *et al.* (2016) in pointed gourd and Chopra *et al.* (2017).

The maximum fibre content was observed in Treatment T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC]. This increase maybe due to the application of nano urea which contains nitrogen and nitrogen influences the synthesis of proteins and enzymes which regulate cellulose and hemicellulose deposition in cell walls. The application of vermicompost may help in increasing in fibre content as vermicompost helps in availability of Ca and Mg which play an essential function in strengthening

cell walls and might enhance in fibre content. Vermicompost also promotes the accumulation of lignin and cellulose which might improve the fibre content in fruit. The control treatment recorded the lowest fibre content among the treatments. This is because no additional nutrients were added to the soil and the available nutrients present in the soil may not be enough to meet the plant demand which resulted in nutritional deficiencies and might lead to reduced synthesis of cellulose and hemicellulose thus leading to a decrease in fibre content. This result is in accordance with Choudhary (2020) in ridge gourd, Islam *et al.* (2018), Mishra and Das (2015) and Singh *et al.* (2015).

The increase in the calcium content in treatments amended with PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) can be explained by the efficiency of applied nano urea which ensures nitrogen availability and indirectly influences calcium uptake and transport within the plant. The utilization of poultry manure along with microbial consortium may release organic acids which might increase calcium availability to plants. The combination of these three components (nano urea, organic manures and microbial consortium) may also increase resistance to physiological order which may improve calcium content in fruit. Similar findings were also reported by Islam *et al.* (2018), Singh *et al.* (2015) and Kim *et al.* (2016).

The effect of nano urea-based INM on the total phenolic content of fruits had a significant effect in which the treatment integrated with T₁₅ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through urea) + MC] recorded the highest chlorophyll content. Statistically par data was also recorded in treatment amended with T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC]. The observed increase in total phenolic content could be credited to the application of nano urea which enhances nitrogen efficiency and plays an essential function in the phenolic biosynthesis pathway. Constant access to nitrogen eliminates oxidative stress in plants which results in increased phenolic production. Vermicompost utilization might also release humic acids and plant growth promoting substances which might increase the spur of phenolic content in the fruit. Sole application of organic manures recorded lower phenol content. This may be because of its slow-release nutrients in nature which it could not provide nutrients at crucial growth stages resulting in a diminution in phenolic content. This finding is in harmony with the findings of Mushtaq (2023) and Islam *et al.* (2018).

Experimental treatments integrated with PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀), VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₆) and FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₂) recorded the maximum shelf life of the fruit. This might be because of the optimum application of nitrogen which may reduce excessive production of ethylene. The increase in shelf life might also be attributed to the entry of nano urea into the plant system and could have mediated respiration by acting as a hydrogen acceptor and thus altering the carbohydrate metabolism of plants promoting the accumulation of sugar (Neeruggi, 2024). The combination effect of organic manures, inorganic fertilizers and microbial consortium may also enhance the accumulation of antioxidants and supplementary phenolic compounds which possibly will increase resistance to fruit decay. The beneficial microbes present in the microbial consortium may also modulate ethylene production which in turn may reduce ripening and senescence. The deterioration of shelf life in control experiments may be related to nutrient deficiencies creating weak cell walls that result in rapid fruit spoilage. Also in control treatment, due to a lack of nutrient regulation, there might be excessive production of ethylene which might accelerate ripening and to a decrease in shelf life. This result is in conformity with the findings of Merghany *et al.* (2019) in cucumber, Kharga *et al.* (2020) in cucumber and Choudhary (2020) in ridge gourd.

4.4. Nutrient uptake by plants

4.4.1 Nitrogen

The findings of the experiment in relation to the influence of nanofertilizers based integrated nutrient management on nutrient content are detailed in Table 4.30, 4.31, 4.32 and 4.33 and total nitrogen uptake in Table 4.34 and Figure 4.30. As per the data shown in the Table, significant differences in nutrient content can be observed in discrete sections of the plant while utilizing diverse sources of nutrients. The highest pooled N content in fruit and in vines was perceived in T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] with 3.36% and 2.24% respectively. While in leaves, the highest pooled N content was perceived in the treatment amended with FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₂) with an average content of 2.52%. Treatment T₁₁ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through urea) + MC] recorded the highest N content in tubers with a pooled value of 0.88%. The data pooled analysis also shows a significant difference in nitrogen uptake and the highest total nitrogen uptake was documented in the treatment T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] with 42.16 q ha⁻¹ and the lowest total N uptake in treatment control (T₂₂) with 25.76 q ha⁻¹.

4.4.2 Phosphorous

The findings of the experiment in relation to the influence of nanofertilizers based integrated nutrient management on nutrient content are detailed in Table 4.30, 4.31, 4.32 and 4.33 and phosphorous uptake in Table 4.34 and Figure 4.31. As per the data shown in the Table, significant differences in nutrient content can be observed in various sections of the plant with the use of diverse sources of nutrients. The highest P content in vines and tubers was noted in the treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] with an average pooled content of 0.41% and 0.30% respectively. In fruits, treatment T₈ (PM @ 10 t ha⁻¹ + MC) documented the highest total P content in fruits with 0.76% while treatment T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] observed the highest total P content in leaves with 0.93%. The pooled data analysis revealed a significant difference in total P uptake with treatment T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] recorded the

highest pooled total P uptake with 10.52 q ha⁻¹ and treatment control (T₂₂) with the lowest average total P uptake with 5.47 q ha⁻¹.

4.4.3 Potassium

The findings of the experiment in relation to the influence of nanofertilizers based integrated nutrient management on nutrient content are detailed in Table 4.30, 4.31, 4.32 and 4.33 and total potassium uptake in Table 4.34 and Figure 4.32. As per the data shown in the Table, significant differences in nutrient content can be observed in various sections of the plant with the application of diverse sources of nutrients. Treatment T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] recorded the highest K content in fruits and leaves with a pooled content of 1.06 % and 2.51% respectively. Treatment incorporated with PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) recorded the highest K content in vines with a pooled value of 1.81% while treatment T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] recorded the highest K content with tubers with an average content of 1.17%. The pooled data analysis also indicates the significant difference in total K uptake as shown in the Table. Treatment amended with FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₂) recorded the highest total K uptake with an average value of 26.24 q ha⁻¹ while treatment control (T₂₂) was recorded the lowest total K uptake with a pooled value of 17.93 q ha⁻¹.

Table 4.30: Effect of nanofertilizer based INM on nutrient content of the fruit

Sl. no.	Treatment	Nutrient content (%)								
		N			P			K		
		2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	3.35	3.30	3.32	0.68	0.71	0.69	0.98	1.03	1.01
T ₂	Full dose of RDF (N through nano urea)	3.18	3.14	3.16	0.71	0.74	0.72	1.01	1.03	1.02
T ₃	FYM @ 20 t ha ⁻¹	3.25	3.26	3.26	0.74	0.73	0.73	1.01	1.01	1.01
T ₄	VC @ 5 t ha ⁻¹	3.25	3.27	3.26	0.73	0.71	0.72	1.00	1.01	1.01
T ₅	PM @ 10 t ha ⁻¹	3.31	3.18	3.24	0.71	0.74	0.73	1.01	1.02	1.01
T ₆	FYM @ 20 t ha ⁻¹ + MC	3.35	3.14	3.24	0.74	0.73	0.73	1.04	1.06	1.05
T ₇	VC @ 5 t ha ⁻¹ + MC	3.47	3.35	3.41	0.73	0.73	0.73	1.05	1.01	1.03
T ₈	PM @ 10 t ha ⁻¹ + MC	3.19	3.24	3.21	0.74	0.78	0.76	1.03	1.02	1.03
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	3.29	3.27	3.28	0.79	0.50	0.64	1.05	1.05	1.05
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	3.07	3.09	3.08	0.62	0.51	0.57	0.95	0.98	0.97
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	3.20	3.24	3.22	0.64	0.52	0.58	1.02	1.01	1.02
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	3.31	3.40	3.35	0.66	0.53	0.60	1.06	1.05	1.06
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	3.20	3.15	3.18	0.67	0.74	0.70	0.98	1.00	0.99
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	3.36	3.03	3.20	0.65	0.74	0.70	0.98	1.01	1.00
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	3.33	3.08	3.20	0.67	0.69	0.68	1.03	1.04	1.04
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	3.50	3.21	3.36	0.66	0.73	0.70	1.03	1.06	1.05
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	3.25	3.26	3.26	0.67	0.73	0.70	1.01	1.03	1.02
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	3.38	3.20	3.29	0.71	0.74	0.73	1.01	1.05	1.03
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	3.12	3.20	3.16	0.53	0.78	0.66	1.02	0.95	0.98
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	3.30	3.34	3.32	0.55	0.50	0.53	1.06	1.02	1.04
T ₂₁	Farmers practise	3.16	3.19	3.18	0.58	0.50	0.54	1.05	1.05	1.05
T ₂₂	Control	2.95	2.99	2.97	0.59	0.52	0.55	1.04	0.98	1.01
SEm±		0.069	0.048	0.036	0.044	0.008	0.03	0.016	0.017	0.009
CD (P=0.05)		0.198	0.138	0.103	0.127	0.024	0.087	0.047	0.05	0.026

Table 4.31: Effect of nanofertilizer based INM on nutrient content of the leaves

Sl. no.	Treatment	Nutrient content (%)								
		N			P			K		
		2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	2.37	2.38	2.37	0.85	0.89	0.87	2.39	2.40	2.39
T ₂	Full dose of RDF (N through nano urea)	2.04	2.05	2.05	0.80	0.84	0.82	2.33	2.35	2.34
T ₃	FYM @ 20 t ha ⁻¹	2.21	2.23	2.22	0.76	0.80	0.78	2.29	2.32	2.31
T ₄	VC @ 5 t ha ⁻¹	2.05	2.06	2.06	0.71	0.77	0.74	2.35	2.36	2.35
T ₅	PM @ 10 t ha ⁻¹	2.09	2.12	2.11	0.73	0.78	0.76	2.31	2.33	2.32
T ₆	FYM @ 20 t ha ⁻¹ + MC	2.28	2.30	2.29	0.74	0.79	0.76	2.32	2.34	2.33
T ₇	VC @ 5 t ha ⁻¹ + MC	2.18	2.20	2.19	0.79	0.84	0.81	2.33	2.36	2.35
T ₈	PM @ 10 t ha ⁻¹ + MC	2.30	2.32	2.31	0.75	0.80	0.77	2.31	2.33	2.32
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	2.24	2.27	2.26	0.79	0.83	0.81	2.33	2.34	2.33
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	2.21	2.25	2.23	0.78	0.83	0.81	2.34	2.37	2.36
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	2.36	2.38	2.37	0.83	0.85	0.84	2.41	2.42	2.41
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	2.51	2.53	2.52	0.86	0.87	0.87	2.50	2.52	2.51
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	1.96	2.00	1.98	0.78	0.84	0.81	2.38	2.39	2.39
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	2.22	2.26	2.24	0.74	0.80	0.77	2.32	2.34	2.33
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	2.24	2.27	2.26	0.87	0.91	0.89	2.45	2.46	2.45
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	2.43	2.22	2.32	0.91	0.95	0.93	2.36	2.39	2.37
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	2.27	2.30	2.29	0.80	0.84	0.82	2.35	2.37	2.36
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	2.23	2.26	2.24	0.82	0.87	0.85	2.32	2.34	2.33
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	2.40	2.43	2.42	0.84	0.88	0.86	2.42	2.45	2.44
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	2.45	2.47	2.46	0.87	0.93	0.90	2.37	2.40	2.39
T ₂₁	Farmers practise	2.15	2.19	2.17	0.74	0.79	0.76	2.30	2.32	2.31
T ₂₂	Control	1.94	1.95	1.94	0.69	0.74	0.72	2.28	2.30	2.29
SEm±		0.09	0.08	0.015	0.022	0.021	0.004	0.024	0.021	0.002
CD (P=0.05)		0.258	0.225	0.042	0.063	0.061	0.011	0.07	0.061	0.007

Table 4.32: Effect of nanofertilizer based INM on nutrient content of the vines

Sl. no	Treatment	Nutrient content (%)								
		N			P			K		
		2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	2.06	2.10	2.08	0.38	0.41	0.40	1.73	1.74	1.74
T ₂	Full dose of RDF (N through nano urea)	1.98	2.02	2.00	0.32	0.35	0.33	1.72	1.74	1.73
T ₃	FYM @ 20 t ha ⁻¹	1.91	1.96	1.94	0.30	0.33	0.32	1.68	1.70	1.69
T ₄	VC @ 5 t ha ⁻¹	1.97	2.02	1.99	0.26	0.29	0.28	1.69	1.72	1.70
T ₅	PM @ 10 t ha ⁻¹	1.92	1.96	1.94	0.28	0.30	0.29	1.66	1.69	1.68
T ₆	FYM @ 20 t ha ⁻¹ + MC	2.01	2.05	2.03	0.32	0.33	0.33	1.72	1.73	1.73
T ₇	VC @ 5 t ha ⁻¹ + MC	2.00	2.04	2.02	0.33	0.34	0.34	1.69	1.71	1.70
T ₈	PM @ 10 t ha ⁻¹ + MC	2.10	2.13	2.11	0.29	0.31	0.30	1.70	1.72	1.71
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	2.08	2.11	2.09	0.33	0.34	0.34	1.73	1.76	1.74
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	2.11	2.14	2.12	0.31	0.33	0.32	1.72	1.74	1.73
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	2.07	2.11	2.09	0.35	0.38	0.36	1.74	1.78	1.76
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	2.21	2.22	2.22	0.37	0.39	0.38	1.77	1.80	1.78
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	2.00	2.03	2.02	0.29	0.31	0.30	1.72	1.75	1.74
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	2.12	2.15	2.13	0.32	0.34	0.33	1.74	1.76	1.75
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	2.09	2.12	2.10	0.33	0.34	0.33	1.76	1.78	1.77
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	2.23	2.25	2.24	0.35	0.34	0.35	1.78	1.79	1.79
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	2.02	2.03	2.02	0.31	0.33	0.32	1.75	1.78	1.77
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	2.11	2.15	2.13	0.33	0.35	0.34	1.71	1.73	1.72
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	2.13	2.17	2.15	0.30	0.32	0.31	1.75	1.78	1.77
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	2.19	2.22	2.21	0.40	0.41	0.41	1.80	1.82	1.81
T ₂₁	Farmers practise	2.03	2.05	2.04	0.29	0.31	0.30	1.68	1.73	1.71
T ₂₂	Control	1.85	1.91	1.88	0.23	0.25	0.24	1.61	1.65	1.63
SEm±		0.035	0.033	0.004	0.017	0.014	0.003	0.019	0.016	0.003
CD (P=0.05)		0.1	0.094	0.01	0.048	0.039	0.008	0.053	0.023	0.009

Table 4.33: Effect of nanofertilizer based INM on nutrient content of the tubers

Sl. no.	Treatment	Nutrient content (%)								
		N			P			K		
		2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	0.80	0.83	0.81	0.25	0.23	0.24	1.02	1.07	1.05
T ₂	Full dose of RDF (N through nano urea)	0.71	0.73	0.72	0.20	0.17	0.19	0.98	1.06	1.01
T ₃	FYM @ 20 t ha ⁻¹	0.68	0.69	0.69	0.16	0.14	0.15	0.99	1.05	1.02
T ₄	VC @ 5 t ha ⁻¹	0.78	0.80	0.79	0.21	0.19	0.20	0.96	1.01	0.99
T ₅	PM @ 10 t ha ⁻¹	0.70	0.72	0.71	0.17	0.16	0.17	0.94	1.02	0.98
T ₆	FYM @ 20 t ha ⁻¹ + MC	0.76	0.78	0.77	0.20	0.18	0.19	1.01	1.07	1.04
T ₇	VC @ 5 t ha ⁻¹ + MC	0.71	0.73	0.72	0.22	0.20	0.21	1.03	1.09	1.06
T ₈	PM @ 10 t ha ⁻¹ + MC	0.72	0.73	0.73	0.23	0.22	0.23	1.00	1.07	1.03
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	0.72	0.74	0.73	0.26	0.24	0.25	1.04	1.11	1.08
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	0.76	0.78	0.77	0.24	0.22	0.23	1.01	1.07	1.05
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	0.88	0.89	0.88	0.26	0.24	0.25	1.06	1.15	1.10
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	0.85	0.86	0.86	0.29	0.27	0.28	1.10	1.18	1.14
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	0.74	0.75	0.74	0.26	0.25	0.26	1.05	1.14	1.08
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	0.81	0.82	0.81	0.22	0.21	0.21	1.02	1.07	1.05
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	0.84	0.86	0.85	0.28	0.26	0.27	1.09	1.19	1.12
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	0.80	0.82	0.81	0.33	0.32	0.32	1.14	1.21	1.17
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	0.75	0.77	0.76	0.23	0.22	0.23	1.02	1.12	1.06
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	0.74	0.76	0.75	0.28	0.26	0.27	1.06	1.09	1.10
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	0.83	0.85	0.84	0.29	0.27	0.28	1.09	1.15	1.12
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	0.79	0.80	0.80	0.31	0.30	0.30	1.12	1.18	1.15
T ₂₁	Farmers practise	0.73	0.75	0.74	0.21	0.20	0.21	0.99	1.05	1.03
T ₂₂	Control	0.68	0.69	0.68	0.14	0.13	0.14	0.90	0.54	0.72
SEm±		0.027	0.025	0.002	0.016	0.017	0.001	0.017	0.013	0.026
CD (P=0.05)		0.076	0.072	0.006	0.046	0.048	0.003	0.048	0.038	0.076

Table 4.34: Effect of nanofertilizer based INM on total nutrient uptake

Sl. no.	Treatment	Total nutrient uptake (q ha ⁻¹)								
		N			P			K		
		2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	35.13	35.89	35.51	9.27	9.59	9.43	23.75	24.55	24.15
T ₂	Full dose of RDF (N through nano urea)	25.63	25.90	25.76	6.73	6.94	6.84	19.63	20.24	19.94
T ₃	FYM @ 20 t ha ⁻¹	27.51	28.23	27.87	6.78	6.98	6.88	20.25	20.92	20.59
T ₄	VC @ 5 t ha ⁻¹	25.65	26.31	25.98	6.33	6.49	6.41	19.35	19.98	19.67
T ₅	PM @ 10 t ha ⁻¹	27.60	27.63	27.62	6.67	6.95	6.81	20.25	20.91	20.58
T ₆	FYM @ 20 t ha ⁻¹ + MC	31.98	31.36	31.67	7.68	7.81	7.75	21.71	22.40	22.05
T ₇	VC @ 5 t ha ⁻¹ + MC	28.91	29.26	29.09	7.33	7.56	7.44	21.22	21.97	21.59
T ₈	PM @ 10 t ha ⁻¹ + MC	28.06	28.76	28.41	7.12	7.48	7.30	20.93	21.56	21.25
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	28.97	29.39	29.18	7.81	6.88	7.35	21.59	22.22	21.90
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	31.70	32.27	31.98	7.76	7.39	7.57	22.39	23.21	22.80
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	34.09	34.60	34.34	8.28	7.86	8.07	23.84	24.52	24.18
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	41.67	42.64	42.16	10.05	9.22	9.64	26.26	26.63	26.45
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	27.12	27.61	27.36	7.15	7.72	7.43	20.55	21.34	20.95
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	30.25	29.36	29.81	7.00	7.61	7.30	20.85	21.61	21.23
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	34.10	33.52	33.81	8.62	8.88	8.75	23.52	24.24	23.88
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	41.72	39.27	40.49	10.27	10.78	10.52	25.89	26.58	26.24
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	29.49	29.84	29.66	7.32	7.71	7.51	21.50	22.17	21.84
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	29.41	29.03	29.22	7.64	8.01	7.82	21.22	21.93	21.57
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	33.49	34.71	34.10	7.81	9.30	8.56	23.44	23.83	23.63
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	40.90	41.50	41.20	9.53	9.38	9.45	26.14	26.61	26.37
T ₂₁	Farmers practise	29.66	30.26	29.96	6.74	6.65	6.69	21.38	22.15	21.76
T ₂₂	Control	25.67	25.85	25.76	5.49	5.44	5.47	18.83	17.02	17.93
SEm±		0.966	1.387	0.229	0.306	0.29	0.147	0.421	0.466	0.156
CD (P=0.05)		2.765	3.973	0.657	0.875	0.831	0.421	1.21	1.335	0.447

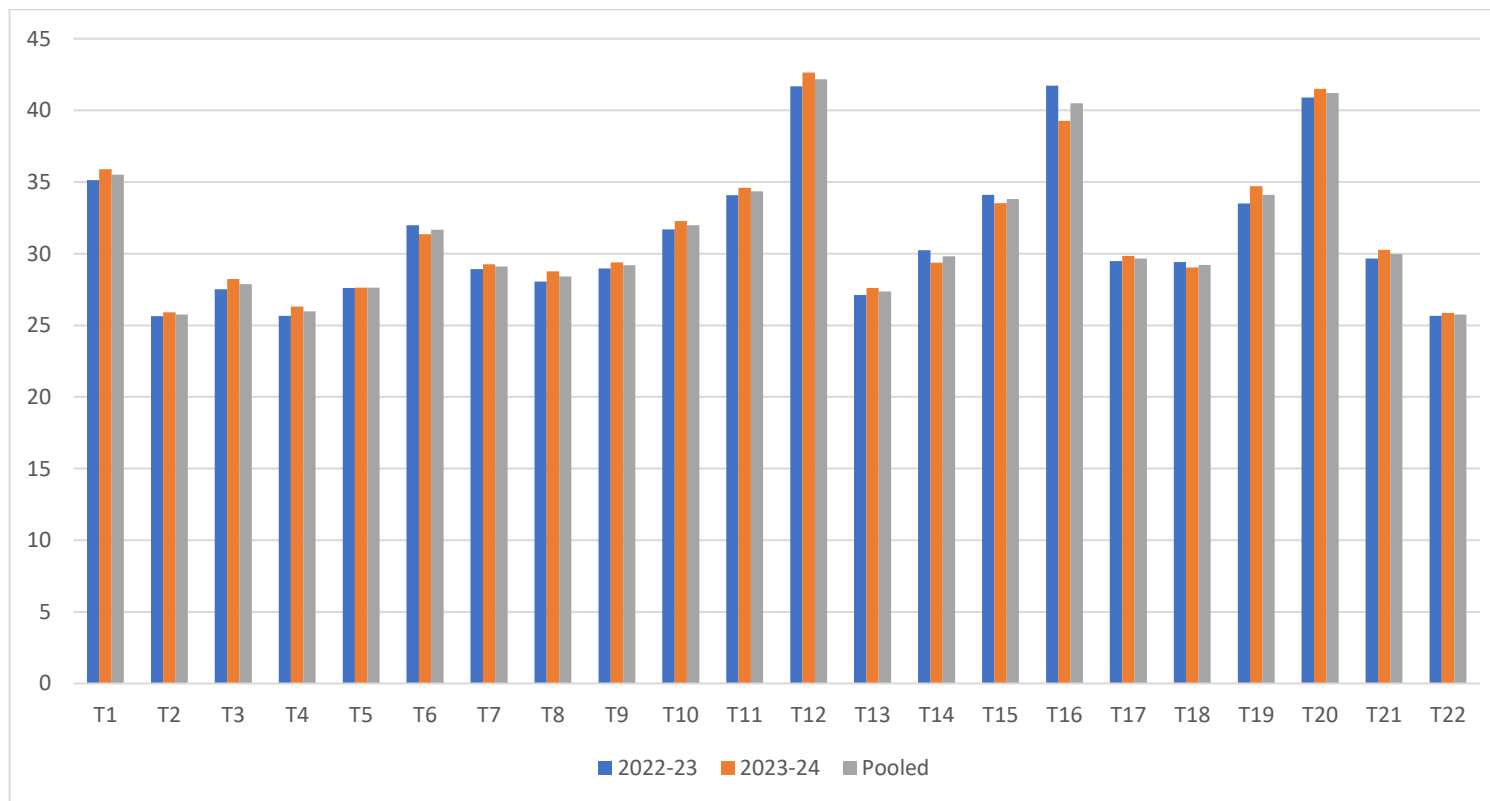


Figure 4.30: Effect of nanofertilizer based INM on total N uptake

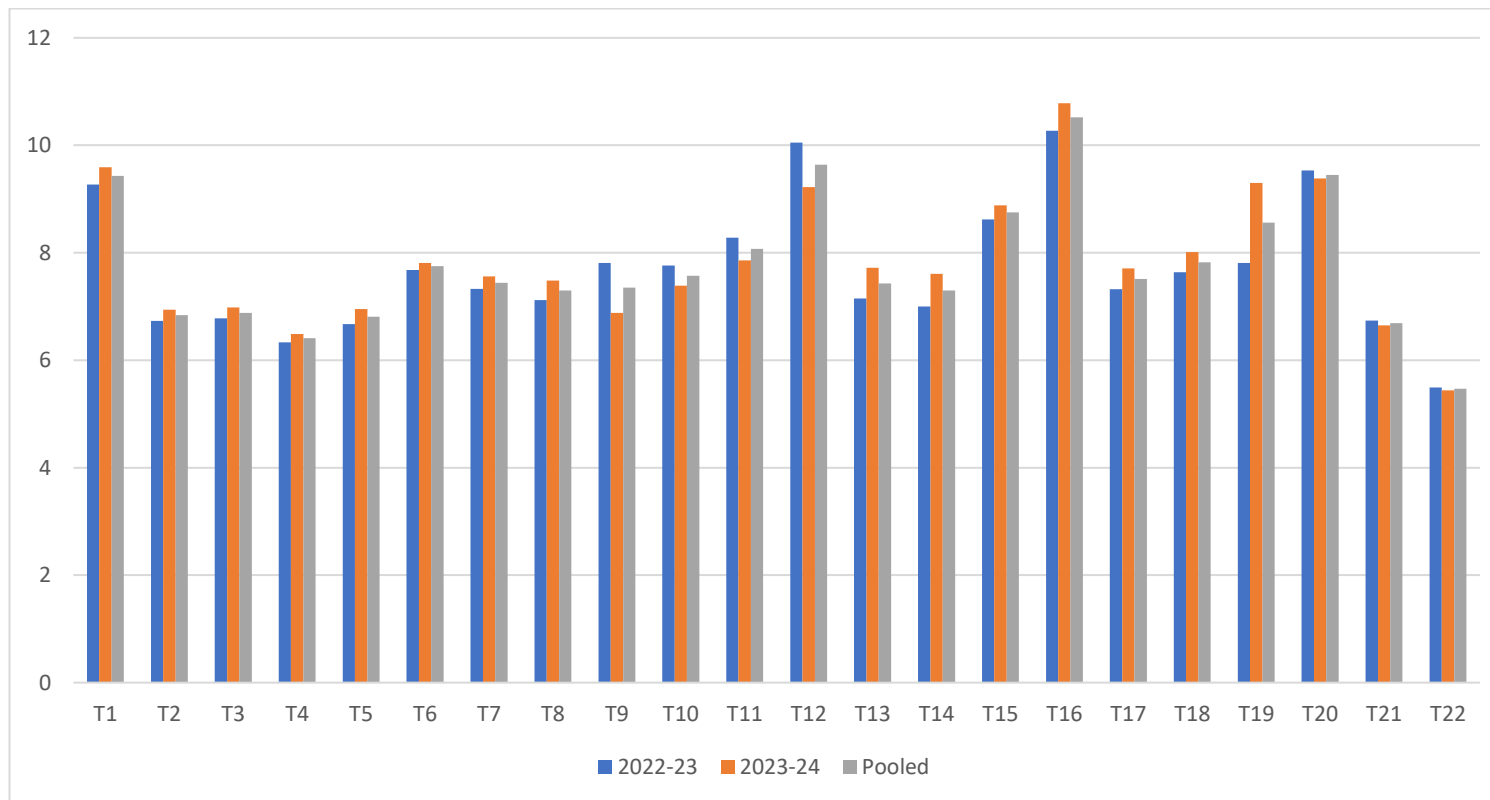


Figure 4.31: Effect of nanofertilizer based INM on total P uptake

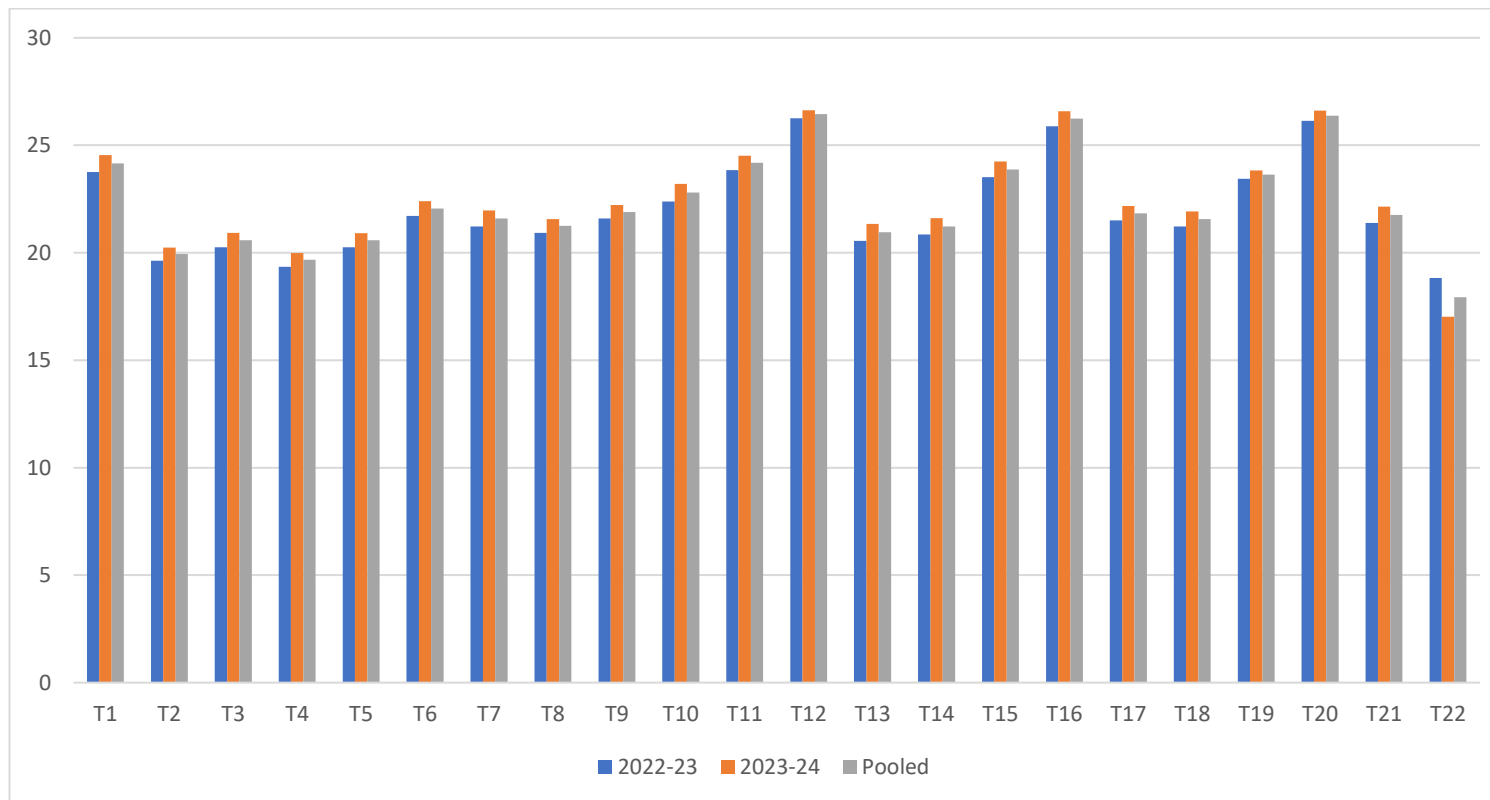


Figure 4.32: Effect of nanofertilizer based INM on total K uptake

Application of FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₂) resulted in higher N uptake as per the analysis specified in Table 4.34. This increase in uptake may be explained by the integrated incorporation of fertilizers which helps in availability of crop nutrients throughout its life cycle (Rathod, 2017). The addition of biofertilizers and manures may also help with N losses due to leaching and volatilization (Vimala *et al.*, 2007). Due to the small size particles of nanourea and having higher nutrient use efficiency, the usage of nano urea might improve the total nutrient uptake. The synergistic effect of application of FYM along with inorganic fertilizers, N through nano urea and microbial consortium may result in stimulation of microbial growth and root growth which may in turn improve the soil physical condition and texture and resulted in better absorption of N. Similarly, the buildup in the treatment amended with VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₆) and PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) can be possibly clarified by the above reasons. Thriveni *et al.* (2015) stated that biofertilizers enhances crop growth, yield and quality and also improves soil fertility through nutrient fixation, solubilization and in addition to release of GRs like IAA, GA, cytokinins and additional substances for growth promoting, which then influenced dry matter production of the crop and improves the nutrient uptake and apparent recovery of specific nutrients in bitter melon. Similar results related to nitrogen uptake were observed by Enigi (2022), Sharma (2019) and Dodake *et al.* (2015)

The pooled analysis on P uptake indicates that the application of VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₆) resulted in higher P uptake as compared to all the treatments. This increase in P uptake might be possibly to the integrated application of organics manures i.e., vermicompost, microbial consortium and inorganic fertilizers (N through nano urea) which enriched the soil microbial activity and therefore increased its nutrient availability (Lalitha *et al.*, 2010). Mineralization of organic matter due to changing oxidation-reduction conditions and its absorption by plants are the main reasons for improved availability. For this reason, the soil treated with poultry manure tends to enhance the ability of plants to uptake phosphorus (Solo, 2024). Sarangthem *et al.* (2011) also reported that the increase in P uptake by application of VC may be attributed to enhancement of nutrient availability

(NPK) which ultimately boosted the activity of the soil microbes and therefore converted the unavailable form of P to available form and improved physical and biochemical condition of soil. This result is in unity with the findings of Enigi (2022), Sharma (2019), Rathod (2017) and Kapse (2016).

According to the pooled analysis as shown in the Table, the highest K uptake was recorded in the treatment integrated with FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₂). This significant difference could be linked to increased availability of nutrients from organic manures, which release essential micro- and macronutrients into the soil solution after decomposition and making them more available for plant uptake. (Diwale *et al.*, 2020). More amount of K was uptake by the plants possibly because more nutrient sources became available, including the nutrients in the mineralized organic manure (Akhila *et al.*, 2019). There could also be more K in soil because adding organic manures increased the effects of organic acids and formed more organic molecule complexes. Similar findings were reported by Enigi (2022), Sharma (2019), Rathod (2017), Ghayal *et al.* (2016) and Thriveni *et al.* (2015).

4.5 Fertility status of the soil after crop harvest

4.5.1 Available N

The experimental results with relation to the influence of nanofertilizers based INM on available N of the soil after crop harvest are detailed in Table 4.35 and Figure 4.33. As portrayed in the Table, the data indicates that there was a significant difference between the treatments as demonstrated by one way ANOVA. The highest pooled available N in the soil was perceived in the treatment T₁₁ where the chow-chow had received [FYM @ 10 t ha⁻¹ + ½ of RDF (N through urea) + MC] with 260.34 kg ha⁻¹ followed closely by treatment T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₁₀ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea)] with 254.57 kg ha⁻¹ and 256.37 kg ha⁻¹ respectively. The lowest pooled available N was detailed in the treatment control (T₂₂) and farmer's practice (T₂₁) with 213.26 kg ha⁻¹ and 221.52 kg ha⁻¹.

4.5.2 Available P

The experimental results with relation to the influence of nanofertilizers based INM on available P of the soil after crop harvest are detailed in Table 4.36 and Figure 4.34. As portrayed in the Table, the data denotes that there was a significant difference between the treatments as demonstrated by one way ANOVA. Treatment T₁₈ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea)] exhibited the highest available P content with a data set of 26.15 kg ha⁻¹ (pooled) followed subsequently by treatment T₁₀ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea)] with 24.11 kg ha⁻¹ and the lowest pooled available P was detailed in the treatment where no nutrients were added i.e., T₂₂ (control) with 9.37 kg ha⁻¹.

Table 4.35: Effect of nanofertilizer based INM on available soil N

Sl. no.	Treatment	Available N (kg ha ⁻¹)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	250.35	251.76	251.06
T ₂	Full dose of RDF (N through nano urea)	247.57	249.54	248.56
T ₃	FYM @ 20 t ha ⁻¹	229.02	237.98	233.50
T ₄	VC @ 5 t ha ⁻¹	218.98	236.02	227.50
T ₅	PM @ 10 t ha ⁻¹	236.02	242.33	239.18
T ₆	FYM @ 20 t ha ⁻¹ + MC	236.87	231.81	234.34
T ₇	VC @ 5 t ha ⁻¹ + MC	215.43	211.47	213.45
T ₈	PM @ 10 t ha ⁻¹ + MC	218.73	220.43	219.58
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	251.55	246.35	248.95
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	257.87	254.87	256.37
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	263.73	256.95	260.34
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	250.84	244.09	247.46
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	212.91	216.65	214.78
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	223.98	223.98	223.98
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	253.25	248.88	251.07
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	259.13	250.02	254.57
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	235.41	244.24	239.83
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	236.10	238.50	237.30
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	253.99	244.58	249.28
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	239.74	235.31	237.53
T ₂₁	Farmers practise	222.40	220.65	221.52
T ₂₂	Control	211.98	214.54	213.26
SEm±		7.82	7.37	6.82
CD (P=0.05)		22.38	21.13	19.54

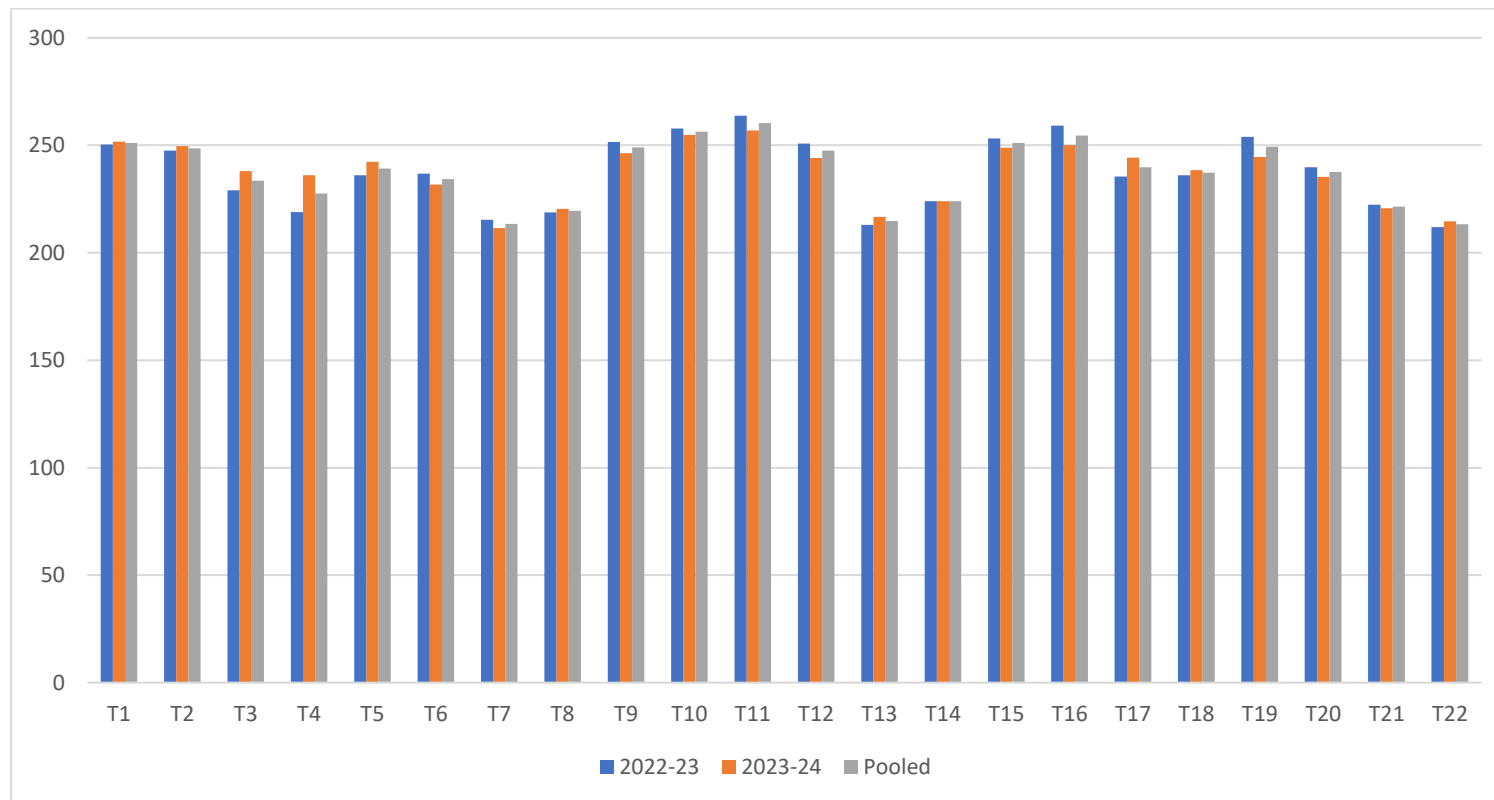


Figure 4.33: Effect of nanofertilizer based INM on available soil N

Table 4.36: Effect of nanofertilizer based INM on available soil P

Sl. no.	Treatment	Available P (kg ha ⁻¹)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	18.57	19.91	19.24
T ₂	Full dose of RDF (N through nano urea)	18.83	19.54	19.19
T ₃	FYM @ 20 t ha ⁻¹	19.80	20.54	20.17
T ₄	VC @ 5 t ha ⁻¹	15.46	17.91	16.69
T ₅	PM @ 10 t ha ⁻¹	14.06	16.43	15.24
T ₆	FYM @ 20 t ha ⁻¹ + MC	20.22	22.06	21.14
T ₇	VC @ 5 t ha ⁻¹ + MC	22.50	22.84	22.67
T ₈	PM @ 10 t ha ⁻¹ + MC	20.87	20.24	20.56
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	16.20	16.54	16.37
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	24.09	24.13	24.11
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	22.58	22.83	22.71
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	13.87	15.57	14.72
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	10.71	13.28	12.00
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	16.57	15.28	15.93
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	12.95	13.90	13.43
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	19.57	22.57	21.07
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	21.06	24.06	22.56
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	26.92	25.39	26.15
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	19.05	23.28	21.16
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	17.94	19.58	18.76
T ₂₁	Farmers practise	10.35	11.91	11.13
T ₂₂	Control	9.35	9.40	9.37
SEm±		1.58	1.56	1.29
CD (P=0.05)		4.53	4.47	3.71

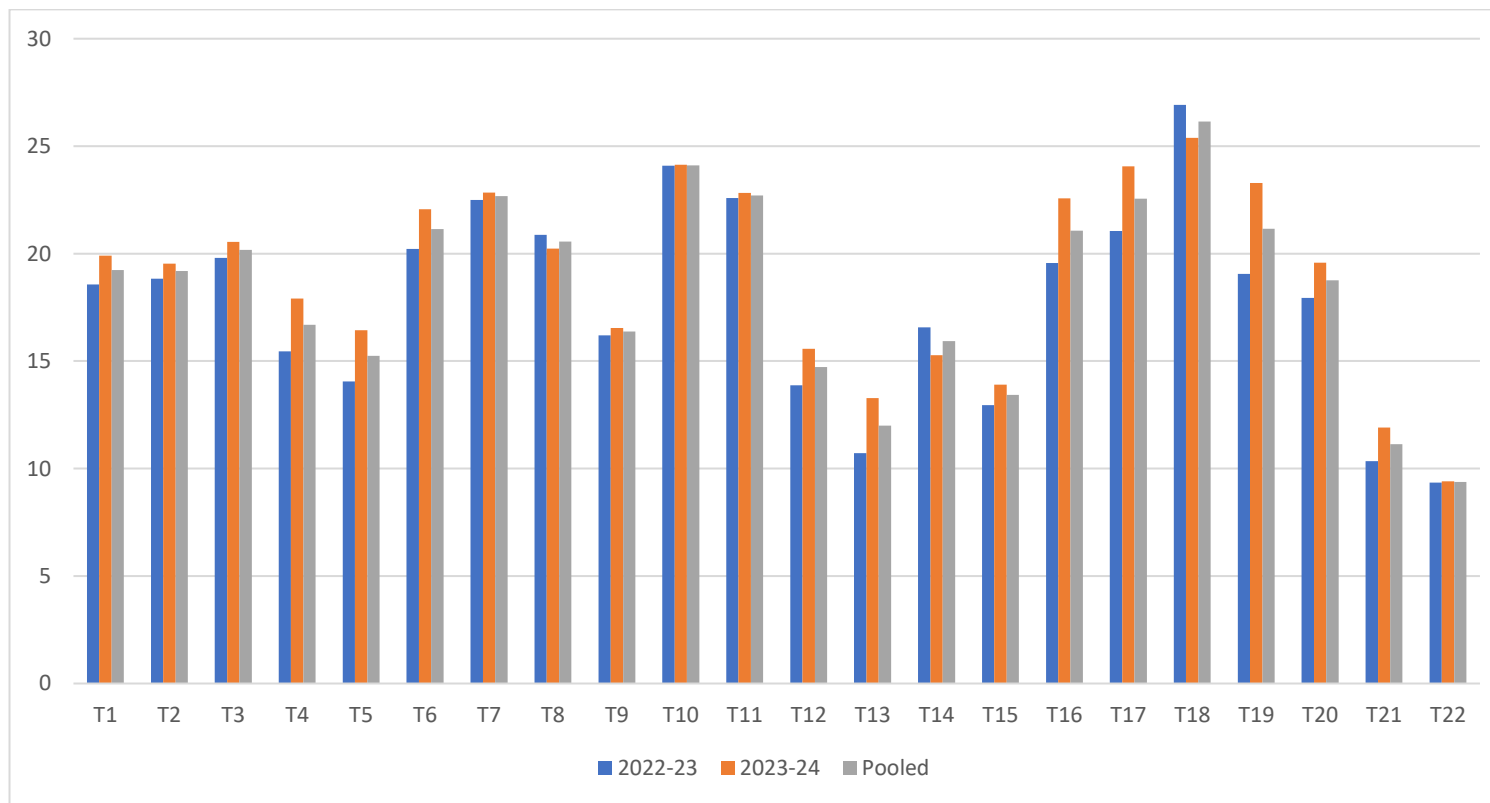


Figure 4.34: Effect of nanofertilizer based INM on available soil P

4.5.3 Available K

The data on available K in the soil following crop harvest is presented in Table 4.37 and illustrated in Figure 4.35. As portrayed in the Table, the study signifies that there was a significant difference between the treatments as demonstrated by one way ANOVA. The highest pooled available K was unveiled in the treatment T₁₈ where PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) was applied with 226.80 kg ha⁻¹. Treatment T₉ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through urea)] was also recorded statistically on par with a pooled value of 221.19 kg ha⁻¹. Treatment T₂₂ (control) recorded the lowest available K with 139.76 kg ha⁻¹.

4.5.4 Soil organic carbon

Table 4.38 and Figure 4.36 depict the data on the influence of soil organic carbon in the soil by different sources of nutrients. The data shows that there was a significant difference between the treatments as determined by one-way ANOVA. Treatment T₃ (FYM @ 20 t ha⁻¹) recorded the maximum organic carbon content in the soil with a pooled value of 1.59% whereas the lowest pooled soil organic carbon was exhibited in the treatment control (T₂₂) with 0.99%.

4.5.5 Soil pH

The data on soil pH after the harvest of the crop are detailed in Table 4.39 and illustrated in Figure 4.37. The data shows that there was a significant difference between the treatments as demonstrated by one-way ANOVA. Treatment T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] reported the highest soil pH with 4.93 (pooled) followed closely by T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] with a pooled value of 4.89 and 4.84 respectively whereas the lowest soil pH was exhibited in the treatment T₁ [Full dose of RDF (N through urea)] with 4.36 (pooled).

Table 4.37: Effect of nanofertilizer based INM on available soil K

Sl. no.	Treatment	Available K (kg ha ⁻¹)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	201.28	207.27	204.27
T ₂	Full dose of RDF (N through nano urea)	217.20	211.17	214.19
T ₃	FYM @ 20 t ha ⁻¹	199.02	207.61	203.31
T ₄	VC @ 5 t ha ⁻¹	188.65	193.31	190.98
T ₅	PM @ 10 t ha ⁻¹	199.31	210.65	204.98
T ₆	FYM @ 20 t ha ⁻¹ + MC	212.61	177.24	194.93
T ₇	VC @ 5 t ha ⁻¹ + MC	213.64	222.94	218.29
T ₈	PM @ 10 t ha ⁻¹ + MC	199.68	199.65	199.67
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	221.57	220.80	221.19
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	171.02	188.31	179.67
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	217.90	218.28	218.09
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	167.24	197.94	182.59
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	203.31	217.20	210.26
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	207.31	207.98	207.65
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	168.98	172.57	170.78
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	182.28	195.31	188.80
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	196.65	198.88	197.76
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	229.62	223.99	226.80
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	210.28	203.83	207.06
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	193.70	200.65	197.18
T ₂₁	Farmers practise	162.98	179.68	171.33
T ₂₂	Control	129.87	149.65	139.76
SEm±		12.17	11.38	9.25
CD (P=0.05)		34.86	32.62	26.49

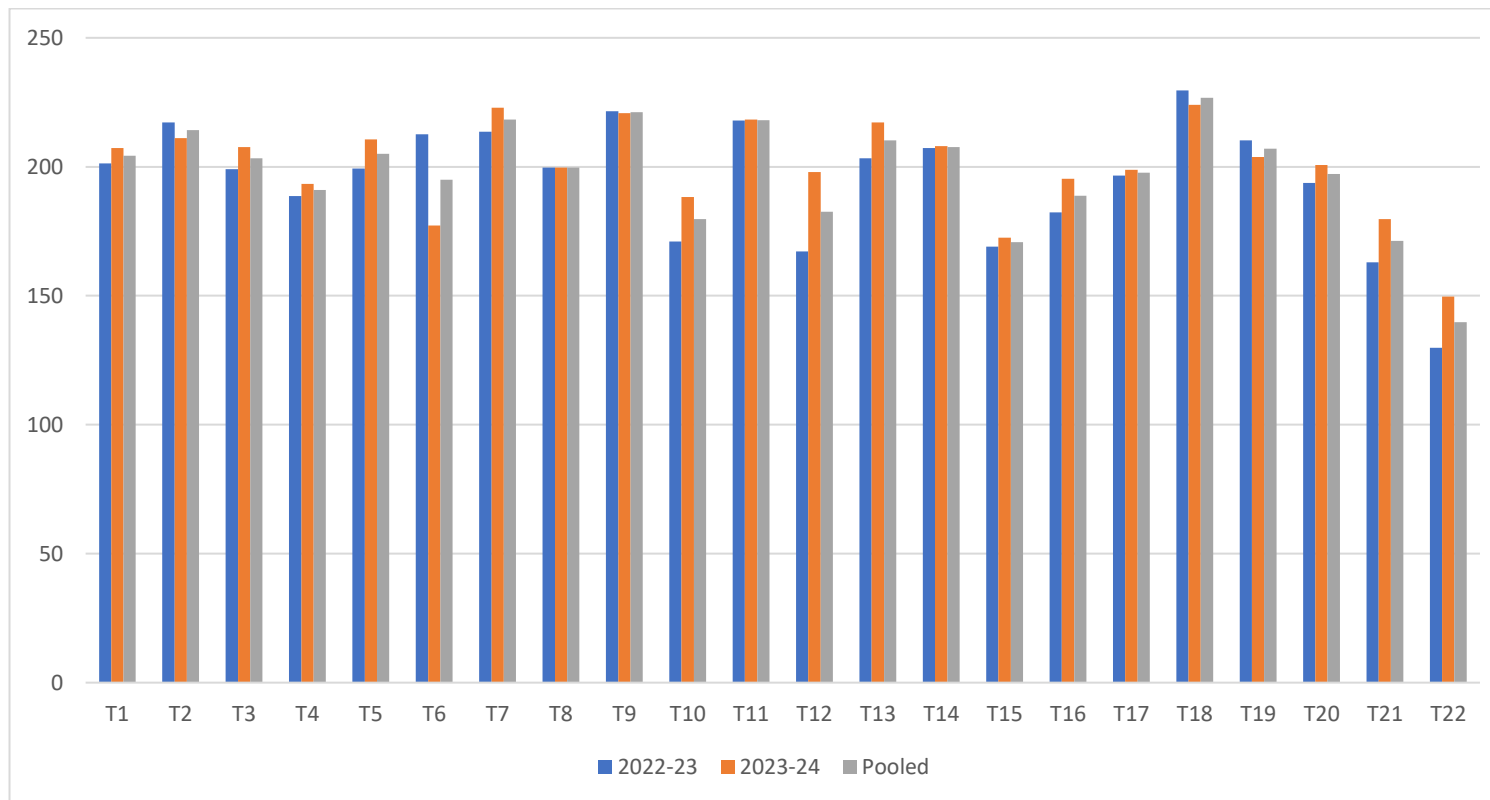


Figure 4.35: Effect of nanofertilizer based INM on available soil K

Table 4.38: Effect of nanofertilizer based INM on soil organic carbon

Sl. no.	Treatment	Soil organic carbon (%)		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	1.26	1.31	1.28
T ₂	Full dose of RDF (N through nano urea)	1.08	1.11	1.10
T ₃	FYM @ 20 t ha ⁻¹	1.57	1.61	1.59
T ₄	VC @ 5 t ha ⁻¹	1.49	1.53	1.51
T ₅	PM @ 10 t ha ⁻¹	1.52	1.57	1.55
T ₆	FYM @ 20 t ha ⁻¹ + MC	1.33	1.34	1.33
T ₇	VC @ 5 t ha ⁻¹ + MC	1.41	1.43	1.42
T ₈	PM @ 10 t ha ⁻¹ + MC	1.21	1.24	1.22
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	1.31	1.35	1.33
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	1.37	1.38	1.38
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	1.32	1.34	1.33
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	1.44	1.48	1.46
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	1.24	1.33	1.29
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	1.26	1.27	1.27
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	1.34	1.36	1.35
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	1.27	1.30	1.29
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	1.25	1.28	1.26
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	1.35	1.40	1.38
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	1.41	1.45	1.43
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	1.43	1.47	1.45
T ₂₁	Farmers practise	1.32	1.35	1.34
T ₂₂	Control	0.96	1.03	0.99
SEm±		0.075	0.086	0.058
CD (P=0.05)		0.215	0.247	0.167

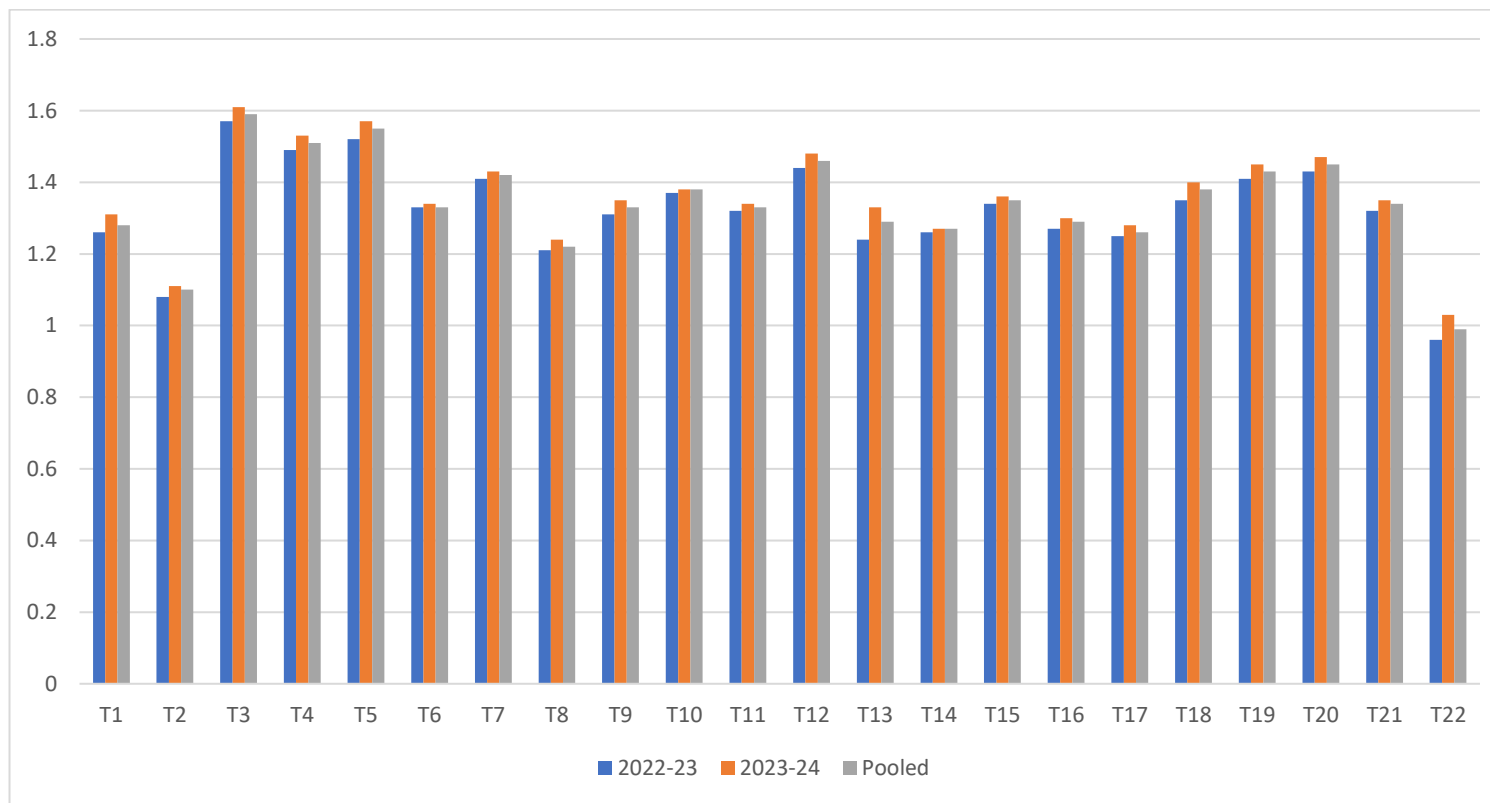


Figure 4.36: Effect of nanofertilizer based INM on soil organic carbon

Table 4.39: Effect of nanofertilizer based INM on soil pH

Sl. no.	Treatment	Soil pH		
		2022-23	2023-24	Pooled
T ₁	Full dose of RDF (N through urea)	4.38	4.33	4.36
T ₂	Full dose of RDF (N through nano urea)	4.51	4.56	4.54
T ₃	FYM @ 20 t ha ⁻¹	4.63	4.66	4.65
T ₄	VC @ 5 t ha ⁻¹	4.74	4.79	4.76
T ₅	PM @ 10 t ha ⁻¹	4.80	4.82	4.81
T ₆	FYM @ 20 t ha ⁻¹ + MC	4.78	4.81	4.80
T ₇	VC @ 5 t ha ⁻¹ + MC	4.73	4.84	4.78
T ₈	PM @ 10 t ha ⁻¹ + MC	4.55	4.58	4.56
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	4.69	4.61	4.65
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	4.63	4.65	4.64
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + MC	4.64	4.55	4.59
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	4.91	4.95	4.93
T ₁₃	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	4.75	4.67	4.71
T ₁₄	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	4.73	4.77	4.75
T ₁₅	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	4.74	4.78	4.76
T ₁₆	VC @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	4.86	4.91	4.89
T ₁₇	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	4.61	4.70	4.66
T ₁₈	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	4.70	4.72	4.71
T ₁₉	PM @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + MC	4.78	4.84	4.81
T ₂₀	PM @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + MC	4.81	4.87	4.84
T ₂₁	Farmers practise	4.67	4.73	4.70
T ₂₂	Control	4.43	4.49	4.46
SEm±		0.08	0.08	0.06
CD (P=0.05)		0.25	0.23	0.18

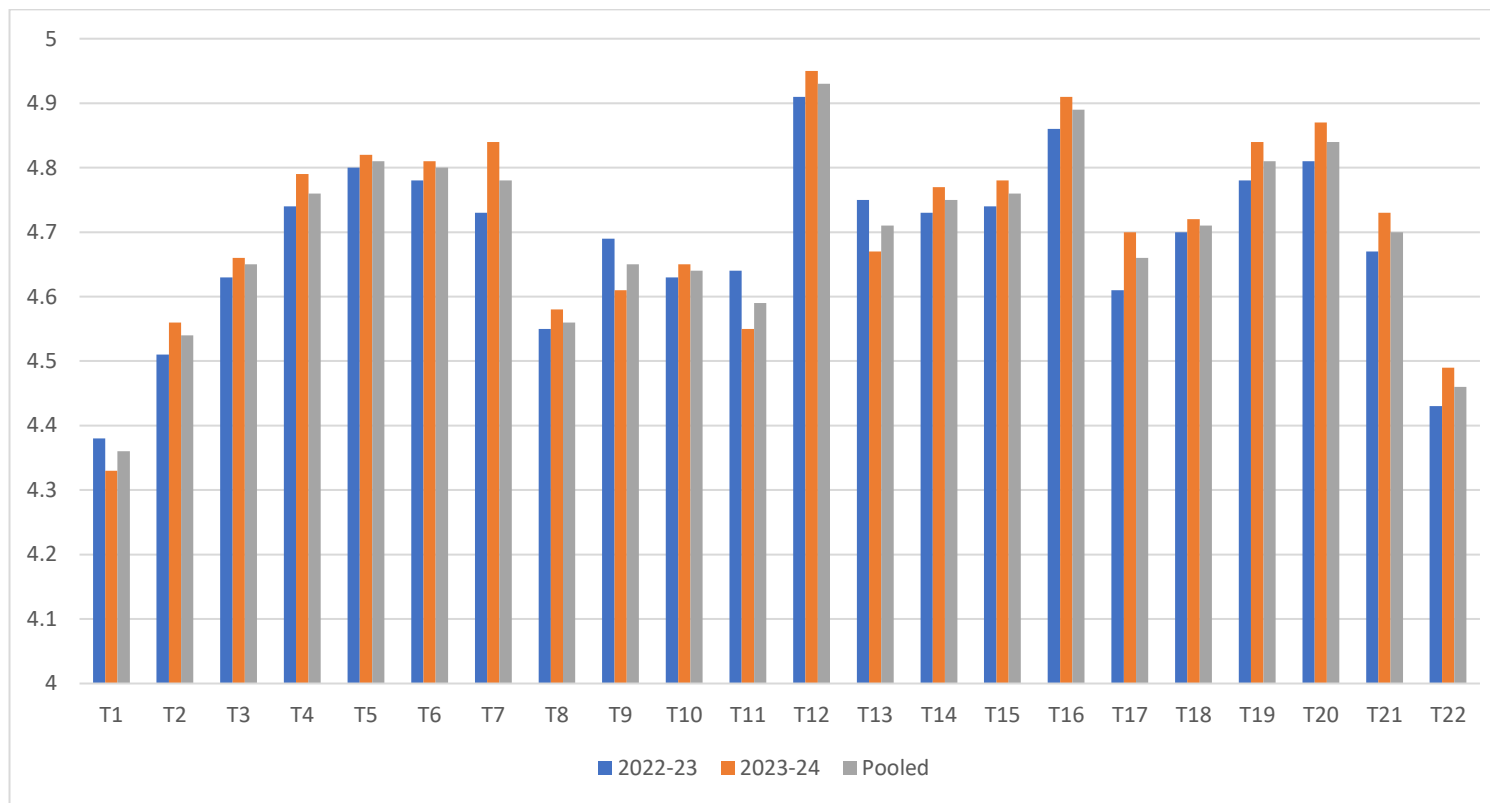


Figure 4.37: Effect of nanofertilizer based INM on soil pH

As per the pooled data given in the Table, the highest available N was exhibited in the treatment with the integration of FYM @ 10 t ha⁻¹ + ½ of RDF (N through urea) + MC (T₁₁). One reason for this could be due to the combination effect of FYM and microbial consortium which makes the nutrients available at a steady rate and reduces the loss of nutrients through leaching and volatilization. FYM also enhances soil organic matter which might improve microbial activity and may result in conceiving a favourable state for nitrogen fixation and retention (Chakraborty and Kumar, 2017). And because of the augmented nutrient application, the residual N might have been raised beside the N absorb by the crop (Behera, 2023). The solicitation of organic manures on top of biofertilizers might have led to mineralization of N which may multiply the soil microbes present in the soil and convert organically bound N to inorganic form (Sharma *et al.*, 2012). The higher pooled data of available N in the integrated treatment of VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₆) may be due to lower C:N ratio in vermicompost as paralleled to other sources. The lower available N recorded in treatment control may possibly be explained by the nutrient mining since no additional nutrients were added during the experimental phase. Lower available N in treatment T₂₁ (Farmers practice) may be due to insufficient nutrients added during the experimental phase which the crop may have absorb or the loss of nutrients either by leaching or volatilization. This is validated by the findings of Thriveni *et al.* (2015) in bitter gourd, Rajawat *et al.* (2019) in tomato, Patle *et al.* (2019) in bottle gourd and Patel *et al.* (2021) in ivy gourd.

The integrated application of inorganic fertilizers with PM *i.e.*, treatment T₁₈ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea)] observed higher available P as paralleled to other treatments. This aspect is justified by the combination effect of inorganic sources together with poultry manure which enhances the P availability. Decomposing minerals in poultry manure could lead to the release of organic acids that help make more microbes active and support greater binding of P (Lodhi *et al.*, 2017). Similarly, P availability from FYM treatment was higher when it was given with inorganic fertilizers, T₁₀ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea)]. This is owed to the FYM application which releases organic P on mineralization and assist in the availability of P. The organic manures also increase CEC which reduces the

nutrient loss and might help in retention of available P in the soil. The integration of organic, inorganic and biofertilizers also improved soil physical, chemical and biological properties thereby maintaining the efficient supply of nutrients especially phosphorus in acidic soil (Kharga *et al.*, 2020). Comparable findings were reported by Thriveni *et al.* (2015) in bitter gourd, Chakraborty and Kumar (2017) in bitter gourd, Patle *et al.* (2019) in bottle gourd and Patel *et al.* (2021) in ivy gourd.

The upsurge in available K supplemented with (T₁₈) PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) is due to a lower C:N:P:K ratio in the poultry manure (Walling *et al.* 2022). Also, the organic matter in PM may improve the K retention within the soil matrix by binding the K ions and enhancing CEC. This might help in holding the K ions in the root zone and reduce their susceptibility to leaching. Furthermore, organic manures are generally slow decomposition rate in nature. This gradual mineralization of K may ensure its availability for a longer period. The treatments comprising the organic manures application tend to show higher available potassium level which is attributable to the slow decomposition release of nutrients from the organic source and maintain long term availability. Sharma (2019) reported that increased in the available K in soil is the result of the beneficial effects of organic manures affecting clay-organic interaction and direct K₂O additions widening the available K. Similar reports in available K were reported by Behera (2023) in sponge gourd, Patle *et al.* (2019) in bottle gourd and Patel *et al.* (2021) in ivy gourd.

As per the pooled data, the highest soil OC was exhibited in the treatment supplemented with (T₃) FYM @ 20 t ha⁻¹. This attribute may possibly be due to the application of organic manures. Organic manures contain carbon compounds like cellulose, lignin and humic substances and when organic manures are incorporated, these compounds decompose slowly thus increasing the organic carbon in the soil (Meena *et al.*, 2014). Organic manures also enhance soil structure by forming soil aggregates which may prevent carbon loss in the soil due to leaching and erosion. The increase in the soil organic carbon may also be due to the decomposition of roots and weeds (Walling *et al.* 2022). This finding is in accordance with Chingak and Swami (2018), Ghayal *et al.* (2018), Chakraborty and Kumar (2017) and Krishnan *et al.* (2014).

From the recorded data, significant differences can be observed in soil pH on application of various treatments across the experimental site. These differences may be accredited to the application of innumerable inputs which might have influenced the soil pH dynamics. The integrated application of inputs allows a balance fertilization which might prevent soil acidification. Also, the application of organic manures might release basic cations on decomposition which may result in gradual increase in soil pH by neutralizing soil acidity. The decrease in soil pH may be associated with the application of urea-based fertilizers which might have released hydrogen ions leading to acidification. Additionally, due to the residual activity of the applied chemical fertilizers, it may contribute to a reduction in soil pH. Another factor may be due to continuous irrigation which might lead to leaching of essential minerals from the soil and further altering the soil pH. Similar findings were reported by Dodake *et al.* (2015), Ghosh *et al.* (2016) and Mahale (2017).

4.6.1 Economics of the treatments

The effect of nanofertilizer based integrated nutrient management on the cost of cultivation, gross return, net return and cost-benefit ratio for various treatments in chow-chow are depicted in Table 4.40 and illustrated in Figure 4.38, 4.39 and 4.40. The highest net return was exhibited in treatment T₂₀ where PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC was applied with a pooled value of ₹ 4,77,528.45 followed closely by treatment T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] with a pooled net return of ₹ 4,68,012.03. However, the lowest net return was computed in Treatment T₄ (VC @ 5 t ha⁻¹) with a pooled value of ₹ 89,286.90.

As per the data portrayed in the Table, the highest C:B ratio was estimated in treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] with a pooled value of 2.34 whereas the lowest pooled C:B ratio was exhibited in the treatment T₄ (VC @ 5 t ha⁻¹) with 0.36.

The significant difference in the C:B ratio in treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] as contrast to other treatments may be due to higher yield which could have augmented the C:B ratio. The higher C:B ratio in treatment T₁ [Full dose of RDF (N through urea)] can be justified by the lower cost of cultivation while decrease in C:B ratio despite higher net return in treatment T₁₂ [FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] and T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] may be due to higher cost of inputs (*i.e.*, organic manures and microbial consortium). This study is related to the findings of Behera. (2023), Rajawat *et al.* (2020), Kharga *et al.* (2020) and Sharma (2019).

Table 4.40: Effect of nanofertilizer based INM on economics of the treatment

Treatment	Total cost of cultivation (ha)			Gross return (₹)			Net return (₹)			C:B ratio		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T ₁	182103.36	182103.36	182103.36	604478.20	606648.4	605563.30	422374.84	424545	423459.94	2.32	2.33	2.33
T ₂	181340	181340	181340	455491.87	458372.7	456932.30	274151.87	277032.7	275592.30	1.51	1.53	1.52
T ₃	235700	235700	235700	386005.07	396374.4	391189.73	150305.07	160674.4	155489.73	0.64	0.68	0.66
T ₄	250700	250700	250700	336077.40	343896.4	339986.90	85377.40	93196.4	89286.90	0.34	0.37	0.36
T ₅	225700	225700	225700	380903.00	381822.8	381362.90	155203.00	156122.8	155662.90	0.69	0.69	0.69
T ₆	236050	236050	236050	477550.40	482099.7	479825.03	241500.40	246049.7	243775.03	1.02	1.04	1.03
T ₇	251050	251050	251050	378603.27	393215.5	385909.37	127553.27	142165.5	134859.37	0.51	0.57	0.54
T ₈	226050	226050	226050	357620.40	362683.7	360152.07	131570.40	136633.7	134102.07	0.58	0.60	0.59
T ₉	208901.68	208901.68	208901.68	381421.73	385719.3	383570.50	172520.05	176817.6	174668.82	0.83	0.85	0.84
T ₁₀	208520	208520	208520	479483.20	480455.1	479969.17	270963.20	271935.1	271449.17	1.30	1.30	1.30
T ₁₁	209251.68	209251.68	209251.68	502509.53	505272	503890.77	293257.85	296020.3	294639.09	1.40	1.41	1.41
T ₁₂	208870	208870	208870	675636.00	678128.1	676882.03	466766.00	469258.1	468012.03	2.23	2.25	2.24
T ₁₃	216401.68	216401.68	216401.68	400851.87	409974.8	405413.33	184450.19	193573.1	189011.65	0.85	0.89	0.87
T ₁₄	216020	216020	216020	417515.47	421233.9	419374.67	201495.47	205213.9	203354.67	0.93	0.95	0.94
T ₁₅	216751.68	216751.68	216751.68	513259.73	524058.3	518659.00	296508.05	307306.6	301907.32	1.37	1.42	1.39
T ₁₆	216370	216370	216370	664291.20	660358.7	662324.97	447921.20	443988.7	445954.97	2.07	2.05	2.06
T ₁₇	203901.68	203901.68	203901.68	404136.73	403469.1	403802.90	200235.05	199567.4	199901.22	0.98	0.98	0.98
T ₁₈	203520	203520	203520	390846.67	387840.7	389343.70	187326.67	184320.7	185823.70	0.92	0.91	0.91
T ₁₉	204251.68	204251.68	204251.68	505396.07	513865	509630.53	301144.39	309613.3	305378.85	1.47	1.52	1.50
T ₂₀	203870	203870	203870	680756.40	682040.5	681398.45	476886.40	478170.5	477528.45	2.34	2.35	2.34
T ₂₁	190700	190700	190700	439948.27	444932.9	442440.60	249248.27	254232.9	251740.60	1.31	1.33	1.32
T ₂₂	175700	175700	175700	370681.73	371114.5	370898.13	194981.73	195414.5	195198.13	1.11	1.11	1.11

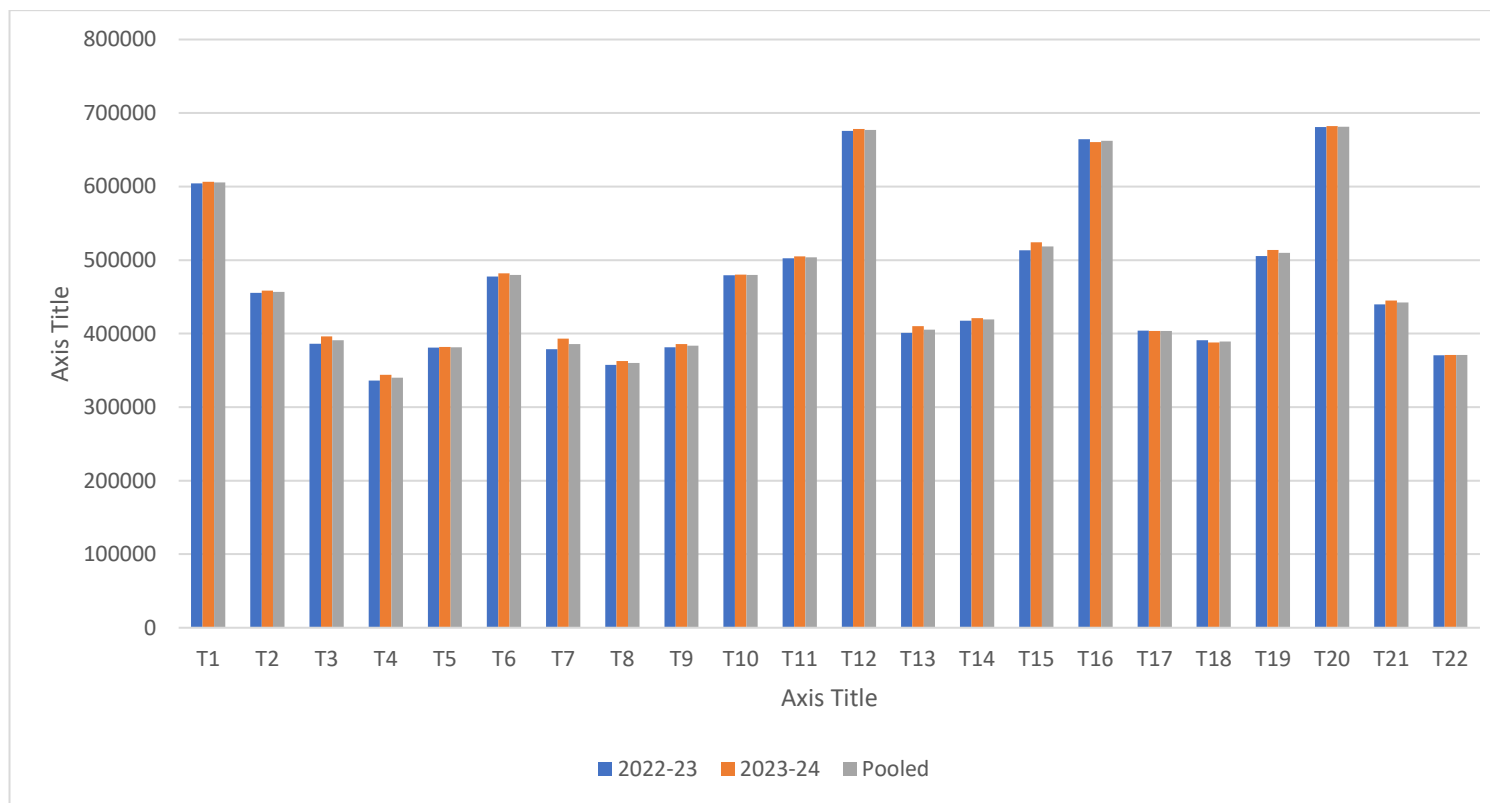


Figure 4.38: Effect of nanofertilizer based INM on gross return of the treatments

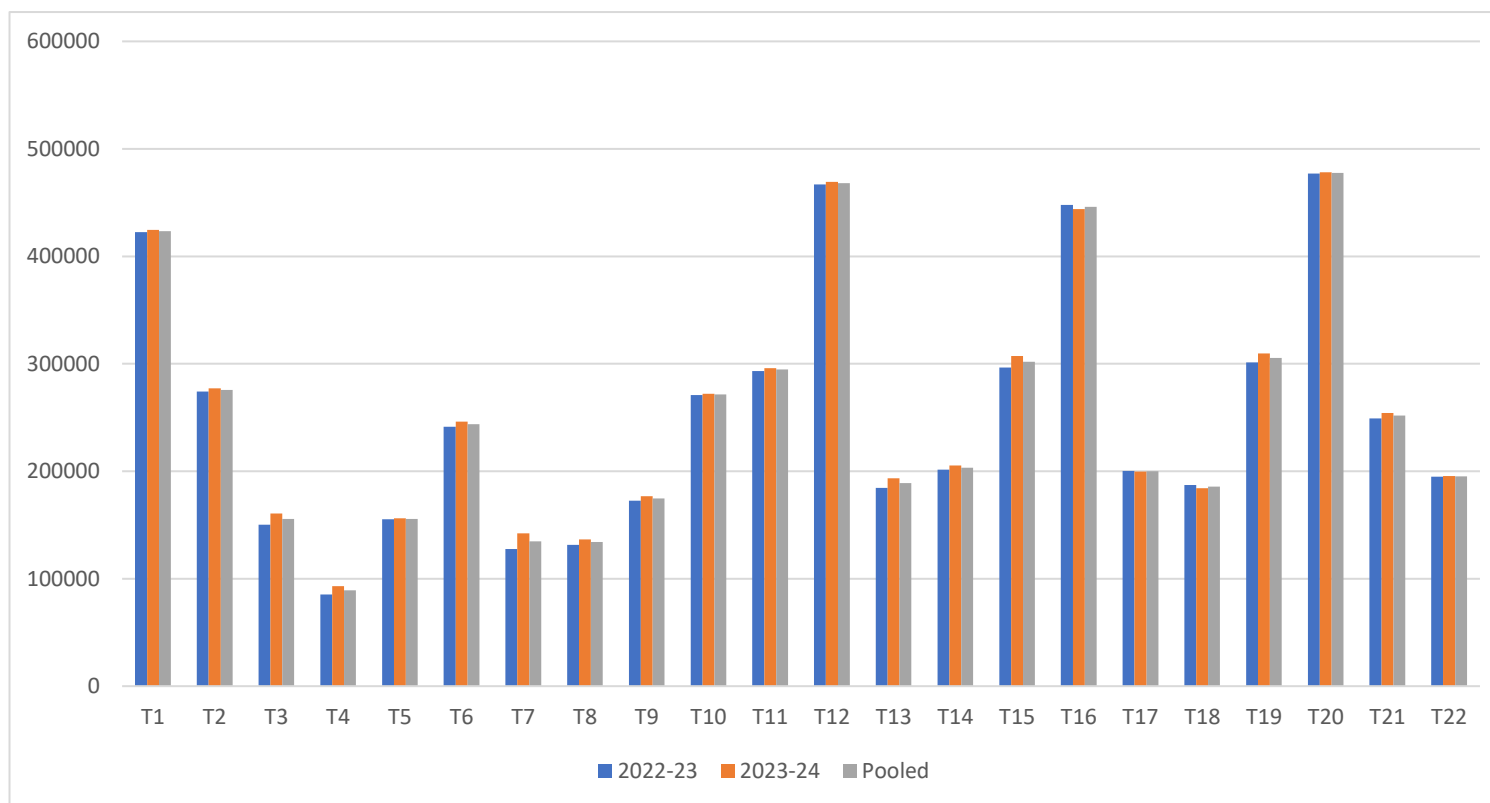


Figure 4.39: Effect of nanofertilizer based INM on net return of the treatments

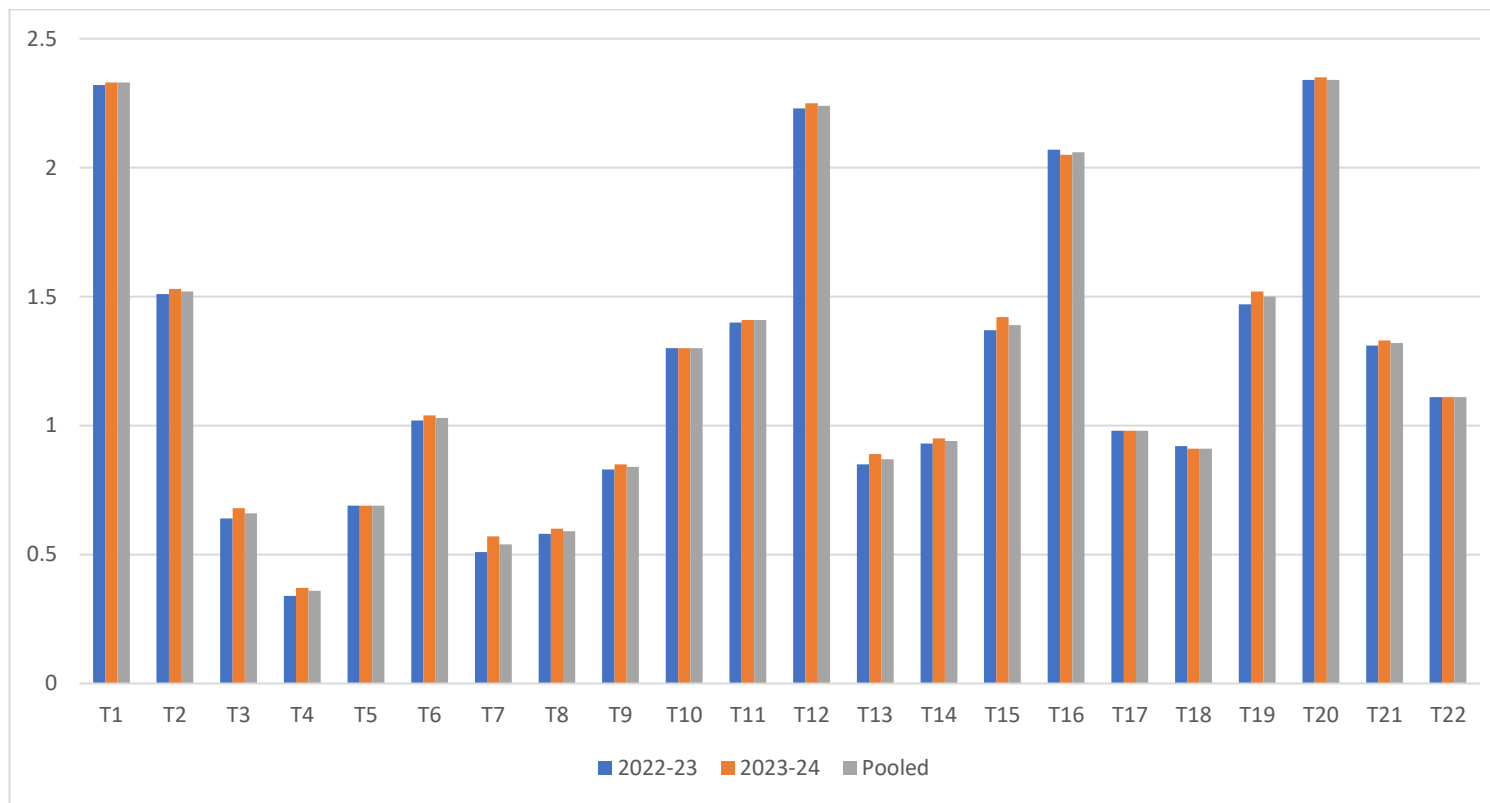


Figure 4.40: Effect of nanofertilizer based INM on C:B ratio of the treatments



Plate 13: Vegetative stage of treatment T_1



Plate 14: Vegetative stage of treatment T_{20}



Plate 15: Vegetative stage of treatment T₂₂



Plate 16: Fruiting of chow-chow in treatment T₁



Plate 17: Fruiting of chow-chow in treatment T₂₀



Plate 18: Fruiting of chow-chow in treatment T₂₂



Plate 19: Determination of fruit length



Plate 20: Determination of fruit diameter



Plate 21: Estimation of fruit weight at harvesting stage

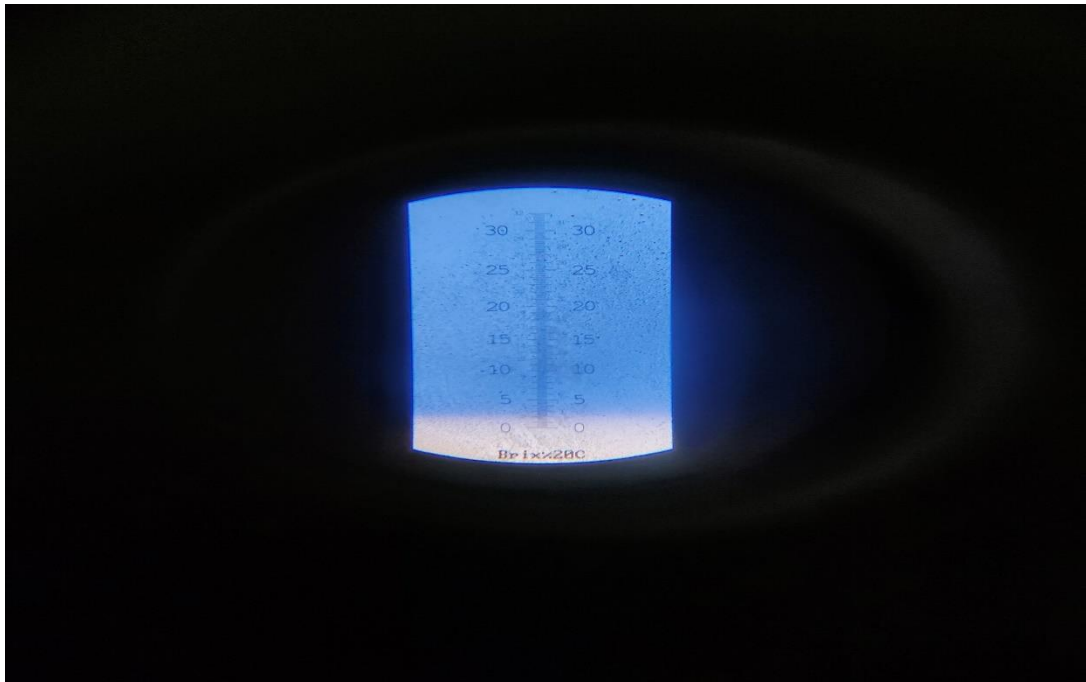


Plate 22: Estimation of TSS of the fruit

CHAPTER V

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

5.1 Summary

A field research project titled "Potentiality of nano fertilizers in integrated nutrient management of chow-chow [*Sechium edule* (Jacq.) Sw.] in Chumukedima district of Nagaland" was carried out over the period from 2022 to 2024 at the horticulture experimental farm of the School of Agricultural Sciences, Nagaland University, Medziphema campus, Nagaland to study the following objectives.

1. To study the effect of nanofertilizers based integrated nutrient management on growth, yield and quality of chow-chow.
2. To study the effect of nanofertilizers based integrated nutrient management on nutrient uptake.
3. To assess the treatment effect on the fertility status of the soil.
4. To study the economics of chow-chow cultivation for different treatments.

The following observations and data were collected after a thorough investigation and analysis, and in this chapter, the key findings and significant outcomes of the investigation are summarized and presented for a comprehensive understanding of the research.

5.1.1 Growth parameters

The present investigation considered several growth factors to evaluate the plant development, included number of leaves per plant, number of primary branches, leaf length (cm), leaf width (cm), leaf area (cm²), internodal length (cm), node at first female flowering, node at first male flowering, days to first female flowering, days to first male flowering, days to marketable maturity (days), crop duration (days), vine length (m) and sex ratio (Male:Female).

Among various treatments, treatment amended with PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) recorded significantly higher values for growth parameters with maximum number of leaves per plant (108.97), number of primary branches (4.21), leaf length (20.15 cm), leaf width (22.30 cm), leaf area (189.08 cm²), crop duration (160.41 days) vine length (7.01 m), minimum days to first female flowering (89.27), days to marketable maturity (102.85) and lower sex ratio (5.87).

This higher performance in growth parameters may be accredited to higher efficient use of nutrients and consistent nutrient availability throughout the growth and development of the plant.

5.1.2 Yield parameters

The yield parameters include number of fruits per plant, fruit length (cm), fruit diameter (cm), average weight of fruit (g), yield per plant (kg) and yield per ha (q). The study indicated that the treatment incorporated with PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) resulted in significant values for yield and yield attributes with a higher number of fruits per plant (15.65), fruit diameter (8.98 cm), average weight of fruit (482.40 g), yield per plant (7.57 kg) and yield per ha (681.40 q). This significantly enhanced crop yield may be attributed to the integrated application of organic manures, conventional fertilizers and microbial consortiums, which continuously supply nutrients and may have stimulated the growth of plants, which in turn, may subsequently enhance the photosynthesis process.

5.1.3 Quality parameters

In the case of quality parameters, the study comprises total soluble solids (°B), crude protein content (%), chlorophyll content (mg g⁻¹), vitamin C content (mg g⁻¹), total carbohydrates content (%), fiber content (%), calcium content (mg 100 g⁻¹), total phenolic content (mg g⁻¹) and shelf life (days). As per the investigation and analysis, the treatment amended with VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₆) resulted in better quality with higher values of TSS (4.66 °B), crude protein (0.64%), total chlorophyll (0.289%), vitamin C (5.00 mg g⁻¹), total carbohydrate (3.75%), crude fibre (0.209%), calcium (12.93 mg 100 g⁻¹), total phenolic content (1.73 mg g⁻¹) and shelf life (30.57 days). This significant increase may be attributed to the application of vermicompost and nano urea, as vermicompost is rich in primary nutrients and micronutrients, while nano urea, owing to its higher efficiency rate helps in the quality improvement of the fruit.

5.1.4 Nutrient uptake by plants

The treatment integrated with FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₂) resulted in higher uptake with N uptake (42.16 q ha⁻¹), P uptake (9.64

q ha⁻¹) and K uptake (26.45 q ha⁻¹). This significant increase in between the treatments may be due to synergistic effect of FYM along with inorganic fertilizers (N through nano urea) and microbial consortium, which may result in stimulation of microbial growth and root growth and in turn improves the soil physical condition and texture further resulting in better absorption.

5.1.5 Fertility status of the soil after crop harvest

The parameters taken for the study of soil fertility include available N (kg ha⁻¹), available P (kg ha⁻¹), available K (kg ha⁻¹), soil organic carbon (%) and soil pH. Statistically significant difference was recorded between the treatments and the treatment incorporated with VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₆) recorded overall better status of soil fertility after harvest with available N (254.57 kg ha⁻¹), available P (21.07 kg ha⁻¹), available K (188.80 kg ha⁻¹), soil organic carbon (1.29 %) and soil pH (4.89). However, statistically on par data were recorded in treatment amended with PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀).

5.1.6 Economics of the treatments

In terms of the economics analysis of various treatments, the highest net return and C:B ratio was recorded in T₂₀ [with PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] with ₹ 4,77,528.45 and 2.34 respectively which may be attributed to higher yield and lower cost of cultivation.

5.2 Conclusions

The following conclusions can be illustrated from the investigation conducted on the “Potentiality of nano fertilizers in integrated nutrient management of chow-chow [*Sechium edule* (Jacq.) Sw.] in Chumukedima district of Nagaland”.

1. The integrated application of PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) leads to a significant increase in growth parameters by 15% in number of primary branches, 5.9% in leaf length, 2.04% in leaf width, 4.21% in leaf area and 4.31% in vine length as compared to the application of full dose of RDF (N through urea) and 60.68% in number of primary branches, 41.5% in leaf length, 28.08% in leaf width, 25.36% in leaf area and 27.45% in vine length as compared to application of full dose of RDF (N through nano urea).
2. In terms of the flowering behaviour, the integrated application of PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) leads to early initiation of female and male flowers by 0.82 day and 1.13 days respectively as compared to application of full dose of RDF (N through urea) whereas 7.13 days and 3.73 days respectively as compared to application of full dose of RDF (N through nano urea).
3. Application of PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) leads to early market maturity by 2.78 days as compared to application of full dose of RDF (N through urea) and 8.36 days as compared to application of full dose of RDF (N through nano urea). Furthermore, it extends the crop duration by 5.72 days and 11.23 days respectively.
4. In the case of yield parameters, the integrated application of PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) leads to a substantial increase in number of fruits per plant by 3.16%, 10.11% in fruit length, 10.73% in fruit diameter, 15.67 % in average weight of fruit and 12.53% in yield per ha as compared to application of full dose of RDF (N through urea) while 37.64% in number of fruits per plant, 39.16% in fruit length, 35.64% in fruit diameter, 53.63 % in average weight of fruit and 49.12% in yield per ha as compared to application of full dose of RDF (N through nano urea).
5. About quality attributes, T₁₆ [VC @ 2.5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] recorded higher TSS (4.66 °B), crude protein (0.64 %), total chlorophyll

(0.289 mg g⁻¹), vitamin c (5.00 mg g⁻¹) and fibre (0.209%). However, this data was statistically on par with T₂₀.

6. The combined application of FYM @ 10 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₁₂) proved to be the best treatment in the overall uptake of NPK. The integrated treatment of FYM @ 10 t ha⁻¹ + ½ of RDF (N through urea) + MC (T₁₁) recorded better retention of nutrients after crop harvest, with available NPK levels of 220.34 kg ha⁻¹, 22.71 kg ha⁻¹, 218.09 kg ha⁻¹ and 1.33% soil organic carbon. However, the values of nutrient uptake and nutrient concentration in T₂₀ were statically on par.
7. The treatment T₂₀ [PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC] delivered the highest economic return in the study. It achieved a maximum net return of ₹ 477528.45 (pooled) and C:B ratio of 2.34 and registered 53.94% increase in C:B ratio over application of full dose of RDF (N through nano urea).

Therefore, based on the investigation it can be drawn that application of PM @ 5 t ha⁻¹ + ½ of RDF (N through nano urea) + MC (T₂₀) was observed 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. In terms of soil fertility, this treatment has retained higher nutrients which shows it can be a component of sustainable agriculture. Thus, nanofertilizers 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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APPENDICES

APPENDICES

APPENDIX 1: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on number of leaves per plant

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8888.742	21	423.2734	6.460202	1.05E-07	1.800885
Within Groups	2882.886	44	65.52015			
Total	11771.63	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8810.345	21	419.5403	7.214684	2.06E-08	1.800885
Within Groups	2558.639	44	58.15089			
Total	11368.98	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8833.333	21	420.6349	6.92058	3.83E-08	1.800885
Within Groups	2674.333	44	60.78029			
Total	11507.67	65				

**APPENDIX 2: Analysis of variance as influenced by nanofertilizer based
integrated nutrient management on number of primary branches**

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	22.88757	21	1.08988 4	2.04131 7	0.02306 7	1.80088 5
Within Groups	23.49213	44	0.53391 2			
Total	46.3797	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	29.45961	21	1.40283 9	2.51672	0.00493	1.80088 5
Within Groups	24.52593	44	0.55740 8			
Total	53.98555	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	22.27272	21	1.06060 6	2.62489 2	0.00347 9	1.80088 5
Within Groups	17.7785	44	0.40405 7			
Total	40.05122	65				

**APPENDIX 3: Analysis of variance as influenced by nanofertilizer based
integrated nutrient management on leaf length**

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	212.4112	21	10.11482	5.223514	1.97E-06	1.800885
Within Groups	85.20167	44	1.936402			
Total	297.6129	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	218.7658	21	10.41742	4.744257	6.81E-06	1.800885
Within Groups	96.615	44	2.195795			
Total	315.3808	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	186.3596	21	8.874269	6.736819	5.7E-08	1.800885
Within Groups	57.96027	44	1.317279			
Total	244.3199	65				

**APPENDIX 4: Analysis of variance as influenced by nanofertilizer based
integrated nutrient management on leaf width**

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	175.7802	21	8.370484	5.125385	2.53E-06	1.800885
Within Groups	71.85827	44	1.633142			
Total	247.6384	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	160.3329	21	7.6349	5.065664	2.95E-06	1.800885
Within Groups	66.3162	44	1.507186			
Total	226.6491	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	158.8893	21	7.566155	8.617946	1.31E-09	1.800885
Within Groups	38.62995	44	0.877953			
Total	197.5192	65				

APPENDIX 5: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on leaf area

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	11873.22	21	565.3912	3.727238	0.000116	1.800885
Within Groups	6674.436	44	151.6917			
Total	18547.65	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	11058.51	21	526.5956	6.259098	1.65E-07	1.800885
Within Groups	3701.844	44	84.13283			
Total	14760.35	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	11136.91	21	530.3288	5.577848	8.21E-07	1.800885
Within Groups	4183.418	44	95.07767			
Total	15320.32	65				

APPENDIX 6: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on internodal length

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	13.29183	21	0.632944	3.051315	0.0009	1.800885
Within Groups	9.127067	44	0.207433			
Total	22.4189	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	15.06583	21	0.71742	2.021946	0.024561	1.800885
Within Groups	15.61193	44	0.354817			
Total	30.67776	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	13.89303	21	0.661573	5.028841	3.24E-06	1.800885
Within Groups	5.78845	44	0.131556			
Total	19.68148	65				

APPENDIX 7: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on node at first female flowering

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	15.77697	21	0.751284	1.855717	0.041969	1.800885
Within Groups	17.81333	44	0.404848			
Total	33.5903	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	15.58121	21	0.741962	3.163406	0.000636	1.800885
Within Groups	10.32	44	0.234545			
Total	25.90121	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	15.30258	21	0.728694	2.807578	0.00194	1.800885
Within Groups	11.42	44	0.259545			
Total	26.72258	65				

APPENDIX 8: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on node at first male flowering

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	189.4594	21	9.021875	2.716831	0.002591	1.800885
Within Groups	146.1123	44	3.320735			
Total	335.5717	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	127.6623	21	6.079159	2.187526	0.014347	1.800885
Within Groups	122.2765	44	2.779011			
Total	249.9388	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	126.4113	21	6.019586	4.300808	2.26E-05	1.800885
Within Groups	61.5842	44	1.399641			
Total	187.9955	65				

**APPENDIX 9: Analysis of variance as influenced by nanofertilizer based
integrated nutrient management on days to first female flowering**

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	492.1336	21	23.43493	3.688203	0.00013	1.800885
Within Groups	279.5771	44	6.354024			
Total	771.7107	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	458.4892	21	21.8328 2	3.46361 1	0.00025 4	1.80088 5
Within Groups	277.3533	44	6.30348 5			
Total	735.8426	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	467.9318	21	22.28247	5.975724	3.18E-07	1.800885
Within Groups	164.0686	44	3.728832			
Total	632.0004	65				

**APPENDIX 10: Analysis of variance as influenced by nanofertilizer based
integrated nutrient management on days to first male flowering**

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	529.139 4	21	25.1971 1	2.43528 8	0.00641 5	1.80088 5
Within Groups	455.253 3	44	10.3466 7			
Total	984.392 7	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	426.149 5	21	20.2928 3	1.91220 8	0.03500 7	1.80088 5
Within Groups	466.938 9	44	10.6122 5			
Total	893.088 4	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	450.2771	21	21.44176	4.003905	5.21E-05	1.800885
Within Groups	235.6294	44	5.355214			
Total	685.9065	65				

APPENDIX 11: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on days to market maturity

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	857.2212	21	40.82006	2.052016	0.022281	1.800885
Within Groups	875.2769	44	19.89266			
Total	1732.498	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	878.0462	21	41.81172	2.029775	0.023946	1.800885
Within Groups	906.3643	44	20.59919			
Total	1784.411	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	873.2012	21	41.58101	3.344567	0.000365	1.800885
Within Groups	547.0258	44	12.4324			
Total	1420.227	65				

APPENDIX 12: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on crop duration

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	635.2707	21	30.25099	2.020215	0.0247	1.800885
Within Groups	658.8623	44	14.97414			
Total	1294.133	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	787.0143	21	37.47687	2.155448	0.015924	1.800885
Within Groups	765.0301	44	17.38705			
Total	1552.044	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	696.1906	21	33.15193	3.710847	0.000122	1.800885
Within Groups	393.0869	44	8.933792			
Total	1089.277	65				

**APPENDIX 13: Analysis of variance as influenced by nanofertilizer based
integrated nutrient management on vine length**

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.995844	21	0.285516	7.957132	4.6E-09	1.800885
Within Groups	1.5788	44	0.035882			
Total	7.574644	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.948145	21	0.283245	4.550342	1.14E-05	1.800885
Within Groups	2.738867	44	0.062247			
Total	8.687012	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	27.50317	21	1.309675	22.86522	3.49E-17	1.800885
Within Groups	2.520233	44	0.057278			
Total	30.0234	65				

**APPENDIX 14: Analysis of variance as influenced by nanofertilizer based
integrated nutrient management on sex ratio**

ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	60.27958	21	2.870456	8.990566	6.64E-10	1.800885
Within Groups	14.04807	44	0.319274			
Total	74.32764	65				

ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	60.16963	21	2.865221	9.182186	4.72E-10	1.800885
Within Groups	13.72981	44	0.312041			
Total	73.89945	65				

ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	60.18629	21	2.866014	9.152574	4.97E-10	1.800885
Within Groups	13.77805	44	0.313137			
Total	73.96434	65				

APPENDIX 15: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on number of fruits per plant

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	168.2861	21	8.013622	21.74749	9.21E-17	1.800885
Within Groups	16.21333	44	0.368485			
Total	184.4994	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	166.202	21	7.91438	21.487	1.16E-16	1.800885
Within Groups	16.20667	44	0.368333			
Total	182.4086	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	166.8505	21	7.945262	23.59182	1.9E-17	1.800885
Within Groups	14.81833	44	0.33678			
Total	181.6688	65				

APPENDIX 16: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on fruit length

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	75.28383	21	3.584944	18.29817	2.47E-15	1.800885
Within Groups	8.6204	44	0.195918			
Total	83.90423	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	80.70298	21	3.842999	10.40233	6E-11	1.800885
Within Groups	16.2552	44	0.369436			
Total	96.95818	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	77.75206	21	3.702479	19.25666	9.42E-16	1.800885
Within Groups	8.459883	44	0.19227			
Total	86.21195	65				

APPENDIX 17: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on fruit diameter

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	26.06817	21	1.241341	10.74402	3.48E-11	1.800885
Within Groups	5.083667	44	0.115538			
Total	31.15184	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	28.84637	21	1.373636	3.755079	0.000107	1.800885
Within Groups	16.09553	44	0.365808			
Total	44.9419	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	26.65454	21	1.269264	7.401756	1.4E-08	1.800885
Within Groups	7.545183	44	0.171481			
Total	34.19972	65				

APPENDIX 18: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on average weight of fruit

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	184132.5	21	8768.216	9.163505	4.88E-10	1.800885
Within Groups	42101.96	44	956.8627			
Total	226234.5	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	181207.2	21	8628.913	3.108299	0.000754	1.800885
Within Groups	122147.9	44	2776.088			
Total	303355.1	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	180922.3	21	8615.348	8.340323	2.2E-09	1.800885
Within Groups	45450.92	44	1032.975			
Total	226373.2	65				

**APPENDIX 19: Analysis of variance as influenced by nanofertilizer based
integrated nutrient management on yield per plant**

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	107.658	21	5.12657	21.84061	8.48E-17	1.800885
Within Groups	10.32797	44	0.234726			
Total	117.9859	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	110.9238	21	5.282084	7.459281	1.24E-08	1.800885
Within Groups	31.15739	44	0.708122			
Total	142.0812	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	95.20777	21	4.533703	15.314	6.71E-14	1.800885
Within Groups	13.02618	44	0.29605			
Total	108.2339	65				

APPENDIX 20: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on yield per ha

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	748216.8	21	35629.37	7.338822	1.59E-08	1.800885
Within Groups	213616.3	44	4854.917			
Total	961833.1	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	773015.1	21	36810.24	17.09895	8.78E-15	1.800885
Within Groups	94722.2	44	2152.777			
Total	867737.3	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	735113.1	21	35005.39	15.83564	3.63E-14	1.800885
Within Groups	97263.97	44	2210.545			
Total	832377.1	65				

**APPENDIX 21: Analysis of variance as influenced by nanofertilizer based
integrated nutrient management on TSS**

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	26.15669	21	1.245557	23.41739	2.2E-17	1.800885
Within Groups	2.340333	44	0.053189			
Total	28.49703	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	27.333	21	1.301571	18.84184	1.42E-15	1.800885
Within Groups	3.039467	44	0.069079			
Total	30.37247	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	26.27557	21	1.251218	26.69674	1.68E-18	1.800885
Within Groups	2.062183	44	0.046868			
Total	28.33776	65				

APPENDIX 22: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on crude protein

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	39.85718	21	1.897961	3.321597	0.000391	1.800885
Within Groups	25.14161	44	0.5714			
Total	64.99879	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	25.38288	21	1.208709	4.251367	2.59E-05	1.800885
Within Groups	12.50967	44	0.284311			
Total	37.89255	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	23.03306	21	1.096812	6.260452	1.65E-07	1.800885
Within Groups	7.708666	44	0.175197			
Total	30.74172	65				

APPENDIX 23: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on total chlorophyll

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.073488	21	0.003499	4.627305	9.29E-06	1.800885
Within Groups	0.033275	44	0.000756			
Total	0.106763	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.073488	21	0.003499	4.67962	8.08E-06	1.800885
Within Groups	0.032903	44	0.000748			
Total	0.106391	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.073488	21	0.003499	4.654476	8.64E-06	1.800885
Within Groups	0.033081	44	0.000752			
Total	0.106569	65				

APPENDIX 24: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on vit C

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	13.26858	21	0.631837	4.854911	5.09E-06	1.800885
Within Groups	5.726333	44	0.130144			
Total	18.99492	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	15.4593	21	0.736157	5.814984	4.64E-07	1.800885
Within Groups	5.570251	44	0.126597			
Total	21.02955	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	13.90404	21	0.662097	5.410341	1.24E-06	1.800885
Within Groups	5.384553	44	0.122376			
Total	19.28859	65				

**APPENDIX 25: Analysis of variance as influenced by nanofertilizer based
integrated nutrient management on total carbobhydrate**

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.453503	21	0.259691	18.02838	3.27E-15	1.800885
Within Groups	0.6338	44	0.014405			
Total	6.087303	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4.212886	21	0.200614	9.369825	3.39E-10	1.800885
Within Groups	0.942067	44	0.021411			
Total	5.154953	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4.750532	21	0.226216	17.81758	4.07E-15	1.800885
Within Groups	0.558633	44	0.012696			
Total	5.309166	65				

**APPENDIX 26: Analysis of variance as influenced by nanofertilizer based
integrated nutrient management on crude fibre**

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.017544	21	0.000835	13.56782	5.98E-13	1.800885
Within Groups	0.002709	44	6.16E-05			
Total	0.020254	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.019541	21	0.000931	12.2167	3.81E-12	1.800885
Within Groups	0.003351	44	7.62E-05			
Total	0.022892	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.017893	21	0.000852	13.58055	5.88E-13	1.800885
Within Groups	0.002761	44	6.27E-05			
Total	0.020653	65				

**APPENDIX 27: Analysis of variance as influenced by nanofertilizer based
integrated nutrient management on calcium**

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	11.59281	21	0.552039	9.504501	2.69E-10	1.800885
Within Groups	2.5556	44	0.058082			
Total	14.14841	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	12.29825	21	0.585631	9.545736	2.5E-10	1.800885
Within Groups	2.6994	44	0.06135			
Total	14.99765	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	11.843	21	0.563953	9.849005	1.49E-10	1.800885
Within Groups	2.519433	44	0.05726			
Total	14.36244	65				

**APPENDIX 28: Analysis of variance as influenced by nanofertilizer based
integrated nutrient management on total phenolic content**

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.152927	21	0.054901	18.7551	1.55E-15	1.800885
Within Groups	0.1288	44	0.002927			
Total	1.281727	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.151036	21	0.054811	16.40609	1.89E-14	1.800885
Within Groups	0.147	44	0.003341			
Total	1.298036	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.149062	21	0.054717	18.31772	2.42E-15	1.800885
Within Groups	0.131433	44	0.002987			
Total	1.280495	65				

APPENDIX 29: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on shelf life

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	134.4884	21	6.404208	3.366652	0.000341	1.800885
Within Groups	83.69893	44	1.902248			
Total	218.1873	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	143.6509	21	6.840519	3.192887	0.00058	1.800885
Within Groups	94.26667	44	2.142424			
Total	237.9176	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	138.0479	21	6.57371	3.37664	0.000331	1.800885
Within Groups	85.66007	44	1.94682			
Total	223.708	65				

**APPENDIX 30: Analysis of variance as influenced by nanofertilizer based
integrated nutrient management on total N uptake**

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1553.592	21	73.98057	26.63636	1.76E-18	1.800885
Within Groups	122.2068	44	2.777427			
Total	1675.799	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1474.818	21	70.22944	12.08451	4.61E-12	1.800885
Within Groups	255.7072	44	5.811526			
Total	1730.525	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1503.582	21	71.59916	444.6741	2.03E-44	1.800885
Within Groups	7.084656	44	0.161015			
Total	1510.667	65				

APPENDIX 31: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on total P uptake

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	93.25183	21	4.440563	15.39908	6.06E-14	1.800885
Within Groups	12.68808	44	0.288365			
Total	105.9399	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	95.88691	21	4.566043	18.06561	3.14E-15	1.800885
Within Groups	11.1209	44	0.252748			
Total	107.0078	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	90.47996	21	4.30857	64.22431	2.66E-26	1.800885
Within Groups	2.951796	44	0.067086			
Total	93.43176	65				

APPENDIX 32: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on total K uptake

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.482671	21	0.26108	7.130457	2.46E-08	1.800885
Within Groups	1.611047	44	0.036615			
Total	7.093718	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.413399	21	0.257781	8.740014	1.05E-09	1.800885
Within Groups	1.297751	44	0.029494			
Total	6.71115	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	312.4861	21	14.88029	102.6303	1.28E-30	1.800885
Within Groups	6.379529	44	0.144989			
Total	318.8657	65				

APPENDIX 33: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on available N

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	17002.96	21	809.6646	4.432542	1.57E-05	1.800885
Within Groups	8037.203	44	182.6637			
Total	25040.16	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	11978.81	21	570.4194	3.527922	0.00021	1.800885
Within Groups	7114.231	44	161.6871			
Total	19093.04	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	13812.56	21	657.7409	63.92009	2.94E-26	1.800885
Within Groups	452.7622	44	10.29005			
Total	14265.32	65				

APPENDIX 34: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on available P

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1330.208	21	63.34325	8.763138	1E-09	1.800885
Within Groups	318.0485	44	7.228375			
Total	1648.257	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1225.349	21	58.34996	8.020175	4.07E-09	1.800885
Within Groups	320.1175	44	7.275398			
Total	1545.467	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1244.81	21	59.27668	12.15584	4.16E-12	1.800885
Within Groups	214.5615	44	4.876397			
Total	1459.372	65				

APPENDIX 35: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on available K

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	34878.11	21	1660.86 2	3.54614 2	0.00019 9	1.80088 5
Within Groups	20607.73	44	468.357 5			
Total	55485.84	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	21053.68	21	1002.55 6	2.52296 5	0.00483 1	1.80088 5
Within Groups	17484.38	44	397.372 4			
Total	38538.07	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	25347.31	21	1207.015	4.359425	1.92E-05	1.800885
Within Groups	12182.49	44	276.8747			
Total	37529.8	65				

**APPENDIX 36: Analysis of variance as influenced by nanofertilizer based
integrated nutrient management on soil organic carbon**

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.207802	21	0.057514	1.822317	0.046698	1.800885
Within Groups	1.388689	44	0.031561			
Total	2.596491	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.152398	21	0.054876	2.53317	0.004675	1.800885
Within Groups	0.953173	44	0.021663			
Total	2.105571	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.174818	21	0.055944	5.556321	8.65E-07	1.800885
Within Groups	0.443013	44	0.010068			
Total	1.617831	65				

APPENDIX 37: Analysis of variance as influenced by nanofertilizer based integrated nutrient management on soil pH

ANOVA Table of first trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.109269	21	0.05282 2	2.33936 6	0.00875 8	1.80088 5
Within Groups	0.993509	44	0.02258			
Total	2.102778	65				

ANOVA Table of second trial						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.382894	21	0.06585 2	3.19946 7	0.00056 9	1.80088 5
Within Groups	0.905617	44	0.02058 2			
Total	2.288512	65				

ANOVA Table of pooled final						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.201592	21	0.057219	4.788886	6.05E-06	1.800885
Within Groups	0.525722	44	0.011948			
Total	1.727313	65				

**APPENDIX 37 (a): Analysis of variance as influenced by nanofertilizer based
integrated nutrient management on economics of the treatments**

Fixed cost		
Particular	unit	Amount (₹)
Seed (planting material)	3 rs per fruit	30000
cost of field preparation		
1. tractor (thrice)	2000 for 1 day	6000
2. bed preparation	10 men@ 500	5000
	5 women @ 400	2000
cost of application of treatments	10 men@ 500	5000
	5 women @ 400	2000
cost of transplanting	10 men @ 500	5000
	5 women @ 400	2000
Cost of training		
iron angle		50000
wire and rope		5000
installation	10 men @ 500	5000
cost of irrigation	3 men for 3 month @ 2500 /head/month	22500
cost of weeding (twice) and earthing up	10 men @ 500	10000
	5 women @ 350	4000
cost of application of fungicide	3 men @ 500	1500
cost of application of instecide	3 men @ 500	1500
cost of harvesting (x4)	3 men @ 500	6000
	2 women @ 400	3200
Miscellaneous		10000
sub total		175700

**APPENDIX 37 (b): Analysis of variance as influenced by nanofertilizer based
integrated nutrient management on economics of the treatments**

T. no.	Treatments	Treatment cost (₹)	Total cost (Fixed + treatment cost in ₹)
T ₁	Full dose of RDF (N through urea)	6403.36	182103.36
T ₂	Full dose of RDF (N through nano urea)	5640	181340
T ₃	FYM @ 20 t ha ⁻¹	60000	235700
T ₄	Vermicompost @ 5 t ha ⁻¹	75000	250700
T ₅	Poultry manure @ 10 t ha ⁻¹	50000	225700
T ₆	FYM @ 20 t ha ⁻¹ + Microbial consortium	60350	236050
T ₇	Vermicompost @ 5 t ha ⁻¹ + Microbial consortium	75350	251050
T ₈	Poultry manure @ 10 t ha ⁻¹ + Microbial consortium	50350	226050
T ₉	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea)	33201.68	208901.68
T ₁₀	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea)	32820	208520
T ₁₁	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through urea) + Microbial consortium	33551.68	209251.68
T ₁₂	FYM @ 10 t ha ⁻¹ + ½ of RDF (N through nano urea) + Microbial consortium	33170	208870
T ₁₃	Vermicompost @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea)	40701.68	216401.68
T ₁₄	Vermicompost @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea)	40320	216020
T ₁₅	Vermicompost @ 2.5 t ha ⁻¹ + ½ of RDF (N through urea) + Microbial consortium	41051.68	216751.68
T ₁₆	Vermicompost @ 2.5 t ha ⁻¹ + ½ of RDF (N through nano urea) + Microbial consortium	40670	216370
T ₁₇	Poultry manure @ 5 t ha ⁻¹ + ½ of RDF (N through urea)	28201.68	203901.68
T ₁₈	Poultry manure @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea)	27820	203520
T ₁₉	Poultry manure @ 5 t ha ⁻¹ + ½ of RDF (N through urea) + Microbial consortium	28551.68	204251.68
T ₂₀	Poultry manure @ 5 t ha ⁻¹ + ½ of RDF (N through nano urea) + Microbial consortium	28170	203870
T ₂₁	Farmers practise	15000	190700
T ₂₂	Control	0	175700