

**EFFECT OF ORGANIC MANURE AND
BIOFERTILIZERS ON GROWTH, HERB,
NUTRIENT UPTAKE, OIL YIELD AND QUALITY
OF FRENCH BASIL (*Ocimum basilicum* L.)**

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BAGALKOT- 587 104**

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BAGALKOT- 587104**

CERTIFICATE

This is to certify that the thesis entitled “**Effect of organic manure and biofertilizers on growth, herb, nutrient uptake, oil yield and quality of French Basil (*Ocimum basilicum* L.)**” submitted by **Ms. BARAA ALMANSOUR ID.No. UHS13PGD68**, in partial fulfilment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY in HORTICULTURE** to the University of Horticultural Sciences, Bagalkot, is a bonafide record of research work carried out by her during the period of her study in this University, under my guidance and supervision, and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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(Baraa Almansour)

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ABSTRACT

Sustainability of agricultural systems has become an important issue throughout the world. Basil has been used as a medicinal herb, so it has to be free from novice chemical substances. In this context, field experiment was carried out at ICAR - Indian Institute of Horticultural Research, Bengaluru, during kharif seasons of 2015 and 2016. Nine treatments with three replications were adopted in a randomized block design to find out the effect of different levels of N through FYM (100, 75 and 50% of the recommended N) along with and without bio-fertilizers, recommended dose of NPK (160:80:80 kg /ha) and recommended FYM (10 t/ha) + recommended NPK (160:80:80 kg /ha) on the growth, herb, nutrient uptake, oil yield and quality of French Basil (*Ocimum basilicum* L). The results from the experiment revealed that among the nine treatments, application of recommended dose of FYM (10 t/ha) along with recommended dose of NPK (160:80:80 kg /ha) recorded maximum fresh herb yield (62.56 and 56.08 t/ha) with average yield of 59.32 t/ha, maximum dry herbage yield (13.02 and 11.37 t/ha) with average yield of 12.19 t/ha and maximum oil yield (356.3 and 258.27 l/ha) with average yield of 307.28 l/ha and highest nitrogen uptake in the main crop (155.67 and 113.19 kg/ha) and ratoon (56.43 and 26.65 kg/ha) during 2015 and 2016 respectively. With respect to oil quality, the maximum methyl chavicol percentage (52.3%) in the main crop 2015 was recorded with application of recommended dose of FYM (10 t/ha) along with recommended dose of NPK (160:80:80 kg/ha) While, in the second season application of FYM (10 t/ha) +100% recommended N through FYM + biofertilizer recorded the highest percent of methyl chavicol (63.78%) in the main crop, as well as, in ratoon crop (59.39 and 59.67%) during 2015 and 2016, respectively.

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January, 2018

ಸಿಹಿ ತುಳಸಿಯ ಬೆಳವಣಿಗೆ, ಪೋಷಕಾಂಶ ತೆಗೆದುಕೊಳ್ಳುವಿಕೆ, ಇಳುವರಿ ಹಾಗೂ ಸುಗಂಧ ದ್ರವ್ಯದ
ಗುಣಮಟ್ಟದ ಮೇಲೆ ಸಾವಯವ ಹಾಗೂ ಜೈವಿಕ ಗೊಬ್ಬರಗಳ ಪರಿಣಾಮಗಳನ್ನೊಳಗೊಂಡ
ಅಧ್ಯಯನ

ಬರಾ ಅಲ್ ಮನ್ಸೂರ್

ಪ್ರಭಂದ ಸಾರಾಂಶ

ಪ್ರಪಂಚದಾದ್ಯಂತ ಸದ್ಯದ ಕೃಷಿ ಪರಿಸ್ಥಿತಿಯಲ್ಲಿ ಸುಸ್ಥಿರತೆ ಅತಿ ಪ್ರಮುಖ ವಿಚಾರವಾಗಿದೆ. ತುಳಸಿಯು ಬಹಳ ವರ್ಷಗಳಿಂದ ಔಷಧಿ ಸಸ್ಯವಾಗಿ ಬೆಳೆಯುತ್ತಿದ್ದು, ವಿಷ ರಸಾಯನಿಕಗಳ ಉಪಯೋಗದಿಂದ ಅದು ಮಕ್ಕಳಿಗೆ ಬೇಕಾಗಿದೆ. ಈ ಹಿನ್ನೆಲೆಯಲ್ಲಿ 2015 ಹಾಗೂ 2016 ನೇ ಸಾಲಿನಲ್ಲಿ ಭಾ.ಕೃ.ಅ.ಪ- ಭಾರತೀಯ ತೋಟಗಾರಿಕಾ ಸಂಶೋಧನಾ ಸಂಸ್ಥೆ, ಬೆಂಗಳೂರುನಲ್ಲಿ ಈ ಪ್ರಯೋಗವನ್ನು ಕೈಗೊಳ್ಳಲಾಯಿತು. ಈ ಅಧ್ಯಯನದಲ್ಲಿ ಒಟ್ಟು ಉಪಚಾರಗಳ ಸಂಖ್ಯೆ 9 ಆಗಿದ್ದು ಅವುಗಳನ್ನು 3 ಬಾರಿ ಆರ್.ಸಿ.ಬಿ.ಡಿ ಮಾದರಿಯಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಯಿತು. ಆ ಉಪಚಾರಗಳೆಂದರೆ ನೂರು, ಎಪ್ಪತ್ತೈದು, ಹಾಗೂ ಐವತ್ತರ ಶೇಖಡಾವಾರಿನಲ್ಲಿ ಶಿಪಾರಸ್ಸು ಮಾಡಿದ ಸಾರಜನಕವನ್ನು ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರದ ರೂಪದಲ್ಲಿಯೂ ಹಾಗೂ ಅವುಗಳ ಜೊತೆಗೆ ಜೈವಿಕ ಗೊಬ್ಬರಗಳನ್ನು ಅಲ್ಲದೆ ಶಿಪಾರಸ್ಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರ (160:80:80 ಕಿ.ಗ್ರಾಂ ಸಾ.ರ.ಪೋ./ಹೆ) + ಶಿಪಾರಸ್ಸು ಮಾಡಿದ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ (10ಟನ್/ಹೆ), ಶಿಪಾರಸ್ಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರ (160:80:80 ಕಿ. ಗ್ರಾಂ ಸಾ.ರ.ಪೋ./ಹೆ) ಹಾಗೂ ಶಿಪಾರಸ್ಸು ಮಾಡಿದ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ ಮಾತ್ರ (10ಟನ್/ಹೆ). ಇವುಗಳು ಸಿಹಿ ತುಳಸಿಯ ಬೆಳವಣಿಗೆ, ಪೋಷಕಾಂಶ ತೆಗೆದುಕೊಳ್ಳುವಿಕೆ, ಇಳುವರಿ ಹಾಗೂ ಸುಗಂಧ ದ್ರವ್ಯದ ಗುಣಮಟ್ಟದ ಮೇಲೆ ಹೇಗೆ ಪರಿಣಾಮ ಬೀರುತ್ತದೆ ಎಂಬುದನ್ನು ಈ ಪ್ರಯೋಗದಲ್ಲಿ ಅಧ್ಯಯನ ಮಾಡಲಾಯಿತು. ಪರೀಕ್ಷಿಸಿದ 9 ಉಪಚಾರಗಳಲ್ಲಿ, ಶಿಪಾರಸ್ಸು ಮಾಡಿದ ಪೂರ್ತಿ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ (10ಟನ್/ಹೆ)+ಶಿಪಾರಸ್ಸು ಮಾಡಿದ ಪೂರ್ತಿ ರಸಗೊಬ್ಬರ (160:80:80 ಕಿ.ಗ್ರಾಂ ಸಾ.ರ.ಪೋ./ಹೆ) ನೀಡಿದಾಗ ಅತಿ ಹೆಚ್ಚಿನ ಇಳುವರಿ (62.56 & 56.08ಟನ್/ಹೆ) ಹಾಗೂ ಸರಾಸರಿ ಇಳುವರಿ (59.32ಟನ್/ಹೆ), ಅತಿ ಹೆಚ್ಚಿನ ಸುಗಂಧ ದ್ರವ್ಯ (356.3 & 258.27ಟನ್/ಹೆ) ಹಾಗೂ ಸರಾಸರಿ ಸುಗಂಧ ದ್ರವ್ಯದ ಇಳುವರಿ 307.28 ಲೀ/ಹೆ ಹಾಗೂ ಮುಖ್ಯ ಬೆಳೆಯಲ್ಲಿ ಅತಿ ಹೆಚ್ಚು ಸಾರಜನಕ ತೆಗೆದುಕೊಳ್ಳುವಿಕೆ (155.67 ಮತ್ತು 113.19.ಕಿ.ಗ್ರಾಂ./ಹೆ) ಹಾಗೂ ಕೂಳೆ ಬೆಳೆಯಲ್ಲಿ (56.43 ಮತ್ತು 26.65 ಕಿ.ಗ್ರಾಂ/ಹೆ) 2015 ಮತ್ತು 2016 ರಲ್ಲಿ ಕಂಡು ಬಂದಿರುತ್ತದೆ. ಸುಗಂಧ ದ್ರವ್ಯದಲ್ಲಿನ ಮಿಥೈಲ್ ಚಾವಿಕಾಲ್ ಅಂಶವು 2015 ರ ಮುಖ್ಯ ಬೆಳೆಯಲ್ಲಿ ಶೇಖಡ 52.3% ಶಿಪಾರಸ್ಸು ಮಾಡಿದ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ (10ಟನ್/ಹೆ)+ಶಿಪಾರಸ್ಸು ಮಾಡಿದ ರಸ ಗೊಬ್ಬರ (160:80:80 ಕಿ.ಗ್ರಾಂ ಸಾ.ರ.ಪೋ./ಹೆ) ಉಪಚಾರದಲ್ಲಿ ಅತ್ಯಧಿಕವಾಗಿರುತ್ತದೆ. ಶಿಪಾರಸ್ಸು ಮಾಡಿದ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ (10ಟನ್/ಹೆ)+100 ಪ್ರತಿಶತÀ ಸಾರಜನಕ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರದ ಮೂಲಕ ನೀಡಿರುವುದು + ಜೈವಿಕ ಗೊಬ್ಬರ ಉಪಚಾರದಲ್ಲಿ. ಅತಿ ಹೆಚ್ಚು ವಿಥೈಲ್ ಚಾವಿಕಾಲ್ ಅಂಶವು 2016ರ ಮುಖ್ಯ ಬೆಳೆಯಲ್ಲಿ ಶೇಖಡ 63.78 ರಷ್ಟು ಕಂಡುಬಂದಿದ್ದು 2015ರ ಕೂಳೆ ಬೆಳೆಯಲ್ಲಿ ಶೇಖಡ 59.39 ರಷ್ಟು ಹಾಗೂ 2016ರ ಕೂಳೆ ಬೆಳೆಯಲ್ಲಿ 59.67 ರಷ್ಟು ಕಂಡು ಬಂದಿರುತ್ತದೆ.

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(ವಿದ್ಯಾರ್ಥಿ ಸಹಿ)

ಡಾ. ಎಂ. ಎ. ಸೂರ್ಯನಾರಾಯಣ

(ಮುಖ್ಯ ಸಲಹೆಗಾರರ ಸಹಿ)

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LIST OF ABBREVIATIONS

Signs	Meanings/Expansion
%	Per cent
°C	Degree centigrade
AMC	Arka Microbial Consortium
BD	Bulk density
BF	Bio- fertilizer
Ca	Calcium
CFU	Colony forming units
cm	Centimeter
Cu	Copper
CV	Coefficient of variation
Ec	Electric conductivity
Fe	Ferrous
g	Gram
GC	Gas Chromatograph
ha	hectare
kg	Kilogram
LCD	Least Significant Difference
m	Meter
m mhos cm	microsiemens per cm
Mg	Magnesium
mm	Millimeter
Mn	Manganese

N	Nitrogen
OC	organic carbon
P	Phosphorus
K	potassium
PDA	potato dextrose agar
pH	potential of hydrogen
ppm	Parts per million
PSB	Phosphate solubilizing bacteria
Rec.FYM	Recommended Farm Yard Manure
Rec.NPK	Recommended Nitrogen, Phosphorus, Potassium
t	Tones
VA	Vesicular abuscular
Zn	Zinc

I. INTRODUCTION

The plant kingdom a vast storehouse for a number of species is a source for chemical molecules waiting to be identified, isolated, manipulated and used. Medicinal and aromatic plants constitute a major segment of the flora reputed to possess distinct alkaloids and fragrances that are considered as a source for therapeutic agents in health care. The past three decades have obviously witnessed a tremendous surge in acceptance and public interest in natural therapies both in developing and developed countries. It is estimated that, up to four billion people (representing 85% of the world's population) living in the developing world rely on herbal medicinal products as a primary source of traditional medical practice. Moreover, approximately 120 drugs in western medicine are obtained from plants, while many other drugs are obtained either by semi synthesis from plant products, or synthesis based on plant molecules (Pezzuto, 1997). Aromatic plants have been used for thousands of years for different purposes including culinary delights, perfumery and cosmetics (Gamal, 2004). They are a special class of plants used for their aroma and flavor. Many of them are exclusively used for medicinal purpose in aromatherapy as well as in various systems of medicines.

India has been considered as treasure house of valuable medicinal and aromatic plants and is rightly called as the "Botanical garden of the World". Considerable attention has been paid in past few decades to utilize medicinal and aromatic plants for the prevention and cure of different human diseases due to their minimum side effects. There are currently about 2,50,000 registered medical practitioners in the Ayurvedic system, as compared to about 7,00,000 in the modern medicine system in India. In rural India, 70 per cent of the population depends on the traditional system of medicine, the Ayurveda. The *Ocimum* genus belonging to the *Lamiaceae* family is characterized by a great variability of both morphology and chemotypes (Marotti, 1996). This genus has 50 to 150 species which are either herbs or shrubs (Jakowienko *et al.*, 2011). Among the species of this genus, *Ocimum basilicum* L. has the most economic importance and is well known as sweet basil/ French basil. It is a large, herbaceous, erect, strongly aromatic annual herb grows to a height of 30-90 cm, leaves opposite, ovate, lanceolate, flowers small born in racemose inflorescence with white, pink or pale purplish color. Sweet basil originally domesticated in India, is also native to tropical region of Asia, where it is grown for more than 5,000 years, and the estimated annual consumption that obtained from cultivation is 2000 MT/year (Ved and Goraya, 2008). The genus *Ocimum* is well represented in the warmer parts of the hemisphere from sea level to 1800 m elevation. The main centers of diversity in the genus are Africa, America and Asia (Beltrame *et al.*, 2014).

Traditionally, sweet basil has been used as a medicinal herb in the treatment for headaches, coughs, diarrhea, constipation, warts, worms and kidney malfunction (Simon *et al.*, 1999). It has also been used for a long time as immune stimulant, sedative, hypnotic, local anesthetic, anticonvulsant, diuretic, carminative, spasmodic and vermifuge purposes (Zarghari, 1997). Sweet basil has shown antioxidant, antimicrobial and antitumor activities due to its phenolic acids and aromatic compound (Hussain and Przybylski, 2008). Since ancient times sweet basil was cultivated as aromatic plant for its essential oil, which is extensively used in perfumery, pharmaceutical industries, confectionery as well as in food, flavor, dental, oral products, and traditional medicines. Sweet basil leaves are used as culinary herb as one of the major sources of income for farmers (Palada *et al.*, 2002). The high economic value of sweet basil oil is due to the presence of phenyl propanoids, like eugenol, chavicol and their derivatives or terpenoids like monoterpen linalool, methyl cinnamate, and limonene (Louie *et al.*, 2007). The quality of essential oil is dependent on the relative composition of the oil constituents, which is greatly influenced by the agro-climatic condition as well as nutrient management (Randhawa *et al.*, 1998).

Due to its diversified use, the demand for sweet basil is growing in recent years. Presently, the cultivation of the crop is confined to North Indian states. Hence, there is a need to

cultivate this valuable aromatic crop extensively in other agro ecological zones as there is an increased demand for the sweet basil. To grow any crop, the point of paramount importance is to get maximum yield with minimum inputs. This includes standardization of nutritional requirements through organic and inorganic fertilizers.

Sweet basil also responds well to the application of organic manures and inorganic fertilizers, depending on the climate condition and soil types. Chemical nutrients especially nitrogen, phosphorus and potassium are very important for plants, as they take part in structure of several components of the whole plants (protein, hormones, amino acids, enzymes, nucleic acids, fats). These three important nutrients are frequently in short supply in soil and their application plays a very important role in altering various growth, yield and quality parameters of the plant. However, modern and intensive agriculture necessitates the heavy dependence on fertilizers and chemicals, which cause pollution and environmental hazards in addition to neglecting the traditional good agriculture practices, resulting in low productivity of soils. Thus, by considering the recent concept of application of organic manures in integration with inorganic fertilizers fulfills the above need in sweet basil.

FYM was the only recognized organic source of plant nutrients added to the soil before the introduction of chemical fertilizers in the middle of the 19th century (Bhanuvally, 2006). Organic nutrition promotes soil health because of their positive effects on soil physical, chemical and biological properties. Utilization of organic manures and bio fertilizers in the cultivation of medicinal and aromatic plants enhances the growth, yield and quality of these crops. Soil microorganisms represent important component in the evaluation of soil quality used as biological indicator or as sustainability index for production systems. Therefore, emphasis is now laid on the use of bio fertilizers in the crop production like, biological nitrogen fixers (*Azotobacter/Azospirillum/Rhizobium*) and *Phosphate Solubilising Bacteria (PSB)*. These bio fertilizers improve crop production by supplying nutrients, producing vitamins such as thiamine and riboflavin and plant hormones viz., indole acetic acid (IAA) and gibberellins (GA) (Bao *et al.*, 2015).

However, the current use of microorganisms in agriculture remains at a low level despite the significant investment in scientific work to understand and use natural microbial resources to improve plant growth and health. Keeping the above facts in view, the present study was undertaken to find out the effect of organic manures and biofertilizers on growth, herb and oil yield and quality of essential oil of sweet basil, with the following objectives:

1. To study the influence of organic manure and biofertilizers on growth, herb, oil yield and quality of the essential oil of French basil.
2. To study the effect of organic manure and biofertilizers on nutrient accumulation.
3. To quantify the changes in physico-chemical properties of the soil resulting from application of organic manure and biofertilizers.
4. To work out the economics of sweet basil cultivation under organic and conventional farming.

II. REVIEW OF LITERATURE

Study of sustainability in agriculture depends on the capacity to assess effects of agricultural practices on farmers, communities and the environment. The need to balance environmental quality, human needs and economic stability is often referred to as “the three pillars of sustainability” (Lehtonen, 2004). Attempts to address these three factors in agriculture has led to the study of whole systems, the concept based on the idea that whole systems have qualities and characteristics apart from the sum total of their individual components, so that understanding the whole is key to a better understanding of the parts . Furthermore, a system approach is a more effective way to evaluate organic and alternative agriculture because the management strategies in these systems are designed to work together, often relying on cumulative effects of different practices to achieve acceptable yields (Kuepper and Gegner, 2004), Due to increased concerns about sustainability, organic farming has become the fastest growing segment of agriculture in the world (Greene, 2007).

2.1 Concept of organic farming

Organic agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved (IFOAM, 2008).

The Food and Agricultural Organization (1989) has stated that "sustainable agriculture should involve the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources.

Organic farming may be considered as a prototype of sustainable farming which attracted increasing attention over the last one decade because they are perceived to offer some solutions to the problems currently besetting the agricultural sector. It has the potential to provide benefits in terms of environmental protection, conservation of nonrenewable resources and improved food quality (Tuomisto *et al.*, 2012).

The National Organic Standards Board (NOSB) describes organic agriculture as “an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that restore, maintain, and enhance ecological harmony.” (Chester and Robson, 2013).

According to Fantilanan (1990), organic farming is a matter of giving back to nature what we take from it. It is safe, inexpensive, profitable and sensible. Organic farming is mere non – chemicalism in agriculture. It is a system of farming based on integral relationship.

2.2 Effect of organic manure

The complexity of soil system is determined by the numerous and diverse interactions among its physical, chemical and biological components and modulated by the prevalent environmental conditions (Buscot, 2005).

2.2.1 Effect of organic manure on soil physical properties

The physical properties of soil have very much to do with its suitability for many uses to which man put it. The rigidity and supporting power, the freedom of drainage, moisture storage capacity, ease of penetration by roots, aeration and retention of plant nutrients are all intimately related with the physical condition of the soil (Muntasir *et al.*, 2000). Soil physical properties can be used as indicators for making soil quality assessments and for determining the sustainability of farming systems (Aggelides and Londra, 2000).

Ekwue, (1992) found that the addition of organic matter improved the soil surface structure, stability, porosity and water infiltration. The studies of Singh *et al.* (2000) indicated that application of FYM significantly brought down the bulk density of both surface and subsurface soils in comparison with control. Similarly, Anderson *et al.* (1990) and Kuchenbuch and Ingram (2004) proved that continuous application of FYM reduced the bulk density, and increased the porosity of subsurface soil, which is a vital soil characteristic for successful root development. This could be attributed to the greater distribution of the organic biomass within the soil profile by incorporation, which facilitates the development of soil pores (Kay and Munkholm, 2004).

Sundaramurthy (1983) reported that application of cattle manure improved the moisture content of the soil and increased its water holding capacity. Organic manure will influence water holding capacity directly by increasing the specific surface area of the soil and indirectly by increasing aggregation generally so that the total number of pores will increase (Khaleel *et al.* 1981)

Herencia *et al.* (2011) observed a high correlation between organic carbon content and some soil physical properties. The aggregate stability showed an increase with time on plots fertilized with organic matter, Dunjana *et al.* (2012) recorded an increase in organic carbon, improved aggregate stability, infiltration with increase of cattle manure application rate and hence increases in plant available water content and decreases runoff and erosion. Franzluebbers (2002) recorded that, greater organic manure increased the infiltration rate by 27% on sandy loam soils in a humid subtropical climate.

2.2.2 Effect of organic manure on soil chemical properties

According to Bhanuvally (2006), organic material in the form of FYM was the only recognized source of plant nutrients added to the soil before the introduction of chemical fertilizers in the middle of the 19th century; FYM is known to increase crop yield by its favorable effect on chemical factors that determines the productivity and fertility status of soil and supply nutrients in the readily available form to plants. For instance, 1 ton of high quality cattle manure can contain up to 23 kg of nitrogen, 11 kg of phosphorus and 6 kg of potassium as evidenced by Vasundhara (2006).

Tennakoon and Bandara (2003) found the nutrient content of FYM to be between 1.2-1.8; 0.4-0.6 and 1.1-1.9 per cent of N, P, K respectively whereas (Sanginga and Woomer, 2009) reported that FYM contains approximately 0.5, 0.2 and 0.5 per cent of N, P and K respectively.

Eghbal *et al.* (2004) observed that, the residual effect of manure and compost application significantly increased soil electrical conductivity, plant available P and NO₃ -N concentration. Rathod *et al.* (2003) reported that, the pH of the sodic soil was reduced significantly by application of FYM at 5 tons per hectare; similarly, electrical conductivity was reduced significantly by application of the FYM.

Adeniyani *et al.* (2011) conducted an experiment to compare FYM with NPK fertilizer effect on improvement of chemical properties of acid soil. Cow dung application resulted in the highest pH levels of 6.37 and 6.50 in acid soil and nutrient depleted soil respectively, while NPK fertilizer gave lowest pH levels of 5.28 and 5.74 for both soils. Also, application of FYM enhanced soil organic C (1.83%), and CEC (2.91 cmolkg^{-1}) compared with NPK fertilizer (0.44% and 2.39 cmolkg^{-1}) respectively.

Nalatwadmath *et al.* (2003) observed that, the production of acids on decomposition of organic manure (FYM) reduced the pH from 8.9 to 8.7, while Niwa *et al.* (2007) reported that, the application of organic matter FYM at 100 t per hectare resulted in an increase in soil pH. The same study also observed that unlike pH, electric conductivity, (EC) of soil remained unaffected.

The amount of exchangeable bases is an important property of soils and sediments as they relate information on a soil's ability to sustain plant growth, retain nutrients, and sequester toxic heavy metals, cation exchange occurs due to the negative charges carried by soil particles, in particular clay minerals, sesquioxides and organic matter. These negative charges are cancelled out by the absorption of cations from solution. The CEC can be estimated by summation of exchangeable bases (Ca, Mg, Na, K) and exchangeable (Al). It is used as a measure of the soil's fertility, and in general the higher the exchangeable bases, the higher the CEC hence the higher the soil fertility. Factors favoring the formation of humus generally increase the exchangeable bases in the soil (Brix, 2008).

A 19-year long-term experiment was conducted to evaluate the effects of fertilization regimes on soil organic carbon (SOC) dynamics. The SOC content in the top 20cm soil layer remained unchanged over time under the unfertilized control plot whereas it significantly increased under both organic, NPK fertilizers and combined manure treatments (Yang *et al.*, 2011).

Organic amendments show a slower nutrient release pattern than mineral fertilizer but facilitate an increased soil organic matter (SOM) content (Pinitpaitoon *et al.*, 2011). At small holder level organic material is applied in form of farmyard manure (FYM) as it is often the only available source of organic matter (Dunjana *et al.*, 2012). Although Vanlauwe and Giller (2006) claim that organic resources are not sufficient enough to supply crops with the required nutrients, the increased SOM is enhancing productivity due to the improved soil properties (Watson *et al.*, 2002).

Available phosphorus (P) exists in the soil and may range from zero to more than 2%. Its content increases with increased organic matter and a positive linear regression exists between organic phosphorus and organic carbon content. Field experiment was conducted to assess the effect of the integrated use of farmyard manure and inorganic fertilizers on soil chemical properties. The results revealed substantial increases in available P (Bayu *et al.*, 2006).

FYM supplies all major nutrients (N, P, K, Ca, Mg and S) necessary for plant growth, as well as micronutrients (Fe, Mn, Cu and Zn). Hence, it acts as a mixed fertilizer (Khan *et al.*, 2010). This was supported by another study that application of FYM significantly increased the Ca and Mg, which could be attributed to higher initial content of these nutrients in amendments and due to effect of organic acids that produced during the process of decomposition which enhance the solubility of native Ca and Mg and their retention by organic colloids (Srikanth *et al.*, 2000)

Chung and Zasoski (1994) reported that, organic matter addition significantly increased cation retention. The variation in cation retention was much greater in the NH_4^+ -Ca system. As NH_4^+ concentration increased in the exchange solution, the sum of Ca and NH_4^+ on exchange sites decreased markedly most likely because displacement of H^+ from soil organic matter decreased. With the addition of organic matter, the solid phase preference for NH_4^+ over K

increased, but NH_4^+ became much less competitive than Ca. These indicate that organic matter sites have a greater affinity for NH_4^+ than for K and a greater affinity for Ca. From a long term experiment, Angelova *et al.* (2013) indicated that FYM increased organic carbon content, total N, available P content of soil and lowered the soil pH of calcareous soil.

Jarecki (1991) conducted an experiment to evaluate the effects of farmyard manure on sandy soil. The farmyard manure led to an increase of available forms of P, K and Mg by 14%, 10% and 20%, respectively.

Yinhu *et al.* (1990) showed through their 5 years of experiments that the absolute content of soil organic matter in check was reduced by 0.028% and that the content of organic matter, total nitrogen and phosphorus tended to increase in treatment of farmyard manure

2.2.3 Effect of organic manure on soil biological proprieties

Soil biology refers to the organisms both animals (fauna/micro-fauna) and plants (flora/microflora). They are important in the overall quality, fertility and stability of the soil and are responsible for the formation of humus and formation of soil and its structural stabilization. Soil contains a vast number and wide range of organisms which are important in the myriad of biochemical reactions and intricate biological processes that take place within the soil (Bajracharya, 2011). Koopmans and Smeding (2008) state that learning how to manage beneficial soil biological processes as the key step towards developing sustainable agricultural systems.

Application of organic manures resulted in a general improvement in the soil organic matter (SOM) which represents the main reservoir of energy for microorganisms and nutrients supply for plants. Microorganisms such as bacteria, fungi and other micro fauna representatives are responsible for the energy and nutrients cycling (Bot and Benites, 2005). So it represents important component in the evaluation of soil quality and can be used as biological indicators or as sustainability index for production systems (Franchini, 2007), generally it has strong correlation with the soil organic matter, which in turn reflects in crop yield (Gundale, 2005).

Soil microbial biomass is defined as the living microbial component of the soil, which includes bacteria, actinomycetes, fungi, algae and micro fauna (Anderson *et al.*, 1990). It has the potential for use as indicators of soil quality. Soil microbial population are immersed in a frame work of interaction known to effect plant fitness and soil quality. They are involved in fundamental activities that ensure the stability and productivity of both agriculture system and natural eco-system (Herrick, 2000).

The appropriate utilization of manures within management systems can increase levels of plant nutrients and enhance soil microbial activity and diversity (Mandal, 2007). Microbial communities react to environmental fluctuations by adjusting their functional and species composition to climatic and nutritional conditions (Wallenstein and Hall, 2012). Their biodiversity and functions are influenced by various factors including agricultural management (Critter *et al.*, 2004).

Increase in the fungi/bacteria population have been linked to increase in soil carbon and ecological buffering capacity and in response to organic management, as well as various organic amendments such as livestock manure (Ling *et al.*, 2014). Effects of agricultural management on the soil microbe are diverse (Nelson and Spaner, 2010). In general, it has been reported that, low-input farming systems promote higher abundance and diversity of most organisms and large positive effects on the microflora (Postma *et al.*, 2010), because the growth and activity of microorganisms are sensitive functions of soil properties including nutrition, texture, pH, temperature, and water content, dynamic changes of microbial community can represent the

improving effects of different types and amounts of organic materials on soil quality (Mele, 2008). The functional groups of micro-organism involved in nitrogen, phosphorus and carbon cycling are important for the maintenance of nutrient turnover. These micro-organisms interact with plant root, to supply nutrients and participate actively in plant nutrition and growth (Andrade, 1997).

Microbial population was higher in organic farming than conventional one. Soil, where organic farming was adapted showed approximately twice the number and wide range of fungal species. The abundance and richness of fungi and occurrence of potentially antagonistic microflora to plant pathogen were greater in organic converted area. Higher population of microbes under organic treatment acted as index of soil fertility because it serves as temporary sink of nutrients flux (Bhuma, 2003). Increasing soil amendments such as FYM that increase soil aggregation is therefore vital because most soils rely on aggregation of particles to maintain favorable conditions for soil microbial and faunal activity and plant growth (Yu *et al.*, 2012).

The rise in agricultural systems studies concerning soil quality and microbial properties is a reflection of the importance of soil to the understanding of agricultural sustainability. How management practices impact the soil is fundamental in evaluating the sustainability of an agricultural system. More than just a substrate for supporting root structure, the soil has its own complex ecosystem in which microorganisms are the dominant form of life and are responsible for performing functions vital to soil productivity, such as decomposition of organic matter and the cycling of major nutrients important to plant growth (Sylvia, 1998).

2.2.4 Effect of organic manure on growth and yield:

2.2.4.1 Effect of organic manure on growth and yield of medicinal crops

Zahida (2009) reported that the use of FYM at 45 t/ha gave maximum number of leaves, leaf area, dry biomass and dry leaf yield and higher glycoside (stevioside, rebaudioside A) yield in sweet herb (*Stevia rebaudiana*). Nevase *et al.* (2009) studied the effect of chemical fertilization singly or in combination with farmyard manure (20 t/ha) on the yield of *Stevia rebaudiana* and found that the application of farmyard manure markedly increased fresh and dry leaf yields. The effect of the interaction between the fertilizer and farmyard manure was significant, it recorded the highest fresh leaf yield (7083 kg/ha) and dry leaf yield (2083 kg/ha).

Gangadhar *et al.* (2010) studied integrated nutrient management (INM) in long pepper (*Piper longum* L.). Application of FYM (40 t/ha) and N:P:K fertilizers (125:50:160 kg/ha) gave significantly higher dry spike yield (2412 kg/ha) and in turn increased the piperine yield (32.3 kg/ha). Further, the growth, yield and quality attributes were also significantly higher with this combination.

Hegde *et al.* (2012) studied the effect of organic nutrition on the performance of betel vine (*Piper betle* L.). Application of FYM (25 t/ha) along with recommended dose of fertilizer (NPK 200:100:100 kg per ha) recorded higher growth and yield attributes resulting in significantly higher annual leaf yield (588.55 leaves/vine).

Artigo (2014) evaluated the effects of different dosages of cattle and poultry manure in *Achillea millefolium* L. on the vegetative growth, content and chemical composition of its essential oil. The dosage of 6 kg m⁻² produced maximum shoot dry weight and highest yield of essential oil.

Ponni and Arumugam (2007) noticed that combined application of organic manures and biostimulants improved the growth and yield in *Phyllanthus niruri* plant. The results revealed that application of FYM at 12.5 t/ha plus vermicompost at 2.5 t/ha along with panchagavya 3 per cent

recorded the highest plant height (83.17 cm), number of branches (30.23) , leaves (1115.87) and maximum herbage yield (44.21 g/ plant).

Vishal and Duhan (2014) reported that, application of FYM at the rate of 12.5 t/ ha in combination with 12.5 mg P₂O₅/ kg soil significantly improved all the vegetative parameters such as plant height (32.3cm) , number of primary branches (2.1), plant spread (218.7 cm²) and dry weight of shoot (5.28 kg/ha). Whereas, FYM at the rate of 12.5 t ha⁻¹ in combination with 25 mg P₂O₅ kg⁻¹ soil significantly enhanced the dry weight of the roots (5.59 kg/ha) of ashwagandha (*Withania somnifera* L.) crop. Shinde *et al.* (2013) studied the effect of inorganic fertilizers (20: 20:00 kg NPK/ha) and organic manures (FYM at 2 kgm⁻²) on Ashwagandha with respect to growth, quality and yield attributing parameters. The interaction effect of inorganic fertilizers and organic manures was significant in respect of number of branches per plant (11) and fresh weight of root (3195 g/plant).

Mandal *et al.* (2013) studied the effect of integrated nutrient management on growth and yield of aonla cv. NA-7. Observations on plant morphological characters and yield attributes were recorded at maturity of 3 years old aonla trees. The highest number of branches (15.30), maximum number of fruits (73.17) and the highest yield (1781.43 g/ plant) was recorded with the application of 100: 25:150 g NPK/ plant+ 10kg FYM+ 50g PSB plant⁻¹.

Patel *et al.* (2008) studied the effect of different organic manures on safed musli (*Chlorophytum borivilianum*) yield. Application of 5 tones of poultry manure/ha followed by 10 tones FYM / ha recorded the highest yield (6090 kg/ha)

Umasha *et al.* (2011) obtained maximum plant height (95 cm), number of branches per plant (19.6), plant spread (4253 cm²), leaf area (5013 cm²) and total dry matter accumulation (27.6 g/plant) with the application of FYM 20 t + vermicompost 1.0 t + neem cake 1.0 t /ha in makoi.

Experiment by Bijit (2016) revealed that, the application of *Azotobacter* at 20 g per plant along with PSB at 20 g per plant and FYM 5t/ha recorded the maximum plant height (89.15 cm), leaf number (374.70), leaf area index (2.62), branches (19.09), flowers (372.54) and fruits per plant (295.09), seed and root yield (8.94kg/ha and 2809.64kg/ha) in *Rauwolfia tetraphylla* .

Jatisatienre *et al.* (2005) reported that, application of FYM at 10.8 t/ha was found to be effective and comparable in increasing content of gel moisture in *Aloe vera* (52.6 g/plant) with inorganic source of nutrients NPK (80:40:80 kg/ha) that recorded (49.5 g/plant). Similarly, influence of organic manuring on *Aloe vera* indicated that, application of FYM at 15 t/ha increased the total fresh weight (128.39 t/ha) and it was the best for producing suckers comparing with higher dose 45 t/ha (Gopichand and Ramjee , 2015).

A study was carried out by Dinesh and Punnet (2014) to find out the effect of integrated nutrient management on yield of periwinkle. Application of 10 tons FYM/ha + (NPK 80: 30: 50 kg/ha) was the best in relation to yield of dry matter through leaves (55.77q/ha), roots (11.27 q/ha) and total dry matter production (114.25 q/ha).

Sivasankar and Manivanna (2015) revealed that 75% of Recommended dose of fertilizer NPK (90:38:56 kg/ ha) along with FYM at 12.5 t/ ha and vermicompost at 5 t/ ha was found to be superior in improving the growth and yield characters like plant height (178.39 cm), number of branches (13.98), number of leaves (246.10), number of flowers (30.21) , number of pods (26.27), pod yield per plant (309.54 g/ plant) and estimated seed yield (836.47 kg /plant) in glory lily.

2.2.4.2 Effect of organic manure on growth and yield of aromatic crops

Silva *et al.* (2016) conducted greenhouse experiment on *Baccharis trimera*, the plants grown in soil containing 0, 5, 10, 20, or 30 per cent (w/w) manure. The results indicated that, the application of FYM at the higher nutrient levels improved the growth as compared with the control without the addition of manure. Maximum height (87.3 cm), branching (22.2 /plant) and number of nodes (101 per plant) was recorded with 30 per cent (w/w) of FYM.

Prakasa *et al.* (2008) found that in davana, nitrogen application at 80 kg/ha along with FYM at 15 t/ha enhanced the biomass yield, essential oil yield, and the nitrogen, phosphorus, and potassium uptake.

In lemon grass (*Cymbopogon flexuosus*), Yadav *et al.* (2006) reported that application of 90:45:45 NPK kg/ ha in combination of FYM @ 5 t/ha produced significantly high yield (5.03 t/ha). Application of FYM 10 t/ha significantly improved growth parameters and yield contributing characters *viz.* herbage yield (3.86 t/ha) and dry matter yield (1.42 t/ ha) of lemongrass (Gajbhiye *et al.*, 2013).

In *Vetiveria zizanioides*, use of FYM at 10 t/ha along with Algae bio-fertilizer as a recommended dose (in 1ha=2.24x10⁶ kg soil) resulted in higher number of culm (8.33), plant height (32.15cm), shoot length (46.75), root dry biomass (2.1 g) and shoot dry biomass (2.59 g) (Dhirendra and Kumar, 2016).

Joy *et al.* (2002) observed that application of FYM at 20 t/ ha to *Alpinia galanga* plants produced significantly higher rhizome yield (45.14 t/ha), number of suckers (57.10), number of clumps (19.17) in comparison with NPK at 100:50: 50 kg /ha (44.86 t/ha, 55.06 and 19) respectively.

Datta *et al.* (2009) recorded maximum fresh and dry rhizome yield (3013.23 kg/ ha, 1389.15 kg/ ha respectively) with the application of 50 t/ha FYM supplemented along with 100 ppm GA₃, followed by application of 50 t/ ha FYM (2879.80 and 1342.65 kg/ ha, respectively) in sweet flag.

Sunanda *et al.* (2014) reported that, in Kasuri Methi maximum plant height (42.81 cm), number of leaves (86.05), number of branches (25.64), absolute growth rate (0.26 g/day), dry herb yield (1.88 t/ha), and fresh herb yield (8.02 t/ha) were recorded in the treatment supplied with 75% recommended Nitrogen (80 kg ha⁻¹) with recommended dose of phosphorus and potassium (25:50 kg ha⁻¹) and recommended dose of farm yard manure (7.5 t /ha).

Adarsh and Subodh (2015) reported that, the maximum growth and biomass production for *C. citratus* and *C. zizanioides* were found in combination with mine waste (90%), chicken manure (2.5%), farmyard manure (2.5%) and garden soil (5%) of 4.5 kg of amended waste was filled in the each clay pots.

Effect of integrated manuring on growth of *Centella asiatica* was investigated by Anjana and Pramod (2013). The plantlets were grown in earthen pots containing soil, with integrated manuring [Urea (%): FYM(%), 75:25; 50:50; 25:75], individual manuring (100 % Urea, 100 % FYM) and control conditions (no manure). The biomass production in integrated manuring (50 % Urea and 50 % FYM) was seven times higher than in control; it was five times higher than in complete organic manuring (100 % FYM) and 1.5 times higher than in inorganic manuring (100 % Urea).

2.2.4.3 Effect of organic manure on growth and yield of *Ocimum basilicum*

Mohamad *et al.* (2014) studied the effect of organic and chemical fertilizers on basil plants (*Ocimum basilicum* L.) The results showed that the organic manures were significantly increased plant height, leaf yield, fresh and dry matter. The highest essential oil yield was obtained with application of cow manure 10 t/ha.

Asieh (2012) studied the effect of organic manure and chemical fertilizer on growth rate and essence amount of basil. The results indicated that cow manure (20 t/ha) had the highest and the most effective influence on growth rate and essence amount of *Ocimum basilicum*.

Cumulative yield of *ocimum basilicum* at 100 days after planting (DAP) was higher with the application of compost at 45 t/ha (8785 kg/ha) than the plants treated with synthetic fertilizer as urea (110kg/ha) which recorded (6863kg/ha) according to (Theodore, 2012).

Mohamad *et al.* (2012) studied the effects of drought stress and three types of fertilizers *viz.*, chemical fertilizer, manure and compost (25 tons per hectare) on quantitative and qualitative characteristics of basil (*Ocimum basilicum* L.). Results showed that using manure fertilizer under high level of drought stress was more effective.

An investigation was carried out to find the effect of different organic manures *viz.*, FYM, vermicompost, *Azospirillum*, phosphobacteria, neem cake and inorganic fertilizers (120: 120: 100 kg NPK ha⁻¹) on the growth and essential oil content of sweet basil. Among the different treatment combinations, application of FYM at 25t/ha along with *Azospirillum* and phosphobacteria recorded highest plant height, number of branches and fresh weight of the herb per plant in sweet basil (Jayasri, 2010).

Salah (2009) studied the effect of different proportion of chemical fertilizer and organic manure on basil (*Ocimum basilicum* L.) plants (100% organic, 100% chemical, 50% organic and 50% chemical, 25% organic and 75% chemical and 75% organic and 25 % chemical). The results showed that application of only 50% from recommended NPK gave about 80% of the yield of 100% recommended NPK. Organic manures gave similar yield but higher quality than fertilization with chemical NPK fertilizers alone.

Basil was given 0, 60, 120, 180 or 240 N kg/ ha in organic, mineral or mixed forms. The organic form was applied before planting whereas two-thirds of the mineral form was applied before planting and the remaining one third 30 days after sowing. Among different N sources the organic form gave the best results when nitrogen rates exceeded 120 kg ha⁻¹ according to Caria and Martinetti (1996).

An experiment was conducted to study the effect of FYM (Farmyard manure), bio, mineral NPK fertilization on vegetative growth, oil production and chemical composition of basil plant. The results obtained indicated that the application of FYM at high level (25t/ha) significantly increased the studied parameters compared with other fertilization including the control. The interaction between the main-plots (FYM treatments) and sub-plots (bio, and NPK treatments) had significant effect on the studied parameters (Zeinab, 2005).

Tahami *et al.* (2010) indicated that the use of cattle manure could significantly increase the plant height, number of branches, leaf yield, essential oil per cent and essential oil yield of basil leaf compared to control.

2.2.4.4 Effect of organic manure on growth and yield of related crop

Application of sheep manure at 10 t/ha on rosemary crop had the highest dried yield (1344 kg/ha), essential oil content (3.72%) and essential oil yield (50 liters per hectare) that increased 2, 2.4 and 4.5 times compared to the controls respectively (Seyede *et al.*, 2015). Herbage yield increased by 66.1% and oil yield by 54.9% with the application of vermicompost 10 t ha⁻¹ + fertilizer NPK (100:25:25 kg ha⁻¹) compared with vermicompost applied alone. which indicated that 50% recommended inorganic fertilizer can be supplemented with organic manure (Munnu, 2013).

Suresh *et al.* (2010) studied the influence of organic manuring on *Coleus forskohlii*. The results indicated that application of 10 FYM t /ha with NPK (40:60:50kg/ha) increased the dry weight of shoot biomass (71.14 g/ plant), dry weight of root (39.56 g/plant) and yield per hectare (1890 kg/ha). Similarly, Nageswara *et al.* (2011) reported that application 50% of recommended dose of NPK (40, 60 and 50 kg/ha) with FYM at 10 tons per hectare recorded higher fresh and dry weight of roots (600 and 60g/plant) respectively, comparing with 100% of recommended dose of NPK that recorded (490 and 47.5 g /plant) respectively in *Coleus forskohlii*.

Application of farmyard manure at 12 t/ha with ½ recommended dose of nitrogen (120 kg/ha) improved the plant height (62.07 cm), number of branches (15.98), fresh and dry weight of leaves (68.47 and 16.36 g), fresh herb yield (7.93t/ha) and essential oil yield (13.68 l/ha) in *Ocimum sanctum* (Raina *et al.*, 2013).

Chand *et al.* (2001) reported that application of FYM @ 6.7 t ha⁻¹ along with NPK at 133:40:40 kg ha⁻¹ recorded highest herb yield (18.7 t ha⁻¹) over control (14.59 t ha⁻¹) in *Mentha arvensis*. Gerami (2016) conducted an experiment to evaluate the effects of irrigation intervals and organic manure on essential oil content and yield of oregano. The highest essential oil content (2.07%) and yield (66.62 kg ha⁻¹) was obtained in three week irrigation intervals with application of cattle manure at 30t/ha.

Application of farmyard manure at the rate of 75 m³/ha along with biofertilizers (Nitraboein and Halex-2 at a rate of 988 g/ha of each) while, the nitroboein contains *Azotobacter*, a nitrogen fixing bacteria; Halex-2 contains a mixture of N-fixing bacteria of the genera *Azotobacter*, *Azospirillum* and *Kelbsiella* in marjoram recorded the maximum fresh yield (7.35 t/ha), dry yield (2.72 t/ha) and oil yield (38.7 kg/ha) according to (Ahmad *et al.*, 2011). An experiment was carried out by Zaghoul (2008) to study the efficiency of biofertilization and compost amendment in the presence of *Trichoderma harzianum* on oil yield of marjoram. The results indicated that dipping the roots of marjoram plants in mixture of cell suspension of each *P. polymyxa* H1 (7x10¹¹ c.f.u./ml), *B. megatherium var phosphaticum* (8.3x10¹¹ c.f.u./ml), *B. circulans* (4.1x10¹¹ c.f.u./ml) and *T. harzianum* (5x10⁷ spores/ml) for 60 minutes before transplanting with application of compost at a rate of recommended dose (20 ton/ha) recorded the highest oil yield (54.57 l /ha).

Kaplan *et al.* (2009) recorded that essential oil quantity of sage plant increased with poultry manure applications at 15t/ha by 68.90% comparing to control. While, the increase in dry weight was 42.63%. In thyme, plant biomass and its components as proportion of leaf, stem and flowers and also essential oil percentage and yield were enhanced by the application of FYM at 10t/ha (Tabrizi *et al.*, 2011).

Katarzyna *et al.* (2014) reported that fresh flower yield (73.33 g/m²), dried flower yield (22.83 g/m²), seed yield (13.45 g/m²) and weight of 1000 kernels (0.75 g) of lavender from organic experiments was higher compared with the yield from conventional cultivation (70 g/ m², 20 g/m², 12.95 g/m² and 0.64 g) respectively.

Weaam *et al.* (2015) investigated the substitution potential of ammonium sulphate by sheep manure and active dry yeast biofertilizer, separately or in combinations. The results indicated that application of sheep manure at the rate of 70 m³ / ha along with 6 g/l active dry

yeast , 715 kg/ ha calcium super phosphate and 238 kg/ ha potassium sulphate recorded the highest fresh herb weight (145.12 g/plant) and oil yield (31.42 ml/plant) in *Lavandula angustifolia*.

2.2.5 Effect of organic manure on quality of medicinal and aromatic crop

Makwana *et al.* (2010) observed that the interaction effect of FYM at 10 t/ha with wider spacing of 30cm x 45cm had recorded higher amount of andrographolide content in Kalmegh (1.40%).

Afaq *et al.* (2013) conducted an experiment to assess the impact of farmyard manure (FYM), sugarcane compost on volatile oil composition of *Ruta graveolens* . Essential oil obtained from plants treated with FYM amounted to 0.36% of fresh weight and consisted mainly of n-Hex-4-en-3-one (53.64%), n-Pent-3-one (37.82%) and n-Hex-3-en-2-one (7.22%).

Abdolshakoor *et al.* (2013) obtained the maximum swelling factor (22.63 mmM³), N (0.33%) and K (0.39%), protein (1.75%) and total carbohydrate (4.40 mg/g DW) by application of FYM 20 t/ ha in *Plantago ovata*.

In *Cichorium intybus*, Zahid *et al.* (2012) recorded that esculin content in leaf reached to 9.05% at flowering stage by application 20 t/ ha FYM. Hunshal (2008) recorded significantly higher growth parameters, yield components and yield (660.19 kg/ha), higher dry root yield (820 kg/ha) and higher total saponin content (29.24%) with the application of FYM @ 40 t/ha in [Safed Musli](#).

Total glycosides in the leaves of *Stevia rebaudiana* reached to 14.63% in organic manure cultivation condition, while it was 13.38% in chemical fertilizer cultivation. Since, the amount of organic manure and chemical fertilizer cultivation converted into equal quantity nitrogen fertilizer (Xiangyang *et al.*, 2011).

In Lemon grass, Punam *et al.* (2012) observed that the application of organic manure (FYM) at 20 t/ha along with vermicompost at 15 t/ha gave the higher oil percentage 0.31% compared to the control 0.18%. Similarly, Mohsen *et al.* (2014) indicated that organic management of lemon grass increased the oil percentage as well as the percentage of α -Myrcene.

2.2.5.1 Effect of organic manure on quality of *Ocimum basilicum*

An experiment was carried out to study the effect of organic fertilization with sheep manure on *Ocimum* crop. Three rates of organic fertilization (4, 8 and 12 kg m⁻²) were compared to control (without fertilizers). There was a significant difference among the treatments on biomass production, where the plants treated with 8 kg m⁻² of organic fertilizer produced higher flowers fresh biomass, and total dry biomass, variations in composition of oil were observed when the essential oil was extracted from flowers and leaves, where the eugenol percentage was more in leaves than flowers (Luiz, 2009). In another study, the effect of various rates of three organic fertilizers on yield and phenolic content of basil (*Ocimum basilicum*) were evaluated. Plants were grown at 75%, 100%, 150%, and 200% of recommended nitrogen through organic fertilizer .There was no difference in yield or total phenolic content across all treatments, which is attributed to the tolerance of basil to a wide range of growing conditions. (Raleigh, 2014).

Anwar *et al.* (2005) conducted a study to evaluate the effect of organic manure (FYM and vermicompost) at 10 t/ha along with inorganic fertilizers (NPK 100:50:50 kg/ ha) on yield and oil quality in basil (*Ocimum basilicum*). Content of principal constituents of basil oil (methyl chavicol and linalool) were higher under integrated nutrient management. Furthermore, it was noticed that

organic carbon, available N, and P were higher in post harvest soils that received organic manure alone or in combination with inorganic fertilizers than control.

Vermicompost at 20/ha along with cattle manure (20t/ha) was applied to assess the performance of basil (Maryam *et al.*, 2013). Application of cattle manure at 30 t /ha gave significant and positive effect on oil yield of basil (44.01 kg/ha) and herbage yield (1573 kg/ha) according to Daneshian *et al.* (2011).

Geetha *et al.* (2009) reported that, the application of vermicompost at 6 t/ha along with recommended dose of chemical fertilization NPK (60:30:52.5 kg/ha) recorded the highest micro nutrient and eugenol content in the oil.

2.2.5.2 Effect of organic manure on quality of related crop

In Mint, application of FYM at 8 t/ha along with N, P and K 150:45:45 kg/ha increased the menthol contents according to Muhammad (2015). Application of poultry manure with sheep manure at (10 t/ha) recorded the highest essential oil per cent (2.9 %) and highest value of 1,8 cineole (50.7 %) in *Salvia officinalis* (Isin *et al.*, 2010).

Edris *et al.* (2003) reported that, the application of organic manure did not change the chemical composition of marjoram essential oil comparing with inorganic fertilization, but rather relative percentage of certain constituents was affected. The highest concentration of *cis*-sabinene hydrate (24.1%) and erpinene-4-ol, (39.5%) were obtained under organic treatment.

In Thyme, application of organic manure at 10t/ha resulted in increase in the constituents of essential oil under field conditions which reached to 25 components, as 43.1% of the total essential oil was thymol as the main constituent (Jacoub, 1999).

Bohloul (2016) studied the effect of organic fertilizer on shoot yield and essential oil content of lavender. The treatment groups consisted of vermicompost (0, 5, 10 and 15 ton/ha) and cow manure (0, 10, 20 and 30 ton/ha). Highest oil yield (82.67 kg/ha) was recorded with the application of 15 t/ha vermicompost. While, among cattle manure treatments, application of 30 t/ha cattle manure recorded the highest oil yield (71.62kg/ha).

Ebrahim (2015) reported that the highest value of carvacrol (53.23%) was obtained from plants received cow manure (30 ton/ha) as compared to control treatment (44.98%) in *Satureja hortensis*.

2.2.6 Effect of organic manure on nutrient uptake in medicinal and aromatic crop

In Java citronella , Nandapure *et al.*(2016) observed that the highest N, P, K and S uptake was with combined application of FYM at 10 t/ha with 140:40:80 kg NPK / ha.

Sanjutha *et al.* (2008) recorded that, the application of FYM at 15 t/ ha along with NPK at 75:75:50 kg/ ha had the highest growth parameters and nutrient uptake in *Andrographis paniculata*.

Ravikumar *et al.* (2012) observed that the recommended dose of FYM @ 15 t/ ha with NPK @ 40:60:50 kg /ha along with 10 kg/ ha each of *Azotobacter crucocum*, *Bacillus megateruim* and *Glomus* produced significantly higher tuber dry matter (14.02%), and nutrient uptake of N (115.83 kg/ ha), P (49.59 kg/ ha) and K (151.55 kg/ ha) in coleus.

In stevia, the maximum nitrogen uptake was also recorded with FYM at 45 t /ha according to (Zahida *et al.*, 2013). Farm yard manure in combination with major nutrients

recorded significantly higher fresh rhizome yield and higher nutrient contents in galangal (*Kaempferia galanga*) as intercrop in coconut garden. (Maheswarappa *et al.*, 2000).

In Glory Lily, available major nutrients (NPK) in soil recorded higher after harvesting the crop in the treatment with FYM at 13.33 t/ha along with $\frac{1}{3}$ of recommended dose of NPK (120:50:75 kg/ha). (Gupta *et al.*, 2013).

Shahi and Singh (2013) indicated that application of farmyard manure, green leaf manure, vermicompost, poultry manure and NPK alone or in combination is very useful in enhancing the status of N, P, K, Ca, Mg and S of soil and crops in Lemon grass.

According to Dwivedi *et al.* (2009) application N 100 kg/ha as FYM and biofertilizers (*Azotobacter* and phosphobacter at 10 kg/ha each) gave higher crop growth parameters, marketable leaves, shelf life of leaves and nutrient uptake and soil nutrient status in betelvine.

Bhende *et al.* (2015) noticed that maximum phosphorus uptake (59.76 t /ha) was recorded with application of half dose of FYM (40 t/ ha) with quarter dose of Vermicompost (25 t/ha) In combination with pre standardized dose of microbial inoculants (*Azospirillum* + AMF + *Pseudomonas*+ *Trichoderma*) in Kasthuri turmeric.

2.3 Concept of biofertilizers

Bio-fertilizers are rhizosphere colonies including plant root growth promoting bacteria. These bacteria help the plants via supplying nutrients, biological controlling, producing pseudo hormone substances of the plant, and making the plant resistant against different kinds of stress including water and nutrients deficiency and decreasing the contamination effect of plant's heavy metals (Shaharoon *et al.*, 2006). Hence the term biofertilizers do not contain any chemicals which are detrimental to the living soil. They are extremely beneficial in enriching the soil with those micro-organisms, which produce organic nutrients for the soil, In large sense, the term may be used to include all organic resources (manure) for plant growth which are rendered in an available form for plant absorption through microorganisms or plant associations or interactions (Khosro, 2012). As biofertilizers contain living organisms, their performance therefore depends on surrounding environment.

Organisms that are commonly used as biofertilizers component are nitrogen fixers (N-fixer), solubilizer (K-solubilizer) and phosphorus solubilizer (P- solubilizer), or with the combination of molds or fungi. These potential biological fertilizers would play key role in productivity and sustainability of soil, it cause an increase in nitrogen and phosphorus uptake and consequently the promotion of roots growth of plants according to Violen, 2007. These bacteria may accumulate either in the rhizosphere or even in root or internal cellular space of the plants (Wu *et al.*, 2005). Bio-fertilizers enhance the efficiency of both organic and chemical fertilizers and increase the activities of plant growth-promoting bacteria in agricultural crops.

Azotobacter belongs to family *Azotobacteriaceae*, aerobic, free living bacteria in nature. The first representative of the genus, *A. chroococcum* was discovered and described in 1901 by the Dutch microbiologist and botanist Martinois Beijerinck. *Azotobacter* are gram negative bacteria and found in neutral and alkaline soil (Martyniuk and Martyniuk, 2003), in water (Tejera *et al.*, 2005) and in association with some plants (Kumar *et al.*, 2007). The isolated culture of *Azotobacter* fixes about 10 mg Nitrogen⁻¹ carbon source under in vitro conditions. Biological Nitrogen Fixation (BNF) is considered to be an important process which determines nitrogen balance in soil ecosystem. Nitrogen inputs through BNF support sustainable environmentally sound agricultural production. The value of nitrogen fixing bacteria in legumes in improving yield of legumes and other crops which can be achieved by the application of biofertilizers (Kannaiyan, 2002). They are known to synthesize biological active growth promoting substances such as

Vitamins of B group, IAA and gibberellins. The occurrence of this organism has been reported from the rhizosphere of a number of crop plants such as rice, maize, sugarcane, bajra, vegetables and plantation crops (Arun, 2007). *Azotobacter* normally fix molecular nitrogen from the atmosphere without symbiotic relationship with plants, although some species are associated with plants.

Microorganisms are able to solubilize and mineralize P pools in soils and are considered to be vital. Bacteria are among the predominant micro organisms that solubilize mineral P in soils, and most of them live in the plant rhizosphere (Barea and Brown, 2005). Phosphorous Solubilizing Bacteria (PSB) inoculants play an important role in making phosphorus available to crops. The plant utilizes only 15-25 per cent nutrition given through phosphorus and rest is converted in insoluble form. PSB convert unavailable P to available form in plant roots. PSB also increases the availability of available P in rock phosphate (Gaur and Gaind, 1990). Therefore, the use of PSB in agricultural practice would not only offset the high cost of manufacturing phosphate fertilizers but would also mobilize insoluble fertilizers to soluble forms in soil (Banerjee *et al.*, 2010).

2.4 Effect of biofertilizers

2.4.1 Effect of biofertilizers on growth and yield of medicinal plant

Mitra *et al.* (2012) recorded that inoculation of *Azotobacter* at the rate of 583 cm³ increased the average width of the leaves by 42% and the biomass by (94%) over control in *Aloe vera*.

In Ambrette, a combination of 2 kg *azospirillum* and *phosphobacteria* with 50% RDF(120 : 30 : 40 kg NPK ha⁻¹) along with FYM (25 t ha⁻¹) recorded maximum number of pods per plant (35), pod length (9.03 cm), pod girth (8.23 cm), mean pod weight (2.20), pod yield per plant (77g), pod yield per hectare (2082.50 kg/ha), number of seeds per pod (115), seed yield per plant (45.85g) and seed yield per hectare (260.33kg/ha) according to Rajeswari and Arumugam, 2015.

Aruw *et al.* (2012) reported increasing in the growth parameters of *Cassia angustifolia* like plant height (78.11 cm), leaf dry weight per plant (13.91g), shoot dry weight per plant (16.81), leaf area (136.37 cm²) and dry matter production (17.51 g/ha) with application of 75 per cent RDF (113:38:38 kg ha⁻¹) along with *Azospirillum* at 200g kg⁻¹ seed.

Dwivedi and Singh (2007) reported that microbial inoculation comprised of *Azotobacter* 5 kg/ha incubated in FYM 5 t/ha with P₂O₅ 100 kg/ha and K₂O 100 kg/ha or *Azotobacter* 10 kg/ha incubated in FYM 5 t/ha with P₂O₅ 100 kg/ha and K₂O 100 kg/ha or *Phosphobacter* 5 kg/ha incubated in FYM 5 t/ha with N 200 kg/ha incubated in FYM 5 t/ha and K₂O 100 kg/ha. These three treatments recorded similar and at par enhancement in vine growth per month (16.37, 16.20 and 16.10 cm) and dry matter production (6.40 6.50 and 6.60 t/ha) respectively in betelvine crop.

Priyadharshini *et al.* (2016) observed maximum growth in plant height (18.2 cm), number of leaves (14), leaf length (5.3 cm) and leaf area (5.3 cm²) in *Andrographis paniculata* plants that treated with integrated use of biofertilizers *Azotobacter chroococcum* (3g/Kg), chemical fertilizers (NPK) (50:25:25 kg/ha) and vermicompost (3g/ Kg).

Atul *et al.* (2011) reported a significant increase in herbage yield (225.80 g/ha) with 75% recommended NPK(100:50:50kg/ha) along with vermicompost 2.5 tons ha⁻¹ and (*Azotobacter* and *phosphate solubilizing bacteria*) in black henbane .

Gaikwad *et al.* (2011) observed that combined application of vermicompost at 2 t/ha along with *Azotobacter* as a root treatment by root dipping for 15-20 minutes gave significantly the higher fasciculated root yield (4444 kg/ha) and sapogenine content (1.494 %) in Safed musli.

In *Phyllanthus niruri*, maximum plant height (16.3 cm), number of branches (5), number of leaves (69) and leaf area (0.7 cm²) were obtained from the combined application of Vermicompost (3g/ kg) along with chemical fertilizer (NPK) (50:25:25 kg/ha) and biofertilizer (*Azotobacter chroococcum*, *Phosphobacteria*) at (3g/kg) according to Priyadharshini *et al.*, 2016.

Patil (2010) reported that the combination of biofertilizer (*Phosphorous Solubilizing bacteria*) 4g / plant and chemical fertilizer (18:18:10) 3g/plant increased the growth measured in terms of height (53 cm), chlorophyll content (0.9 mg/g), and proteins content (70 mg/g) in *Stevia rebaudian*.

Application of 75 % recommended dose of NPK (100:50:50 NPK kg/ha) with constant dose of K (50 kg/ ha) along with FYM (10 t/a) and biofertilizer (*Azotobacter*, *Aspergillus*) recorded significantly superior values of plant height (91.3 cm), number of leaves (500.3), number of branches (35.1), plant spread (8374.26 cm²), leaf area (5417 cm²) per plant, yield of fresh whole herbage (38.56 t ha⁻¹) in makoi (Raju *et al.*, 2010).

Amir *et al.* (2015) indicated that application of 10 tons of cow manure and integration with *Azospirillum* and *Pseudomonas* bacteria leads to increase in height (52.33cm), flower number (13.40), number of leaves (35.60), the size of the canopy (56.20 cm) and leaf dry weight (53.83g) in *Echinacea purpurea*.

2.4.2 Effect of biofertilizers on growth and yield of aromatic crops

In *Cymbopogon Citratus*, maximum content of essential oil (35.62%) was recorded by using 150 kg N/fed + 1 kg Microbein/fed led to significant increment in yield of essential oil according to El-Gendy *et al.*, 2015. Similarly, Ratti *et al.* (2001) investigated the effect of some strains of arbuscular mycorrhizal fungi (AMF) *e.g.* *Glomus mosseae* and *G. fasciculatum* on the yield of *Cymbopogon martini* and concluded that, the biomass yield increased by 3-10% compared to the control condition.

Kumar *et al.* (2009) observed that application of nitrogen and phosphorus at the rate of 93.75 kg/ ha along with *Azospirillum* gave the highest plant height, number of laterals, fresh and dry weight of shoot, dry matter production, fresh herbage yield and essential oil yield in davana.

Hammam *et al.* (2014) indicated that application of compost (2 ton/fed) + Chicken manure (2 ton/fed.) + 100kg feldspar + 100 kg rock phosphate mixed inoculation with *Bacillus megatherium* and *B. circulanse* were resulted in highest values of plant height, root length, number of tillers, fresh and dry weights of roots and shoot in *Vetiveria zizanioides*

In sweet flag, the plant height (95.05 cm), number of rhizomes per plant (16 rhizomes/plant), rhizome length (45cm) and rhizome wet and dry weight per plant (75.011 and 37.893 g/plant) respectively, were improved by plant growth promoting rhizobacteria (PGPR) like *Azotobacter*, *Bacillus*, *Pseudomonas* and *Enterobacter* with concentration of 10⁹ CFU/ml (Prakash and Karthikeyan, 2015).

A study was conducted by Abdulhalim (2009) to evaluate the effect of enhancing biofertilizer with N-fixer bacteria on patchouli plant. The results showed improvement of leaves and branch growth up to 8% and 5%, respectively compared to original biofertilizer.

Application of nitrogen fixing biofertilizers increased the number of seeds per plant and seed yield nearly 32 and 32.5% more than control in dill (Fateme *et al.*, 2013).

2.4.3 Effect of biofertilizers on growth and yield of *Ocimum basilicum*

Inoculation of nitrogen fixing bacteria (*Azotobacter*+*Azospirillum*) by dipping the seeds in the cells suspension of 108 CFU/ml for 15 min, resulted in maximum increase of leaf yield (2533.38 kg/ha), stem yield (2908.25 kg/ha) and essential oil content (0.33%) in basil plant (Maryam, 2014).

Shoae (2013) recorded that inoculation the seed of basil with PGPRs such as *Pseudomonas putida* (1×10^9 CFU g⁻¹) and *Azospirillum lipoferum* (2×10^{17}) resulted in increase of shoot wet weight (34.9%), shoot dry weight (44.7%), essence yield (47.32%), plant height (15.85%), leaf area (22.04%), chlorophyll a (63.23%), chlorophyll b (61.86%) and chlorophyll a+b (62.96%) relative to control.

Paramanik and Chikkaswamy (2014) studied the effect of Biofertilizers (*Azospirillum*, *Trichoderma*, *Azotobacter*, PSB, *Rhizobium*) on growth of basil. Maximum values of plant height (25 cm), number of branches (5 branches/plant), stem girth (0.6 cm) were recorded with *Azotobacter* application (100 g for each pot). Similarly, Samane (2014) indicated that Inoculated seeds with Nitrajin (include *Azotobacter*, *Azospirillum* and *Pseudomonase*) in the time of implanting increased significantly concentration of chlorophyll a (2.929 mg/g.f.w.t), chlorophyll b (1.788 mg/g.f.w.t), leaf area (233.5 cm²) and nitrogen density (4.84%) comparing with chemical fertilizer.

Vahid *et al.* (2013) studied the effect of biofertilizers (*Mycorrhiza*, *Azotobacter* and *Azospirillum*), and foliar spray of citric acid on vegetative traits of basil. Results showed that the three-fold interaction of citric acid × *Azotobacter* × *mycorrhiza* had highest root fresh weight (5156.87 kg ha⁻¹) Whereas, the highest root dry weight was observed in combination of inoculated with *Azotobacter* and *Azospirillum* (3290.81 kg ha⁻¹)

Amiri *et al.* (2013) studied the effect of biofertilizers and no cover crop cultivation on basil. The results indicated that use of the biofertilizers especially nitroxin and biophosphorous in no cover crop condition enhanced the most characteristics of basil fresh and dry total shoot yield, dry leaves and LAI.

Shirzadii *et al.* (2014) observed that the triple use of *Mycorrhiza*, *Azotobacter* and vermicompost increased plant height, number of leaves per plant, number of inflorescences per plant, stem diameter and fresh and dry matter, compared to control treatment.

Sandip (2015) reported that application of biofertilizer *Bacillus thuringiensis* and *Bacillus megaterium* resulted in high catalase and peroxidase activity in leaves, increased seed germination rate, sugar and phosphate content in leaves as well as dry weight.

Mostafa *et al.* (2011) observed that inoculation with combination of three bacterial (*Pseudomonades sp.*, *Bacillus lentus*, *Azospirillum brasilens*) increased soluble carbohydrates (2.5μ mol glucose g⁻¹ FW), chlorophyll (12 SPAD) and K content(250 mg. DW) in basil under water stress.

2.4.4 Effect of bio-fertilizers on growth and yield of related crop

Fateme (2014) studied the effect of different types of fertilizers on growth, characteristics of *Thymus vulgaris*. The results indicated that application of nitroxin as liquid

culture from each strain at the rate of 5ml/Liter along with compost (25t/ha) recorded highest fresh weight (605g), dry weight (130g) and number of inflorescences (26) followed by the plants treated by NPK chemical fertilizers (100:50:50 kg/ha) that recorded (535g, 116g and 19g) respectively.

A pot experiment was conducted by Nagappa and Thirumala (2014) in *Coleus* to optimize nutrient requirement through organic sources for optimum plant and root growth. Application of bio-fertilizer as (*Azotobacter chroococcum* (5g) + *Bacillus megaterium* (5g) (phosphorus solubilizing bacteria) + *Glomus mosseae* (5g) (Arbuscular mycorrhiza fungi) in 1:1:1 to each pot) along with 100% of rec. N through FYM recorded the highest number of leaves (41), number of branches (8), root weight (31.34g) and total biomass (290.85g).

Abd El- Wahab (2013) studied the effect of biofertilizer and chemical fertilizers on *Origanum syriacum*. Plants received 3/4NPK dose (200:100:50 kg/fed) along with biofertilizer as mixture of 5 strains of bacteria namely (*Azotobacter chroococcum*, *Azospirillum lipoferum*, *Bacillus polymixa*, *Bacillus megatherium* and *pseudomonas fluorescence*) at (1×10^8 / c.f.) gave higher values of vegetative characters as plant height (32 cm), number of branches (21) and fresh weight of herb (80.20g).

Application of combination of FYM at 30 m^3 /fed. + phosphorein (4kg/fed) and humic acid (6l/fed) in *Mentha piperita* plants recorded maximum plant height (93.3cm), number of branches (23.80), herb fresh weight (806.8g) and dry herb weight (88.66g) comparing to control according to Sharaf el-din *et al.* (2013).

Nadjafi *et al.* (2014) conducted an experiment to study the effect of bio-fertilizers on growth and yield of sage (*Salvia officinalis*). Application of nitroxin at 50 ml /liter water recorded maximum plant height (33.08cm), fresh weight (70.43 g) and dry weight (1714.4g) compared to control.

Hadis *et al.* (2014) studied the effect of chemical and biological fertilizers on growth and essential oil content of lavender (*Lavandula angustifolia*). Mean comparison showed that flower yield was the highest (3932.5 kg/ha) in application of P at 150 kg/ha along with the triple inoculation of *G. mosseae* + *G. intraradices* + *P. fluorescens*. The highest flower essential oil yield (114.27 kg/ha) was achieved in application of P (150 kg/ha) along with the double inoculation *mycorrhiza* fungi.

2.4.5 Effect of biofertilizers on quality of medicinal and aromatic crops

Karthikeyan *et al.* (2010) observed that the combinations of PGPR strains such as *Azotobacter*, *Bacillus* and *Pseudomonas* significantly increased alkaloid content in *Catharanthus roseus*.

In *Plumbago zeylanica*, the bioactive component (plumbagin) was high with application of *Azospirillum* (0.026% w/w) according to Hetal *et al.*, 2016.

Addition of bio-fertilizer such as *Azotobacter* (as seed inoculants) and AM fungi (2 g per plant at the depth of 2–3 cm in soil) showed higher pigment concentration, while Malondialdehyde (MDA) content as an index of lipid peroxidation increased in *Plantago ovate* (Haneef *et al.*, 2014).

According to Mohammad *et al.* (2012) application of biological fertilizers such as Nitroxin [include bacteria which stimulate growth (*Azotobacter* and *Azospirillum*)], Bio-phosphorus [include

bacteria which stimulate growth (*Bacillus* and *Pseudomonas*) lead to increase in active ingredient artemisinin and chlorophyll concentration in *Artemisia annua*.

In Kalmegh, Hemalatha and Suresh (2012) observed that maximum alkaloid content (0.73%) was recorded in the combination of 15 t FYM /ha along with 45:25:25 kg NPK/ha and 1 kg Azospirillum/ ha.

A study conducted by Rajasekar and Elango (2012) showed that the combinations of PGPR strains like *Azospirillum*, *Azotobacter*, *Pseudomonas* and *Bacillus* significantly increased plant height, root length, and alkaloid content in *Withania somnifera*.

Janahiraman *et al.* (2013) revealed that inoculation of Azophos (2 kg/ ha), AM (2 kg/ ha) along with FYM (10 t/ha) and 40:60:50 NPK kg / ha significantly improved the chlorophyll content of leaves as well as forskohlin content of the tubers of coleus.

In lemon balm, Harshavardhan *et al.* (2007) observed that application of 9 t/ha of enriched farmyard manure with *Azotobacter* and Phosphobacteria recorded higher percentage of neral (28.23%), geranial (39.86%) and geranyl acetate (8.67%) in the oil.

Dehghani *et al.* (2014) indicated that application of biosulfur recorded the highest dry weight of capitulum and content of essential oil in *Matricaria recutita*.

In *Lallemantia iberica*, EL- Sherbeny *et al.* (2015) recorded that application of combined fertilizer of compost at 7.5 ton along with 90 kg N / Fed and rhizobacterin increased the total carbohydrates and mucilage and essential oil percentage, and the two main compounds germacrene and caryophyllene of essential oil.

Makkizadeh *et al.* (2011) observed that combinations of biofertilizer and 50% chemical fertilizer recorded the highest harvest index, essential oil content, and carvone percentage in dill plant.

According to Hadipour (2014) application of Nitroxin had a significant effect on yield of essential oil and main constituents, Muurolol (epi-alpha) and alpha-Cadinol (%) in *Calendula officinalis*.

2.4.6 Effect of biofertilizers on quality of *Ocimum basilicum*

Nazanin *et al.* (2014) conducted an experiment with four treatments viz., *Azotobacter chroococcum* (A) *Azospirillum lipoferum* (B) *Bacillus circulans* (C). The maximum geranial and the minimum caryophyllene in essential oil were obtained by using two biofertilizers (A + C). The highest methyl chavicol was obtained after applying two biofertilizers (B + C).

Shatta (2009) showed that the growth of basil plants and their active constituents were positively influenced by seedling inoculation with the symbiotic N₂-fixers with organic fertilizer. Similarly, Hanan *et al.* (2010) indicated that application of 50% compost and 50% sand in the presence of biofertilizer resulted in enhancement of fresh and dry weights, total phenolics, total flavonoids and pigment content as compared with compost alone.

El-Naggar *et al.* (2015) reported that application of cattle manure at 142 m³/ha combined with 2.0 and/or 4.0 g/l of biofertilizer resulted in significant increases in the main chemical components of leaves essential oil (estragole, eucalyptol, linalool, and trans-4-methoxycinnamaldehyde).

Sanjeet *et al.* (2016) indicated that the major constituent of essential oil (methyl chavicol) was significantly improved with application of (vermicompost with *Bacillus* sp.), (vermicompost with *P. monteilii*), and (vermicompost with *G. intraradices*) when compared to control.

Rashmi *et al.* (2008) studied the effects of inoculation of biofertilizers viz., *Glomus fasciculatum*, *Azotobacter chroococcum* and *Aspergillus awamori* singly or in combination on growth, biomass and biochemical constituents of *Ocimum gratissimum*. Inoculated plants showed increased plant height, number of leaves, number of branches, biomass, major and micronutrients, essential oil content and total phenol content.

Hanaa *et al.* (2016) reported that the highest percentages of Linalool, Camphor and Anethol were recorded in essential oil extracted from plants treated with combination of microorganisms encapsulated with sodium alginate, while the highest percentages of cineol resulted under the effect of combination of microorganisms carried on free suspension compared to control.

2.4.7 Effect of bio-fertilizers on quality of related crop

Gharib *et al.* (2008) conducted an experiment to determine the effect of compost and bio-fertilizers on oil constituents of marjoram (*Majorana hortensis*). The highest level of cis-sabinene hydrate (18.47%) and terpinene-4-ol (24.24%) was obtained with aqueous extracts of compost at 30% + *B. circulans* and aqueous extracts of compost at 30% + (*A. brasiliense* + *A. chroococcum* + *B. polymyxa*).

Eisa (2004) reported that microbein and nitroben bio-fertilizers increased the essential oil content per plant and oil yield /ha in *Salvia officinalis*. Mafakheri *et al.* (2016) indicated that application of vermicompost at 30 % pot volume along with biological phosphate fertilizer (containing two strains of bacteria *Pantoea agglomerans* P5 and *Pseudomonas putida* P13) recorded the maximum citronellal content (47.8 %) and geraniol contents (18.902 %) in the essential oil of *Melissa officinalis*.

Application of 75% NP(100:50 kg/ha) + 100% K (50kg/ha) + Azotobacter + Azospirillum + VAM in patchouli recorded significantly superior values for oil yield (1.231 g/g) which is 155% increase compared to control according to Manjunathatha (2002).

Rajamanickam (2011) recorded that application of 75% of recommended dose of NPK (200:50:40 kg/ha) along with vermicompost (5t/ha) and clostridium of bio-fertilizer had given (0.28%) of essential oil content. While, application of full recommended dose of NPK recorded (0.25%) in *Mentha arvensis*.

Ismail *et al.* (2009) indicated that combination between sheep manure (10 t/ha) along with *B. polymyxa* (10^8 c.f.u. /ml) resulted in highest oil yield (27.6 l/ha) and linalool per cent (7.22 %) compared to control (1.5 l/ha and 4.77%) in marjoram plant.

2.4.8 Effect of bio- fertilizers on nutrient uptake in medicinal and aromatic crops

Kaushal *et al.* (2013) showed that the highest uptakes of nutrients such as nitrogen (95.92 kg/ha), phosphorus (31.60 kg/ha) and potassium (100.92 kg/ha) at harvest were recorded with Jatropa cake at 3t/ha along with 50% RDF (20:30:10 kg/ha) and biofertilizer (*Phosphate solubilizing bacteria*, *Azospirillum*) at 2 kg/ha in ashwagandha.

Kalmegh plants inoculated with microbial consortia showed maximum increase in nitrogen, phosphorus and potassium percentage in the shoot (70, 33, 8%) respectively over uninoculated control (Hemlata *et al.*, 2015).

Das *et al.* (2008) studied the response of Stevia plant to bio-fertilizers application. The results showed the amount of available nitrogen (N), phosphorus (P) and potassium (K) contents in soil have been found to increase significantly up to third month and thereafter, the amount of the same decreased with the progress of the plant growth up to sixth month irrespective of treatments.

Adding biological fertilizer (*Silicate bacterium*) at the rate 50 g/l with feldspar or rock phosphate recorded the maximum N, P and K contents (2.8 %, 0.30% and 2.9 %) in *Ruta graveolens* leaves (Khalid *et al.*, 2007).

The effects of 10 strains of plant growth-promoting rhizobacteria (PGPR) and 4 arbuscular mycorrhizal fungi (AMF) inoculants were examined in vetiver. The results showed that PGPR x AMF interaction affected nutrient assimilation and increased shoot potassium uptake (Bhromsiri and Bhromsiri, 2010).

In celery, the plants treated with S (300 kg/fed) along with S-solubilizing bacteria showed higher N, P, K and S uptake and content (Khalid *et al.*, 2005).

Lenin and Jayanthi (2012) observed that root inoculation of PGPR strains (*Azospirillum lipoferum*, *Azotobacter chroococcum*, *Pseudomonas fluorescens* and *Bacillus megaterium*) significantly increased nutrient contents (N 2.34, P: 0.34, K: 2.20 %) of *Catharanthus roseus* plants.

Rupam and Mukerji (2005) investigated the effect of two arbuscular mycorrhizal (AM) fungi, *Glomus fasciculatum* and *G. macrocarpum* on nutrient content of *Cassia siamea*. The results indicated that the concentration of P, K, Cu, Zn and Na was significantly higher in AM inoculated seedlings than in non-inoculated seedlings

According to Varsha *et al.* (2016) application of the *Trichoderma* in combination with biofertilizer exhibited in general a considerable improvement in bio nutrient parameters as compared to their respective control in *Kaempferia galanga* and *Costus igneus* plants.

In mint, application of 100% NPK in combination with vermicompost at 5 t /ha and consortium of biofertilizers significantly increased the nutrient uptake, fresh herbage yield and dry matter production (Rajamanickam *et al.*, 2011)

2.5 Economics of cultivation

The economic analysis of plant nutrient sources on sweet basil (*Ocimum basilicum* L.) was evaluated by Thakur (2014). Net monetary returns was maximum with 100 percent recommended dose of fertilizer which fetched net income of Rs. 36,160/ha, the economics of production of tulsi has been worked out using farm-level data from the districts of Barabanki, Sitapur and Raebareilly in Uttar Pradesh. The net returns over total cost have been found to be 40,094 Rs /ha. The benefit-cost ratio however has been observed to be 3.21:1 (Ram *et al.*, 2012).

In davana, higher net income with B: C ratio of 2.53:1 was registered with application of *Azospirillum* and nitrogen at 150 kg/ha (Kumar and Vijayakumar, 1997).

Application of 50:20:40 N,P and K kg/ha along with *Azotobacter*+ *Azospirillum* + VAM gave the highest returns as compared to control in rosemary (Anurada, 2002).

In coleus, Sudhakara *et al.* (2010) obtained the highest net return and benefit cost ratio by the application of FYM 15 t/ha+VC 1.0 t/ha + 10 kg/ha bio-fertilizer. While, Vennila (2014) indicated that the higher net returns (61,252 Rs /ha) was obtained with normal planting of medicinal coleus and with the application of 40:60:50 kg NPK/ha + FYM 10 t/ha or application of poultry manure at 3 t/ha.

Guruprasad *et al.*, (2014) obtained highest net returns of Rs. 23,580 /ha and benefit: cost ratio of 2.27:1 in ashwagandha with application of FYM 5 t/ha + vermicompost at 0.5 t/ha. While, Patil (2014) indicated that application of FYM at 2 t/ha + vermicompost at 0.5 t/ha + NPK (20:30:20 kg /ha) recorded significantly maximum benefit cost ratio (4.83) in ashwagandha.

In a study on palmarosa, application of N and P each at 20 kg/ha with *Azospirillum* at 2 kg/ha and Phosphobacteria at 3 kg/ha was found to be remunerative and most economical (Maheshwari *et al.*, 1998)

Application of FYM at 200 q ha⁻¹ + half dose of (N:P:K::150:120kg/ha) + P-solublizer, *Pseudomonas floescence* and *Trichoderma* as seed treatment and soil application at 20 kg /ha each gave the maximum net profit of Rs.4,26,403/ha and cost: benefit ratio (Rs.4.46) in turmeric (Singh, 2012).

III. MATERIALS AND METHODS

The present investigation entitled “**Effect of organic manure and biofertilizers on growth, herb, nutrient uptake, oil yield and quality of French Basil (*Ocimum basilicum* L.)**” was carried out at ICAR- Indian Institute of Horticultural Research (IIHR), Bengaluru during 2014-2016. The details of materials used and methodology adopted during the course of investigation are given below.

3.1 Geographical location of the experimental site

The field experiments and laboratory studies were conducted at ICAR-Indian Institute of Horticultural Research, Hessaraghatta Lake Post, Bengaluru located at an altitude 890 m above mean sea level and 13^o58” latitude and 78^o East longitudes

3.2 Climate condition of the experimental site

The meteorological data recorded during study period are presented in Appendix I.a and I.b. The mean maximum temperature ranged from 29.42°C (2015) to 30.05°C (2016) while, the minimum temperature ranged from 20.21°C (2015) to 19.93°C (2016). The maximum relative humidity of 59.63 per cent was recorded during 2015 and the annual rainfall was (1113.8 and 559.2 mm) during 2015 and 2016 respectively.

3.3 Soil characteristic

The experimental area comprised of red sandy loamy soils with uniform fertility. The soil pH was in the range of 7.4 – 7.8. In order to know its fertility status a representative soil sample from randomly selected spots was collected from a depth of 0-30 cm. The collected samples were analyzed for pH, electrical conductivity, organic carbon, available nitrogen, phosphorus and potassium and micronutrients and the data furnished in Appendix II. Further, after the final harvest, also soil samples were collected and analyzed for available nitrogen, phosphorus, potassium and micronutrients.

3.4 Experimental details

The experiment was carried out to study the “Effect of organic manure and biofertilizers on growth, herb, nutrient uptake, oil yield and quality of French basil (*Ocimum basilicum* L.)”

3.4.1 Design and layout of the experiment

The experiment was laid out in Randomized Complete Block Design (RBD), with nine treatment combinations replicated three times. The treatments in each block were allotted randomly. The plan of layout is presented in (Fig 1)

Gross plot size	:	4.8 x 4.0 m
Net plot size	:	3.6 x 3.2 m
Spacing	:	0.60 x 0.40 m
Variety	:	<i>Ocimum basilicum</i> : Cim-Saumya (CIMAP)

Treatments Combinations

T₁: FYM (10 t/ha) +100% Recommended N through FYM

- T₂: FYM (10 t/ha) +100% Recommended N through FYM + biofertilizer
T₃: FYM (10 t/ha) +75% Recommended N through FYM
T₄: FYM (10 t/ha) +75% Recommended N through FYM + biofertilizer
T₅: FYM (10 t/ha) +50% Recommended N through FYM
T₆: FYM (10 t/ha) + 50% Recommended N through FYM + biofertilizer
T₇: Recommended FYM (10 t/ha) only
T₈: Recommended NPK (160:80:80 kg /ha) only
T₉: Recommended FYM (10 t/ha) + Recommended NPK (160:80:80 kg /ha)

The nutrients were supplied in the form of straight fertilizers like urea (347.82 kg/ha), Single super phosphate (500 kg/ha) and Muriate of potash (133 kg/ha). For biofertilizers, Arka Microbial Consortium (AMC) was used in the experiment developed by **ICAR-IIHR**, it contains N fixing, P and Zn solubilizing and plant growth promoting microbes in a single carrier. Considering the FYM average content of plant available N as 0.64%, the recommended FYM dose has been fixed at 10 t/ha. Recommended quantity of FYM as well for N source through FYM according to different levels were incorporated to the plots and mixed thoroughly in soil.

3.4.2 Culture operation

The details of cultural practices adopted during the course of investigation are furnished below.

3.4.2.1 Preparation of nursery

Seedlings were raised in nursery beds. The land used for the nursery was dug twice and clods were crushed to bring the soil to a fine tilth. The seeds were sown in two nursery beds of 6.0 m in length with 1.0 m in width and 10 cm height were prepared for sowing the seeds.

3.4.2.2 Land preparation

The land was brought to a fine tilth by ploughing and harrowing. The experimental site was divided into plots having dimensions of 4.8 m × 4.0 m with 0.50 m ridges between the plots, as shown in (Fig.2). Irrigation channels of 0.5 m size were provided between two rows of plots. Drip irrigation was followed in which 16 mm (dia) drip pipes were laid out having drippers 30 cm apart.

3.4.2.3 Planting

Forty days old (40) healthy and uniformly rooted seedlings of sweet basil were transplanted at a spacing of 60 cm between the rows and 40 cm between the plants. Gap filling was taken up whenever necessary till all plants established.

3.4.2.4 Bio-fertilizer application

After 15 days of transplanting, recommended dose of AMC @ 5 kg/ha was applied at 2 cm deep to individual plants and immediately covered by soil. Similar method of application was followed for ratoon crop after harvest of main crop .

3.4.2.5 Fertilizer application

The recommended quantity of 160 kg nitrogen, 80 kg phosphorus and 80 kg potassium per hectare was applied in the form of urea, single super phosphate and muriate of potash. Fifty per cent of nitrogen and full dose of phosphate and potash were applied as basal dose and the remaining fifty per cent of N was applied after 45 days of transplanting in T₈ and T₉ treatments.

3.4.2.6 Aftercare

3.4.2.6.1 Weeding

The plants were kept weed free throughout the growing period by weeding at regular intervals. First weeding was done after 20 days of transplanting and later as and when required. Totally six weedings were done during the entire period of crop growth and harvest.

3.4.2.6.2 Irrigation

Immediately after transplanting, the field was irrigated and later drip irrigations were given daily for half an hour in the earlier stages and subsequently irrigation was given depending on the soil moisture condition.

3.4.2.6.3 Inter culture

After first harvest, earthing up was taken to provide good anchorage to the plants.

3.4.2.6.4 Plant protection

There was no serious pest or disease incidence observed throughout the experiment. However, as preventive measure, neem soap was sprayed to the crop

3.4.2.7 Harvesting

The crop was harvested at full bloom stage before setting the seed. The plants were cut to 10-15 cm above the ground level to ensure good regeneration capacity using secateurs to avoid any physical damage to the plants.

3.4.3 Distillation of essential oil

One hundred gram of harvested fresh herbage and flower top from each plots of the experiment were distilled in the steam distillation unit. The duration of the each distillation was 3 hours.

3.4.4 Observations recorded

Five plants were randomly selected in each plot and labeled according to different treatments for recording the growth and yield parameters. Growth parameters were recorded at 30 and 60 days after planting and at harvest time. While, second set of observation for the ratoon was recorded at 30 days after planting and at harvest time.

3.4.4.1 Growth parameter

3.4.4.1.1 Plant height (cm)

Height of five labeled plants was measured from the base of the plant at ground level to the tip of the main stem. The average was worked out and the values were expressed in centimeters (cm).

3.4.4.1.2 Number of branches

The numbers of branches per plant were recorded in respect of five labeled plants were counted and the average was calculated.

3.4.4.1.3 Number of leaves

The numbers of leaves per plant were recorded in respect of five labeled plants were counted and the average was calculated.

3.4.4.1.4 Time taken for first flowering

Time taken for producing first flowering after transplanting in main field was recorded and expressed as number of days.

3.4.4.1.5 Time taken for 50% flowering

Time taken for producing 50% flowering after transplanting in main field was recorded and expressed as number of days.

3.4.4.1.6 Leaf area (cm²)

Twenty leaves picked randomly from five labeled plants, and their leaf area were measured by Leaf Area Meter: Windias 3 (WD-UM-3.2.1), the average were calculated and expressed as leaf area (cm²).

3.4.4.2 Yield parameters

Yield parameters were recorded as and when the herbage and inflorescence were harvested.

3.4.4.2.1 Fresh weight of leaves per plant

The labeled five plants were harvested, and then the leaves were separated from the herb, weighed and expressed in grams (g).

3.4.4.2.2 Fresh weight of stems per plant

The labeled five plants were harvested, and then the stems were separated from the herb, weighed and expressed in grams (g).

3.4.4.2.3 Fresh weight of inflorescence per plant

The labeled five plants were harvested, and then the inflorescences were separated from the herb, weighed and expressed in grams (g).

3.4.4.2.4 Fresh weight of the herb per plant

Fresh herb from all the five sampled plants were taken and weighed. The mean weight was calculated and expressed in grams as fresh weight of herb per plant.

3.4.4.2.5 Fresh weight of the herbage per plot

At the time of harvest the whole plot was harvested and the herbage weighed and expressed in terms of kilograms (kg) per plot.

3.4.4.2.6 Fresh weight of the herb per hectare

Fresh herbage from plot was weighed and converted to per hectare on area basis and expressed in tonnes (t).

3.4.4.2.7 Dry weight of leaves per plant

The harvested leaves of the labeled five plants were dried in the shade for 15 days and the dry weight was recorded and expressed in gram (g).

3.4.4.2.8 Dry weight of stems per plant

The harvested stems of the labeled five plants was dried in the shade for 15 days and the dry weight was recorded and expressed in gram (g).

3.4.4.2.9 Dry weight of inflorescence per plant

The harvested fresh inflorescence of the labeled five plants was dried in the shade for 15 days and the dry weight was recorded and expressed in gram (g).

3.4.4.2.10 Dry weight of the herbage per plot

The dry weight of stem, leaves and inflorescence was collected and expressed in terms of kilograms (kg) per plot.

3.4.4.2.11 Dry weight of the herb per hectare

Dry weight from plot was converted to per hectare on area basis. The dry weight of the herb was expressed in tonnes (t).

3.4.4.2.12 Essential oil content

The essential oil was estimated using Clevenger's Apparatus. Hundred grams of the fresh herb was taken to estimate the essential oil content according to different treatments and expressed in per cent (%). The distillation time was standardized to three hours.

3.4.4.2.13 Essential oil yield (l/ha)

Oil volume was recorded and oil yield was calculated as the volume (liter) of oil per weight (t) of fresh basil herbage yield.

3.4.4.3 Quality parameter

3.4.4.3.1 Gas Chromatographic analysis of the essential oil composition

The oil samples were filtered through Sodium Sulphate to remove the traces of moisture and their pH was checked before performing the test. Only a very little amount (1-2 ml) of the oil was injected into injector port of the GC using a microsyringe. The details of the equipment and the conditions are described below.

1. GC Model : Varian 3800 series
 2. Colum : VH-5for GC and VH-5 MS for GCMS
30 m x 0.2 mm with 0.2 mm film thickness
- Fused silica column
3. Carrier gas : He
 - Flow rate : 1 ml/min
 4. Detector : FID (Flame ionization detector) and MS
 5. Temperature parameters (For GC)
 - Column temperature programmed : 60°C for 5 min then 210 °C hold for 1 min then 240 °C hold it for 1 min
 - Injector temperature : 270 °C

Finally, the major components of essential oil were identified by comparing peak retentions times with those authentic standards obtained from Sigma, Aldrich, Bengaluru and run under identical conditions, then it were estimated in respect to total components and expressed as area percentage.

3.4.5 Analysis of soil proprieties

Soil samples were collected from the experimental plots at a depth (0-50 cm) before and after the experiment, was analyzed for important physical and chemical proprieties of the soil.

3.4.5.1 Physical proprieties

3.4.5.1.1 Bulk density

Bulk density of each treatment was determined by core sampler method as described by Black (1965).

3.4.5.1.2 Porosity

Porosity was determined by following the equation (1):

$$\text{Porosity (\%)} = (\text{total volume} - \text{volume of the solid}) / \text{total volume}) \times 100\%$$

3.4.5.1.3 Particle density

The weight of an individual soil particle per unit volume was determined by following the equation (2):

$$\text{Particle density} = \text{soil weight} / (\text{soil volume} - \text{pore volume})$$

3.4.5.2 Chemical proprieties

3.4.5.2.1 Soil pH

Soil pH was determined in 1: 2.5 soil : water suspension by glass electrode using digital pH meter (Piper, 1966).

3.4.5.2.2 Electrical conductivity (d Sm⁻¹)

The soil and water suspension used for measuring pH was filtered and the electrical conductivity of the solution was measured with the help of the electrical, Conductivity Bridge and expressed in d Sm⁻¹ (Jackson, 1973).

3.4.5.2.3 Organic carbon (%)

The organic carbon was estimated by Walkey and Black wet oxidation method as described by Jackson, 1973.

3.4.5.2.4 Available nitrogen (kg/ha)

The available nitrogen content was determined using alkaline potassium permanganate method (Subbaiah and Asija, 1956) by digestion, distillation and collection of NH₃ in 2% boric acid, then titrating it against standard sulphuric acid.

3.4.5.2.5 Available phosphorus (kg/ha)

Available phosphorus in soil was extracted with the help of Brays No.1 extract (0.03 N ammonium fluoride + 0.025 N HCl), Further, phosphorus in the filtered extract was determined by chlorostannus reduced molybdophosphoric blue colour method (Jackson, 1973). The intensity of blue colour was read on UV Spectrophotometer at 660 nm wave length.

3.4.5.2.6 Available potassium (kg/ha)

The available potassium in the soil was estimated by flame photometer method after extracting with neutral 1 N ammonium acetate solution as suggested by Jackson (1973).

3.4.5.2.7 Available micronutrient

Micronutrient content were estimated in DTPA (Diethylene Triamine Penta Acetic Acid) extract using atomic absorption spectrophotometer as mentioned by (Lindsay and Norvell 1978).

3.4.5.3 Microbial population of the soil (biological proprieties)

Microbial population of the soil under different treatments is determined by standard plate count technique. Total bacterial count in soil was determined by serial dilution method. Initial soil

samples were collected prior to the start of the experiment and after harvest, soil samples were taken from the surface layer (0–15 cm) according to different treatments with three replications. Exactly 5 g of soil sample was taken into 50 ml of sterile distilled water and shaken for 15 minutes. A series of 9 fold dilutions were prepared and 0.1 ml of each dilution was spread on media plates. To enumerate fungal, azotobacter, phosphate solubilising bacteria and actinomycetes population potato dextrose agar (PDA), Jensen's media, Pikovskaya Aga and kenknight media were used, respectively. After 3-5 days of incubation microbial population was counted following the spread plate technique and expressed as CFU $\times 10^3$ /g of oven dry soil.

3.4.6 Plant analysis

Dried plant samples were ground to a fine powder and analyzed for N, P, K content and micronutrient.

3.4.6.1 Total nitrogen

The total nitrogen (%) was determined by Micro- kjeldhal method as outlined by Piper (1966). A plant sample (0.5 g) was digested using 10 ml concentrated sulphuric acid in presence of digestion mixture (CuSO_4 , K_2SO_4 and Se in 100:20:1 ratio) in a digestion chamber .The digested mixture was then distilled in an alkaline medium and ammonia released was trapped in 4 per cent boric acid with mixed indicator. This was titrated against standard sulphuric acid.

3.4.6.2 Total phosphorus

A plant sample (0.5 g) was digested using diacid mixture ($\text{HNO}_3 + \text{HClO}_4$ in 10: 4 ratio) and volume made upto 50 ml. A known aliquot was taken for estimating the total phosphorus content (%) using vandomolybdate yellow colour method (Piper, 1966)

3.4.6.3 Total potassium

The total potassium content in the plant sample (%) was determined by feeding the diacid digested extract to a flame photometer as mentioned by Piper (1966).

3.4.6.4 Micronutrients

Micronutrients were determined with the help of Atomic absorption spectrophotometer (AAS) as outlined by Lindsay and Norvell (1978).

3.4.6.5 Plant nutrient uptake

3.4.6.5.1 Macro nutrient uptake

Plant uptake of macro nutrient was calculated by following the equation (3):

$$\text{Macro nutrient (kg/ha)} = \frac{\text{Dry matter yield (kg/ha)} \times \text{nutrient content (\%)}}{100}$$

3.4.6.5.2 Micro nutrient uptake

Plant uptake of micro nutrient was calculated by following the equation (4):

$$\text{Micro nutrient uptake (kg/ha)} = \frac{\text{Dry matter yield (kg/ha)} \times \text{nutrient content (ppm)}}{10^6}$$

3.4.7 Nitrogen balance:

Nitrogen balance is the actual nitrogen gain/losses in soil (kg/ha), which was determined by two steps:

In the first step, the expected balance (**D**) is computed by following the equation (**4**):

D=B-C where:

D: the expected nitrogen balance;

B: the initial nitrogen soil content (**A**) + the added nitrogen through fertilizer and

C: nitrogen uptake by plant;

In the second step, the apparent gain/losses (**F**) is computed by following the equation (**5**):

F=E-D where:

E: actual soil fertility after harvest;

D: expected balance.

There after the actual nitrogen gain/losses in soil (**G**) is computed by following the equation (**6**):

G=E-A

3.4.8. Economics of cultivation

3.4.8.1 Total costs

The prices of the inputs and labor cost that prevailed at the time of their use were taken into consideration while working out the total cost of cultivation and expressed as rupees per hectare (APPENDIX –III a and III b).

3.4.8.2 Gross income

Gross income was calculated based on the prevailing market price of the product, in this study, oil was considered the most important product.

3.4.8.3 Net income

The net income per hectare was calculated on the basis of gross income and total costs per hectare as follows.

$$\text{Net income} = \text{Gross income} - \text{Total costs}$$

Benefit cost ratio: The benefit cost ratio was worked out by following the equation (7):

$$\text{Benefit : Cost ratio} = \frac{\text{Gross income (Rs/ha)}}{\text{Total costs (Rs/ha)}}$$

3.5 Statistical Analysis

The experimental data recorded on various biometric parameters collected during the study were subjected to statistical analysis by Fisher's method of analysis of variance (ANOVA) as outlined by Sundararaj *et al.* (1972). Wherever the "F" test was significant for comparison of treatment means, LSD values were worked out at 0.05 probability level.

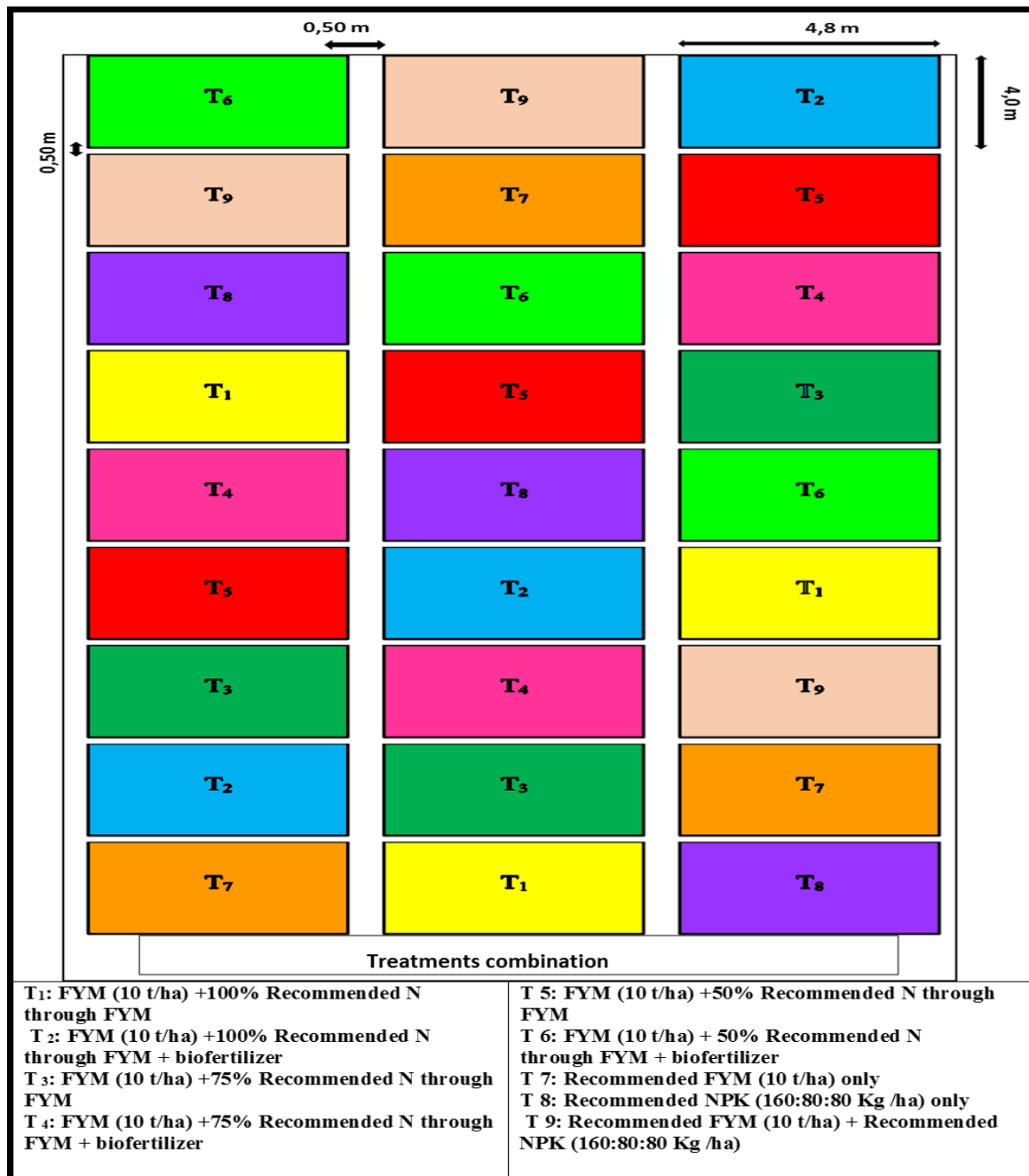


Fig. 1: Layout of experimental plot



Fig. 2: Preparation of Experimental land

IV. RESULTS

The present study on “Effect of organic manure and biofertilizers on growth, herb, nutrient uptake, oil yield and quality of French basil” was undertaken to find out the effect of different levels of N through FYM (100, 75 and 50% of the recommended N along with and without bio-fertilizers), recommended dose of NPK (160:80:80 kg/ha) and recommended FYM (10 t/ha) + NPK (160:80:80 kg/ha) on the growth, yield, essential oil quality and nutrient content in the soil and plant of *Ocimum basilicum*. Field experiments were carried out at ICAR - Indian Institute of Horticultural Research, Bengaluru during kharif season of 2015 and 2016, respectively. Nine treatments with three replications were adopted in a randomized block design to identify the best treatment that leads to improve the plant growth, oil quality and soil nutrients.

4.1 Experiment: Effect of organic manure and biofertilizers on growth, herb and oil yield, nutrient uptake and oil quality of French basil

4.1.1 Growth parameters

Data pertaining to growth parameters *vis.*, plant height, number of branches per plant, number of leaves per plant and leaf area as influenced by different levels of N through organic manures along with and without bio-fertilizers and inorganic fertilizer in basil are presented in Tables 1. to Table 4.

4.1.1.1 Plant height

Data on plant height of the main crop and ratoon during I and II year as influenced by different levels of N through organic manure along with and without bio-fertilizers and inorganic fertilization in basil are presented in Tables 1a. to 1c.

4.1.1.1.a Plant height at 30 days after planting (DAP)

Plant height at 30 (DAP) of the main crop and ratoon during I and II year differed significantly. For the main crop application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) in T₉ recorded significantly maximum plant height (53.53, 55.27 and 54.40 cm) during kharif 2015, 2016 and in the pooled data respectively, and was found to be *on par* with treatment T₈ (52.07, 54.60 and 53.33 cm) respectively. While, the results were non-significant between different levels of N through FYM during the first year. However, no definite trend could be observed due to application of bio-fertilizer, unlike during the first season, the plant height in second year differed significantly by application of different levels of N through organic manures and biofertilizers and higher level of FYM in (T₁) resulted in higher plant (48.67 cm) compared to lower level in T₇ (41.80 cm). The perusal of data in second year indicated that application of biofertilizer along with organic manure improved the plant height comparing with FYM alone.

At second harvest (ratoon) plant height differed significantly between treatments, plants applied with NPK (160:80:80 kg/ha) + FYM (10 t/ha) *i.e.*, T₉ recorded significantly maximum plant height (55.9, 54.20 and 55.05 cm) during kharif 2015, 2016 and in the pooled data respectively, and was found to be *on par* with treatment T₈ (54.60, 51.87 and 53.23 cm) respectively. The data indicates in general, higher level of N through organic manure resulted in taller plants compared to lower level in the first and second year, maximum plant height recorded in T₁ (49.17 and 51.80 cm) while the lowest height was recorded in T₇ (40.40 and 46.07 cm) respectively. Application of bio-fertilizer along with FYM enhanced the plant height and maximum plant height was recorded in T₂ (50.13, 52.53 and 51.33 cm) during kharif 2015, 2016 and in the pooled data respectively.

4.1.1.1. b Plant height at 60 days after planting (DAP)

There was significant difference in plant height between treatments at 60 days after planting (DAP), maximum plant height of 74.40, 83.13 and 78.77 cm was recorded in T₉ *i.e.*, NPK (160:80:80 kg/ha) + FYM (10 t/ha) during kharif 2015, 2016 and in pooled data respectively, and it was found to be *on par* with treatment T₈ (72.93, 80.27 and 76.60 cm) respectively. However, there was a considerable variation observed in plant height at different levels of N through FYM in the first and second year. The treatment (T₁) FYM (10 t/ha) +100% Rec. N through FYM recorded maximum plant height (69.60, 74.47 and 72.03 cm) while the treatment T₇ recorded minimum plant height (59.13, 66.73 and 62.93cm) during kharif 2015, 2016 and in pooled data respectively, the data confirmed that there was no significant variation between the treatments that manured with biofertilizers. Among these T₂, *i.e.*, FYM (10 t/ha) +100% Rec. N through FYM + BF recorded the higher values in two years (72 , 76.80 and 74.40 cm) during kharif 2015, 2016 and in the pooled data respectively.

4.1.1.1. c Plant height at harvest

The data on plant height at harvest revealed that the effect different levels of N through FYM along with and without bio-fertilizers and inorganic fertilization at time of harvest in the main crop and ratoon during I and II year was significant. Applications of 100% NPK in combination with FYM (10 t/ha) *i.e.*, T₉ resulted in maximum plant height of the main crop (76.43, 86 and 81.22 cm) during kharif 2015, 2016 and in the pooled data respectively, and it was *at par* with T₈ (75.10, 82.90 and 79 cm). Whereas, the lowest plant height was recorded with application of recommended dose of FYM in T₇ (62.37, 70.13 and 66.25). The treatments that manured with bio-fertilizer did not differ significantly, while the highest value was recorded with application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ (74, 79.73 and 76.87cm) respectively. Following the same trend, application of Rec. NPK along with FYM (10 t/ha) recorded the highest plant in the ratoon at harvest time (61.33, 59.07 and 60.2 cm) during kharif 2015, 2016 and in the pooled data respectively. Whereas, the lowest plant height had been observed with application lowest level of N through FYM *i.e.*, T₇ (48.83, 41.30 and 45.06 cm) respectively. The data is also represented by figures 3.a to 3.c.

4.1.1.2 Number of branches

Number of branches of the main crop and ratoon during two years of the experiment as affected by different levels of N through organic manures along with and without bio-fertilizers and inorganic fertilizer are presented in Tables 2a. to 2c.

Table 1a. Effect of organic manure, bio-fertilizers and inorganic fertilizer on plant height (cm) in basil (*Ocimum basilicum*) at 30 days after planting (DAP)

Treatments		2015		2016		Pooled	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	46.20 ^B	49.17 ^B	48.67 ^{BC}	51.80 ^B	47.43 ^B	50.48 ^D
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	46.47 ^B	50.13 ^{AB}	51.73 ^{AB}	52.53 ^{AB}	49.10 ^B	51.33 ^C
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	45.73 ^B	43.53 ^C	43.60 ^E	49.27 ^{CD}	44.66 ^{BC}	46.40 ^F
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	46.93 ^B	47.73 ^B	47.73 ^{CD}	50.73 ^{BC}	47.33 ^B	49.23 ^E
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	45.53 ^B	41.93 ^{CD}	43.53 ^E	47.53 ^{DE}	44.53 ^{BC}	44.73 ^G
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	45.47 ^B	42.07 ^{CD}	44.27 ^{DE}	48.60 ^{CD}	44.86 ^{BC}	45.34 ^G
T ₇	Rec. FYM (10 t/ha) only	43.00 ^B	40.40 ^D	41.80 ^E	46.07 ^E	42.4 ^C	43.23 ^H
T ₈	Rec.NPK (160:80:80 kg /ha)	52.07 ^A	54.60 ^A	54.60 ^A	51.87 ^{BA}	53.33 ^A	53.23 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	53.53 ^A	55.9 ^A	55.27 ^A	54.20 ^A	54.40 ^A	55.05 ^A
General Mean		46.24	50.71	47.91	47.21	47.56	48.78
CV (%)		6.26	2.44	4.73	5.05	3.96	0.73
LSD at 5%		4.81	2.13	3.92	4.12	3.26	0.86

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio- fertilizer

Table 1b. Effect of organic manure, bio-fertilizers and inorganic fertilizer on plant height (cm) in basil (*Ocimum basilicum*) main crop at 60 days after planting (DAP)

Treatments		2015	2016	Pooled
		Main crop	Main crop	Main crop
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	69.60 ^{ABCD}	74.47 ^{CD}	72.03 ^{BCD}
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	72.00 ^{ABC}	76.80 ^{BC}	74.40 ^{ABC}
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	63.80 ^{CD}	73.07 ^{CD}	68.44 ^{DE}
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	68.00 ^{ABCD}	74.13 ^{CD}	71.07 ^{CD}
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	61.33 ^D	70.00 ^{DE}	65.67 ^{EF}
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	65.40 ^{BCD}	72.47 ^{CD}	68.93 ^{DE}
T ₇	Rec. FYM (10 t/ha) only	59.13 ^D	66.73 ^E	62.93 ^F
T ₈	Rec.NPK (160:80:80 kg /ha)	72.93 ^{AB}	80.27 ^{AB}	76.60 ^{AB}
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	74.40 ^A	83.13 ^A	78.77 ^A
	General Mean	67.84	74.56	70.98
	CV (%)	7.08	3.56	3.19
	LSD at 5%	8.31	4.59	3.92

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio- fertilizer

Table 1c. Effect of organic manure, bio-fertilizers and inorganic fertilizer on plant height (cm) in basil (*Ocimum basilicum*) at harvest

Treatments		2015		2016		Pooled	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	71.48 ^{ABC}	55.03 ^{BC}	77.43 ^C	51.97 ^{CD}	74.46 ^{BCD}	53.5 ^{BC}
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	74.00 ^{ABC}	55.47 ^B	79.73 ^{BC}	54.73 ^{BC}	76.87 ^{ABC}	55.1 ^B
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	68.47 ^{BCD}	51.93 ^{DE}	75.63 ^{CD}	50.53 ^D	72.05 ^{DE}	51.23 ^{DEF}
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	69.83 ^{ABCD}	52.90 ^{CD}	77.07 ^{CD}	46.03 ^E	73.45 ^{CD}	49.46 ^{CDE}
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	63.43 ^D	50.30 ^{EF}	72.67 ^{DE}	44.37 ^{EF}	68.05 ^{EF}	47.33 ^{FG}
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	67.00 ^{CD}	51.43 ^{DE}	75.33 ^{CD}	43.93 ^{EF}	71.17 ^{DE}	47.68 ^{EF}
T ₇	Rec. FYM (10 t/ha) only	62.37 ^D	48.83 ^F	70.13 ^E	41.30 ^F	66.25 ^F	45.06 ^G
T ₈	Rec.NPK (160:80:80 kg /ha)	75.10 ^{AB}	53.70 ^{BCD}	82.90 ^{AB}	58.00 ^{AB}	79.00 ^{AB}	55.85 ^{BCD}
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	76.43 ^A	61.33 ^A	86.00 ^A	59.07 ^A	81.22 ^A	60.20 ^A
General Mean		69.79	53.44	77.43	49.99	73.61	51.71
CV (%)		6.26	2.63	3.41	4.77	3.59	2.54
LSD at 5%		7.56	2.43	4.57	4.12	4.57	2.40

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

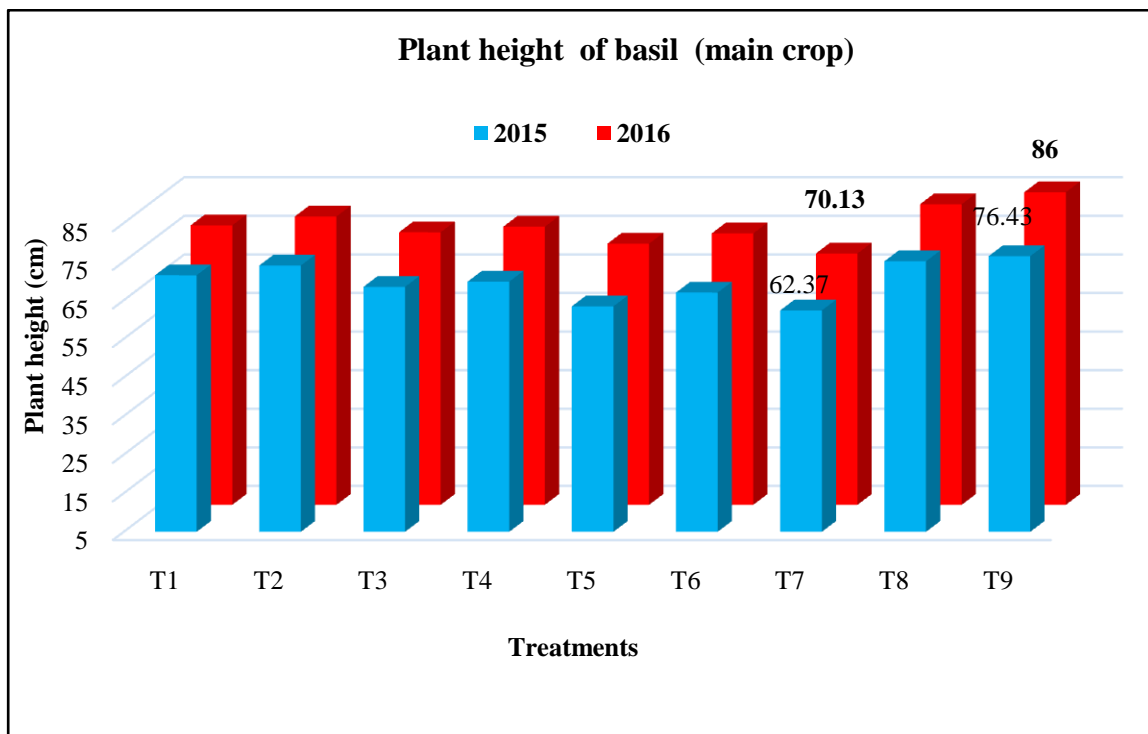


Fig. 3a: Effect of organic manure, bio-fertilizers and inorganic fertilizer on plant height at harvest (cm) in basil (*Ocimum basilicum*) main crop

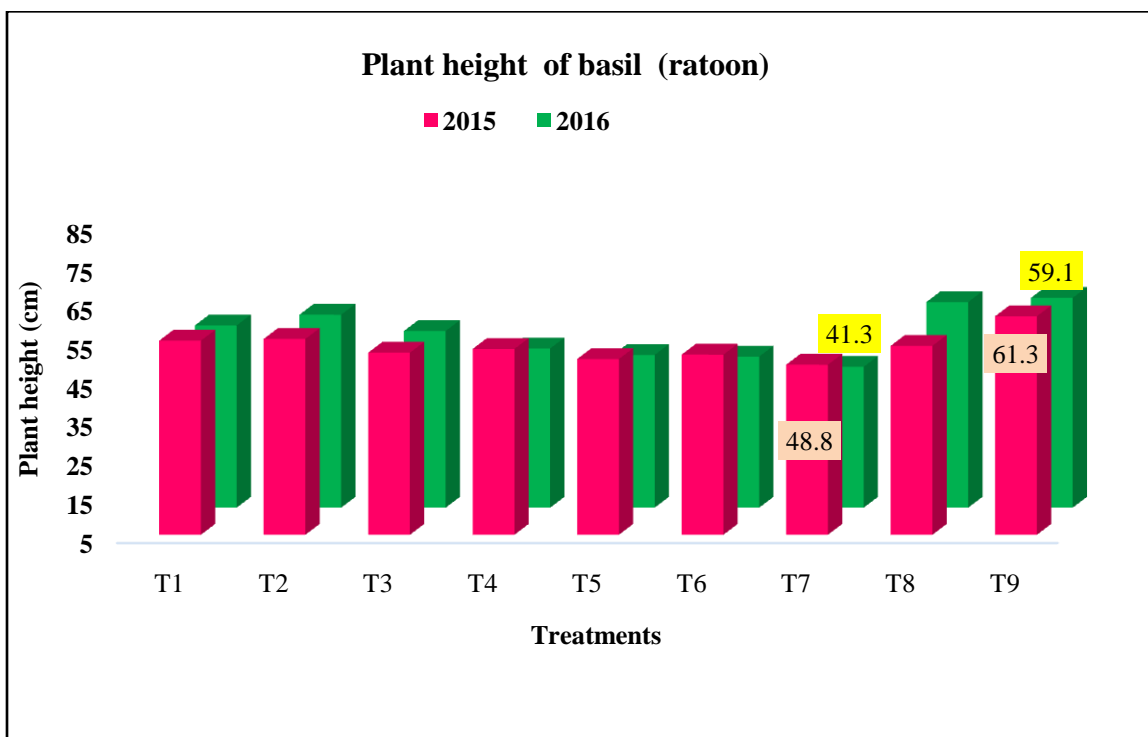


Fig. 3b: Effect of organic manure, bio-fertilizers and inorganic fertilizer on plant height (cm) at harvest in basil (*Ocimum basilicum*) ratoon

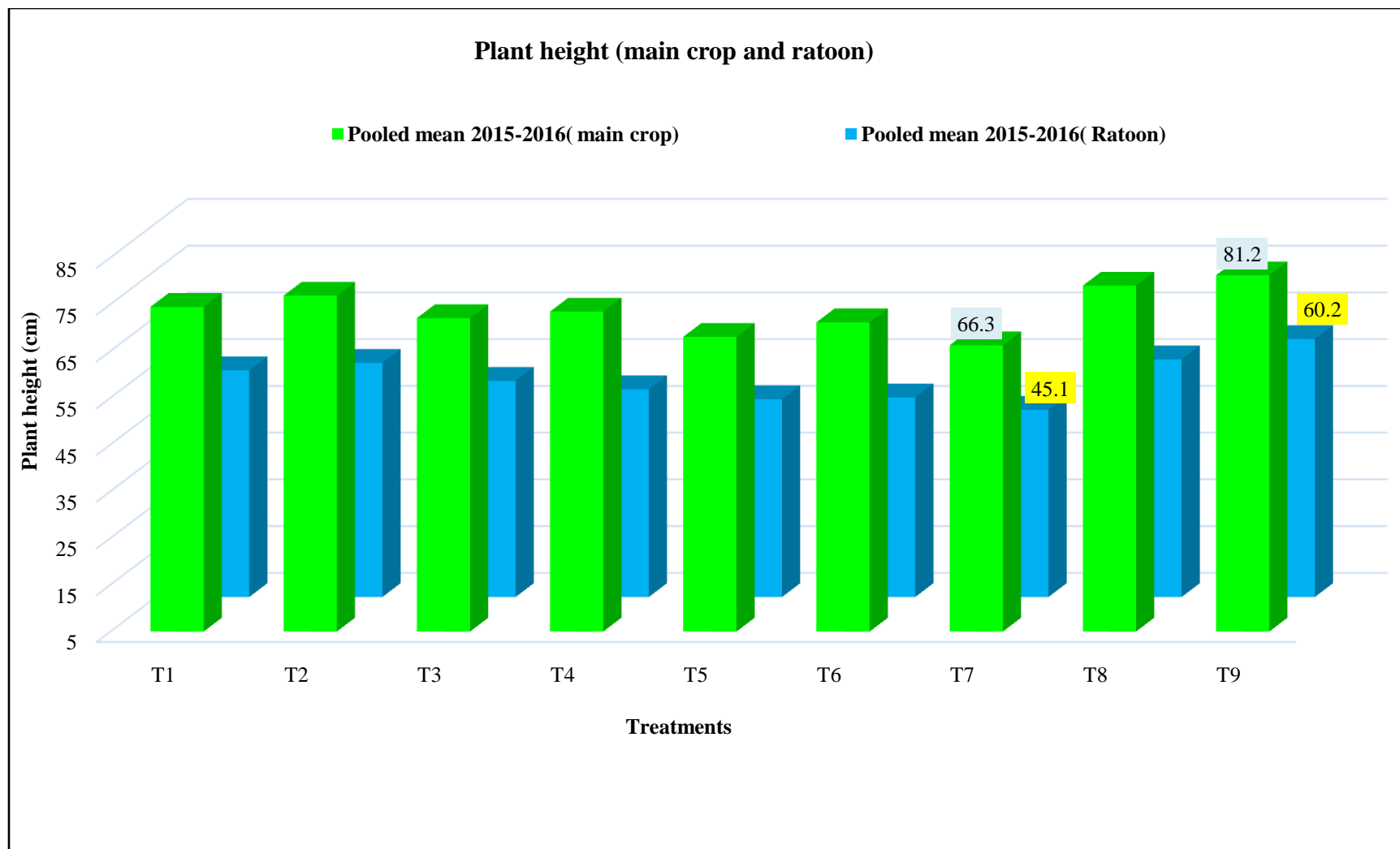


Fig. 3c: Effect of organic manure, bio-fertilizers and inorganic fertilizer on plant height (cm) at harvest in basil (*Ocimum basilicum*) pooled data of main crop and ratoon

4.1.1.2. a Number of branches at 30 days after planting (DAP)

As evident from the data shown in Table 2a., there was significant difference in the production of number of branches of the main crop and ratoon at 30 (DAP) during I and II year. And the highest value in the main crop was recorded with T₉ *i.e.*, NPK (160:80:80 kg /ha) + FYM (10 t/ha) during kharif 2015, 2016 and in pooled data respectively (15.33, 14.53 and 14.93 plant⁻¹) While, the differences were non significant between different levels of organic manure. But, in general, the perusal of data indicated that, the plant manured with T₁ FYM (10 t/ha) +100% Rec. N through FYM recorded the highest number of branches (14.27, 13.20 and 13.73 plant⁻¹) compared with lower level of FYM *i.e.* T₇ that recorded the lowest value (11.73, 11.60 and 11.66 plant⁻¹) between the treatments during kharif 2015, 2016 and in pooled data respectively. Application of bio-fertilizer has no significant effect in respect to the number of branches. However, the plants that manured with T₂ (FYM (10 t/ha) +100% Rec. N through FYM + BF) recorded the highest value than the other treatments (14.47, 13.83 and 14.15 plant⁻¹) during kharif 2015, 2016 and in pooled data respectively.

There was increase in the number of branches in the second harvest (ratoon) when compared with the main crop and the maximum production of number of branches (21.73, 21.27 and 21.50 plant⁻¹) was recorded in (T₉) *i.e.*, application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) during kharif 2015, 2016 and in pooled data respectively, and was found to be *on par* with the treatment T₈ (20.93, 19.86 and 20.40 plant⁻¹) respectively. Different levels of N through organic manure had significant influence on production of branches. The highest value was recorded in T₁ *i.e.*, FYM (10 t/ha) +100% Rec. N through FYM (17.73, 18.13 and 17.93 plant⁻¹) compared with application of recommended FYM *i.e.*, T₇ that recorded the lowest number of branches (12.66, 14.23 and 13.44 plant⁻¹) during kharif 2015, 2016 and in pooled data respectively. In general, application of bio-fertilizer increased the number of branches when it is applied along with FYM than application of FYM alone, and the highest value was recorded in T₂ with application of FYM (10 t/ha) +100% Rec. N through FYM + BF (20.66, 18.40 and 19.53 plant⁻¹) between the other treatments.

4.1.1.2. b Number of branches at 60 days after planting (DAP)

The data pertaining to number of branches per plant as influenced by different levels of N through FYM along with and without bio-fertilizers and inorganic fertilizer in main crop at 60 (DAP) during I and II year are presented in Table 2b. As is apparent from the data the highest number of branches (28.53, 26.77 and 27.65 plant⁻¹) was recorded in T₉ *i.e.*, NPK (160:80:80 kg/ha) + FYM (10 t/ha) during kharif 2015, 2016 and in the pooled data respectively. Different levels of N though FYM produced significant difference with respect to number of branches and the maximum value observed in T₁ *i.e.*, FYM (10 t/ha) +100% Rec. N through FYM (20.27, 20.33 and 20.30 plant⁻¹). While, the minimum values were recorded in T₇ (15.92, 15.71 and 15.82 plant⁻¹) respectively. However, application of bio-fertilizer along with FYM in T₂ *i.e.*, Application of FYM (10 t/ha) +100% Rec. N through FYM + BF recorded the maximum value (21.67, 21.73 and 21.70) respectively comparing with other treatments in respect to bio-fertilizer application.

4.1.1.2. c Number of branches at harvest

The information pertaining to number of the branches of the main crop and ratoon during kharif 2015, 2016 and in the pooled data as influenced by different levels of N through FYM along with and without bio-fertilizers and inorganic fertilizer at harvest is presented in Table 2.c. As is apparent from the data, highest number of branches in the main crop (31.50 plant⁻¹) was obtained with application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) *i.e.*, T₉ during kharif 2015 and (29 plant⁻¹) during kharif 2016 and (30.25 plant⁻¹) in the pooled data, respectively. The perusal of data indicates that in general, higher level of N through organic manure resulted in higher value in the number of branches compared to lower level, that the maximum number was observed in the plants that manured in T₁ with application of FYM (10 t/ha) +100% Rec. N through FYM (23.23,

23.63 and 23.43 plant⁻¹). While, T₇ recorded the lowest value (17.83, 17.66 and 17.75 plant⁻¹) during kharif 2015, 2016 and in the pooled data respectively. Application of biofertilizer along with FYM increased the number of branches, and the maximum value was recorded in T₂ *i.e.*, FYM (10 t/ha) +100% Rec. N through FYM + BF (24.07, 24.13 and 24.10 plant⁻¹) during kharif 2015, 2016 and in the pooled data respectively when compared with other treatments.

At the second harvest (ratoon) we can observe from the data in Table 2.c that the number of branches decreases in second harvest. However, application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) in T₉ resulted in highest number of branches (24.40, 23.80 and 24.10 plant⁻¹). Whereas, in respect to N levels through organic manure application the highest number of branches were recorded in T₁ with application of FYM (10 t/ha) +100% Rec. N through FYM (19.53, 20.56 and 20.05 plant⁻¹) while, the lowest value was recorded in T₇ (14.13, 16 and 15.06 plant⁻¹) during kharif 2015, 2016 and in the pooled data respectively. The data confirmed that there was no significant variation between the treatments that manured with bio-fertilizers, however, the plants treated with T₂ *i.e.*, FYM (10 t/ha) +100% Rec. N through FYM + BF recorded the highest values between the other bio-fertilizer treatments (22.40, 21.20 and 21.80 plant⁻¹) respectively and it differed significantly from the rest of the treatments. The data concerning number of branches per plant was represented graphically in figures 4a. to 4c.

4.1.1.3 Number of leaves

The effect of different levels of N through FYM along with and without bio-fertilizers and inorganic fertilization on number of leaves of basil in the main crop and ratoon during I and II year has been depicted in Tables 3a to 3c.

4.1.1.3. a Number of leaves at 30 days after planting (DAP)

A close look of the data in Table 3.a on number of leaves in the main crop and ratoon at 30 (DAP) as affected by different levels of N through FYM along with and without bio-fertilizers and inorganic fertilization, showed that application of NPK (160:80:80 k/ha) + FYM (10 t/ha) *i.e.*, T₉ recorded highest number of leaves in the main crop (206.20, 158.67 and 182.43 plant⁻¹) and in ratoon (400.93, 325 and 362.97 plant⁻¹) during kharif 2015, 2016 and in the pooled data respectively.

Table 2a. Effect of organic manure, bio-fertilizers and inorganic fertilizer on number of branches per plant in basil (*Ocimum basilicum*) at 30 days after planting (DAP)

Treatments		2015		2016		Pooled	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	14.27 ^{ABC}	17.73 ^{CD}	13.20 ^{BC}	18.13 ^C	13.73 ^{ABC}	17.93 ^{CD}
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	14.47 ^{AB}	20.66 ^{AB}	13.83 ^{ABC}	18.40 ^{BC}	14.15 ^{AB}	19.53 ^{BC}
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	14.20 ^{ABC}	16.13 ^{CDE}	12.40 ^C	17.13 ^C	13.33 ^C	16.63 ^{DE}
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	14.57 ^{ABC}	16.93 ^{CDE}	12.93 ^C	17.87 ^{BC}	13.57 ^C	17.4 ^{CD}
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	13.07 ^C	14.86 ^{EF}	12.60 ^C	16.13 ^{CD}	12.83 ^C	15.49 ^E
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	13.27 ^{BC}	15.46 ^{DE}	12.80 ^C	16.73 ^{CD}	13.03 ^C	16.10 ^{DE}
T ₇	Rec. FYM (10 t/ha) only	11.73 ^D	12.66 ^F	11.60 ^D	14.23 ^D	11.66 ^D	13.44 ^F
T ₈	Rec.NPK (160:80:80 kg /ha)	15.20 ^A	20.93 ^{AB}	14.47 ^{AB}	19.86 ^{AB}	14.83 ^{AB}	20.40 ^{AB}
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	15.33 ^A	21.73 ^A	14.53 ^A	21.27 ^A	14.93 ^A	21.50 ^A
General Mean		13.98	17.21	12.99	17.57	13.48	17.60
CV (%)		5.32	9.06	5.70	8.84	4.89	5.05
LSD at 5%		1.58	2.70	1.28	2.71	1.14	1.98

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertiliz

Table 2b. Effect of organic manure, bio-fertilizers and inorganic fertilizer on number of branches per plant in basil (*Ocimum basilicum*) main crop at 60 days after planting (DAP)

Treatments		2015	2016	Pooled
		Main crop	Main crop	Main crop
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	20.27 ^{CD}	20.33 ^D	20.30 ^D
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	21.67 ^C	21.73 ^C	21.70 ^C
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	17.93 ^{EF}	19.46 ^D	18.70 ^E
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	19.33 ^{DE}	19.56 ^D	19.45 ^{DE}
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	16.60 ^{FG}	17.80 ^E	17.21 ^F
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	18.73 ^{DE}	19.16 ^D	18.95 ^E
T ₇	Rec. FYM (10 t/ha) only	15.92 ^G	15.71 ^F	15.82 ^G
T ₈	Rec.NPK (160:80:80 kg /ha)	25.87 ^B	24.33 ^B	25.10 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	28.53 ^A	26.77 ^A	27.65 ^A
General Mean		20.54	20.59	20.54
CV		4.43	3.41	2.92
LSD		1.57	1.12	1.04

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertiliz

Table 2c. Effect of organic manure, bio-fertilizers and inorganic fertilizer on number of branches per plant in basil (*Ocimum basilicum*) at harvest

Treatments		2015		2016		Pooled	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	23.23 ^{CD}	19.53 ^{DE}	23.63 ^B	20.56 ^{BC}	23.43 ^C	20.05 ^{CD}
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	24.07 ^C	22.40 ^{BC}	24.13 ^B	21.20 ^{ABC}	24.10 ^{AB}	21.80 ^{BC}
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	20.23 ^F	18.20 ^{EF}	22.80 ^{BC}	19.53 ^C	21.51 ^D	18.86 ^{DE}
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	22.17 ^{DE}	20.80 ^{CD}	23.66 ^B	20.16 ^{BC}	22.91 ^C	20.48 ^C
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	18.57 ^G	16.93 ^F	19.10 ^D	20.46 ^{BC}	18.83 ^E	18.70 ^{DE}
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	21.40 ^{EF}	17.66 ^F	21.33 ^C	18.40 ^{CD}	21.36 ^D	18.03 ^D
T ₇	Rec. FYM (10 t/ha) only	17.83 ^G	14.13 ^G	17.66 ^D	16 ^D	17.75 ^E	15.06 ^F
T ₈	Rec.NPK (160:80:80 kg /ha)	29.37 ^B	23.23 ^B	27.33 ^A	22 ^{AB}	28.35 ^B	22.61 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	31.50 ^A	24.40 ^A	29.00 ^A	23.80 ^A	30.25 ^A	24.10 ^A
General Mean		23.15	19.70	23.15	20.23	23.15	19.97
CV (%)		3.89	5.26	4.73	8.84	3.08	4.17
LSD at 5%		1.55	1.79	1.89	2.97	1.23	1.44

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

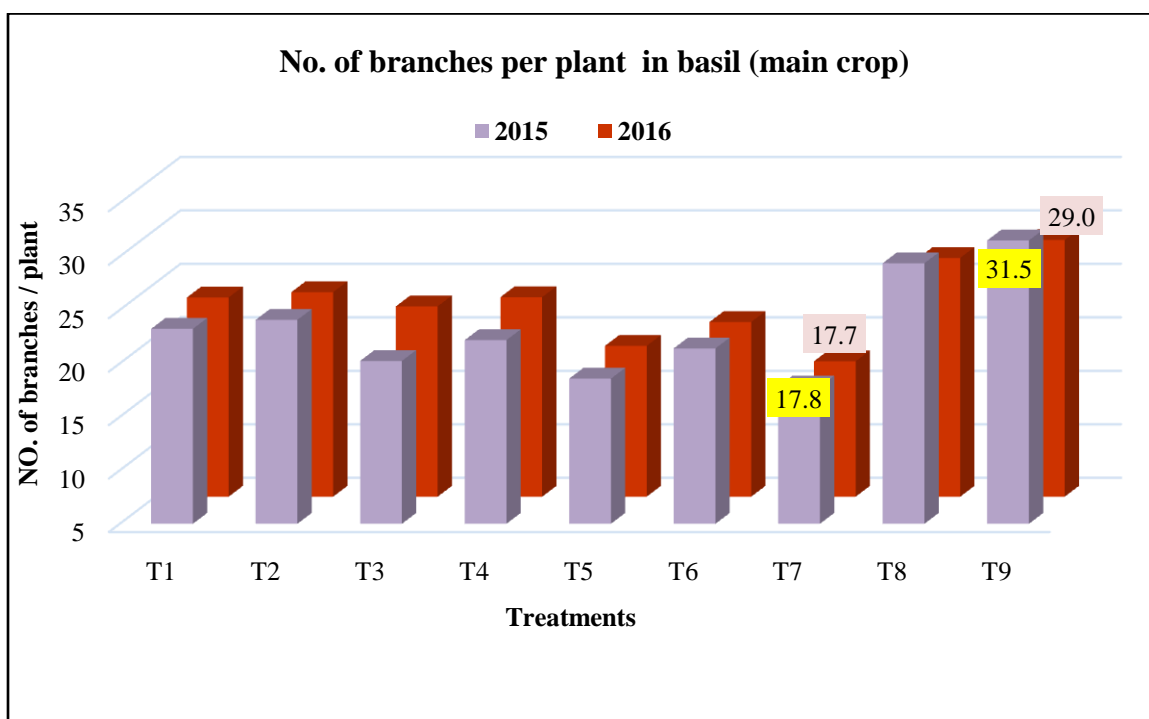


Fig. 4a: Effect of organic manure, bio-fertilizers and inorganic fertilizer on number of branches per plant at harvest in basil (*Ocimum basilicum*) main crop

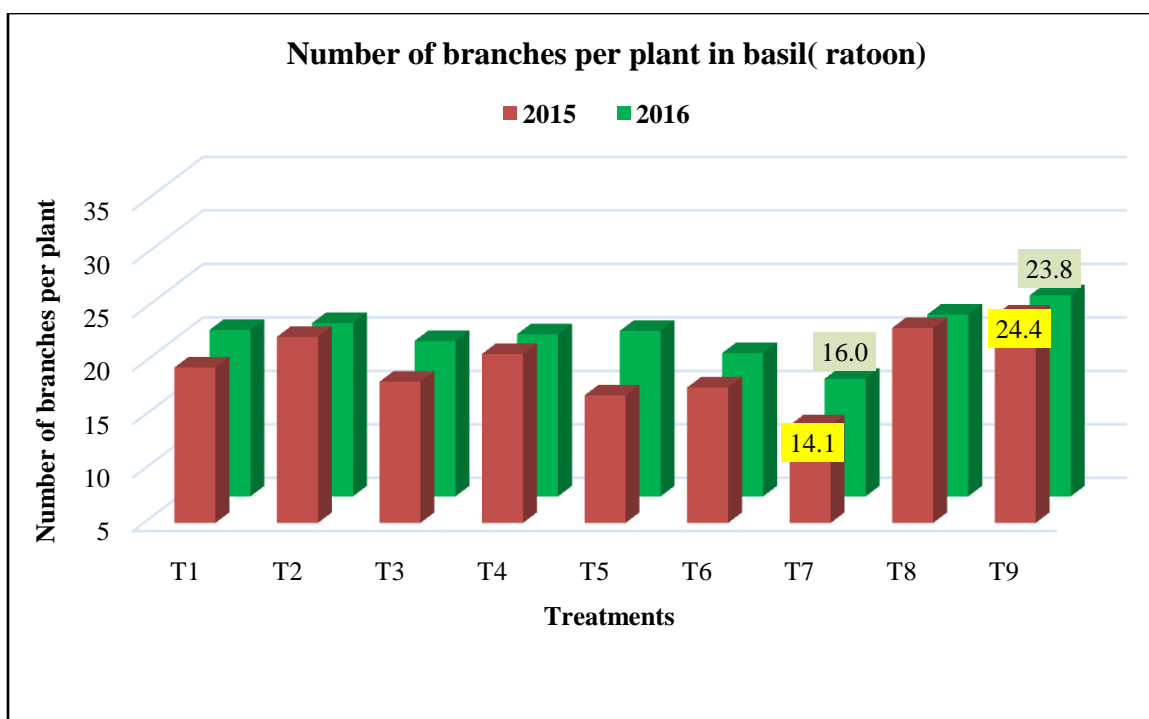


Fig. 4b: Effect of organic manure, bio-fertilizers and inorganic fertilizer on number of branches per plant at harvest in basil (*Ocimum basilicum*) ratoon

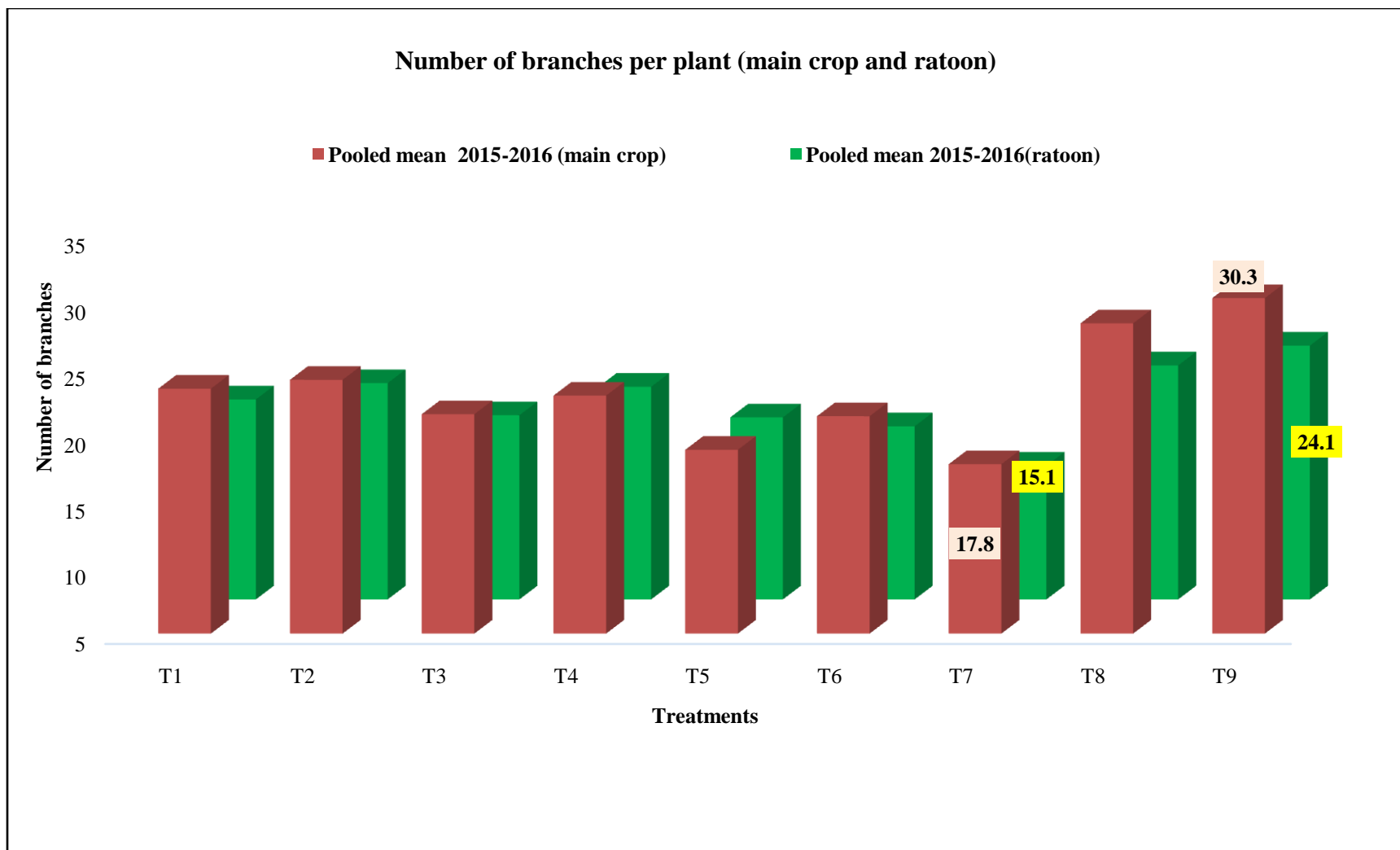


Fig. 4c: Effect of organic manure, bio-fertilizers and inorganic fertilizer on number of branches per plant at harvest in basil (*Ocimum basilicum*) pooled data of main crop and ratoon

Production of leaves differed significantly due to application of different levels of N through organic manure in the main crop during kharif 2015, and the highest value achieved by application of highest level of N through organic manure in the treatment (T₁) FYM (10 t/ha) +100% Rec. N through FYM (162.20 plant⁻¹) while, the lowest value was in T₇ (149.47 plant⁻¹). Whereas, during kharif 2016, there was no significant differences between different levels of organic manure. Application of biofertilizer increased the number leaves in the main crop during kharif 2015, and the maximum value (168.53) was recorded in with application of FYM (10 t/ha) +100% Rec. N through FYM + BF (T₂) when compared with other application of bio-fertilizer treatments. Whereas, no significant differences could be observed due to application of bio-fertilizer during kharif 2016. In the second harvest (ratoon) different levels of N through FYM significantly increased the number of leaves, and maximum number (297, 260.67 and 278.83 plant⁻¹) was observed in with application of FYM (10 t/ha) +100% Rec. N through FYM (T₁) while the lowest was in T₇ (208.13, 230 and 219.07 plant⁻¹) during kharif 2015, 2016 and in the pooled data respectively.

4.1.1.3. b. Number of leaves at 60 days after planting (DAP)

A perusal of the data in Table 3.b revealed that there is significant difference in the number of leaves of the main crop at 60 (DAP) in response to different levels of N through organic manure along with and without bio-fertilizers and inorganic fertilization. The plants that manured with NPK (160:80:80 kg/ha) + FYM (10 t/ha) *i.e.*, T₉ exhibited highest number of leaves (352.53, 331.33 and 341.93 plant⁻¹) during kharif 2015, 2016 and in the pooled data respectively. There was no significant difference among different levels of N through organic manure during kharif 2015. Whereas, during kharif 2016 maximum number of leaves (273.33 plant⁻¹) was recorded with application of FYM (10 t/ha) +100% Rec. N through FYM (T₁) while, the lowest number was observed in T₇ (172.67 plant⁻¹). With respect to bio-fertilizer, application of FYM (10 t/ha) +100% Rec. N through FYM + BF (T₂) recorded the highest number of leaves (262.47, 308 and 285.23 plant⁻¹) between the other bio-fertilizer treatments during kharif 2015, 2016 and in the pooled data respectively.

4.1.1.3. c. Number of leaves at harvest time

The effect of different levels of N through FYM along with and without bio-fertilizers and inorganic fertilization is furnished in Table 3.c A close look of the data revealed that the maximum number of leaves per plant in the main crop is (365.50, 417.67 and 391.6 plant⁻¹) due to application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ during kharif 2015, 2016 and in the pooled data respectively, and was found to be *on par* with T₈ (341.50, 388.50 and 365 plant⁻¹) *i.e.*, NPK (160:80:80 kg /ha), respectively. Highest level of N through FYM in the treatment T₁ (FYM (10 t/ha) +100% Rec. N through FYM) recorded maximum number of leaves per plant (273.27, 328.93 and 301.10 plant⁻¹) while, the lowest number was observed in T₇ (232.53, 208.5 and 220.5 plant⁻¹) during kharif 2015, 2016 and in the pooled data respectively. A perusal of the data indicated that application of FYM (10 t/ha) +100% Rec. N through FYM + BF (T₂) recorded the maximum number of leaves (309.60, 380.77 and 345.19 plant⁻¹) among the other bio-fertilizer treatments during kharif 2015, 2016 and in the pooled data respectively. In the second harvest (ratoon) application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) (T₉) as soil incorporation radically increased the number of leaves during kharif 2015 (446.73 plant⁻¹) and (389.33 plant⁻¹) during kharif 2016 and in pooled data (418.03 plant⁻¹) respectively. There were significant differences between different levels of N through FYM and the maximum number of leaves (346.37, 297.30 and 321.84 plant⁻¹) was recorded with application of FYM (10 t/ha) +100% Rec. N through FYM (T₁) while, the lowest number (248.47, 254.47 and 251.47 plant⁻¹) was observed in (T₇) during kharif 2015, 2016 and in the pooled data respectively. Application of bio-fertilizer enhanced the number of leaves and among the bio-fertilizer application the maximum number could be observed with application of FYM (10 t/ha) +100% Rec. N through FYM + BF (T₂) during kharif 2015 (376.73 plant⁻¹), kharif 2016 (331.63 plant⁻¹) and in the pooled data (354.18 plant⁻¹) respectively.

The data concerning the number of leaves per plant, was represented graphically in figures 5a. to 5c.

Table 3a. Effect of organic manure, bio-fertilizers and inorganic fertilizer on number of leaves per plant in basil (*Ocimum basilicum*) at 30 days after planting (DAP)

Treatments		2015		2016		Pooled	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	162.20 ^{CD}	297.00 ^C	162.13 ^A	260.67 ^E	162.17 ^{BC}	278.83 ^C
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	168.53 ^C	327.40 ^B	162.47 ^A	284.67 ^C	165.50 ^{BC}	306.03 ^B
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	154.07 ^{DE}	260.73 ^D	154.53 ^A	262.67 ^E	154.30 ^{CD}	261.70 ^{DE}
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	158.73 ^{CDE}	273.27 ^{CD}	150.20 ^A	282.67 ^{CD}	154.47 ^{CD}	277.97 ^C
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	152.47 ^{DE}	247.47 ^D	143.40 ^A	253.33 ^E	147.93 ^{DE}	250.40 ^E
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	156.00 ^{DE}	271.53 ^{CD}	151.87 ^A	267.33 ^{DE}	153.93 ^{CD}	269.43 ^{CD}
T ₇	Rec. FYM (10 t/ha) only	149.47 ^E	208.13 ^E	121.67 ^B	230.00 ^F	135.57 ^E	219.07 ^F
T ₈	Rec.NPK (160:80:80 kg /ha)	193.87 ^B	330.73 ^B	156.00 ^A	307.33 ^B	174.93 ^{AB}	319.03 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	206.20 ^A	400.93 ^A	158.67 ^A	325.00 ^A	182.43 ^A	362.97 ^A
General Mean		166.84	290.80	151.21	274.85	159.03	282.83
CV (%)		3.97	5.97	7.58	3.63	4.83	3.22
LSD at 5%		11.46	30.03	19.82	17.28	13.29	15.77

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

Table 3b. Effect of organic manure, bio-fertilizers and inorganic fertilizer on number of leaves per plant in basil (*Ocimum basilicum*) main crop at 60 days after planting (DAP)

Treatments		2015	2016	Pooled
		Main crop	Main crop	Main crop
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	235.47 ^{CD}	273.33 ^{BCD}	254.40 ^{CD}
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	262.47 ^{BC}	308.00 ^{ABC}	285.23 ^{BC}
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	219.93 ^{CD}	254.67 ^D	237.30 ^{DE}
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	237.20 ^{CD}	269.67 ^{CD}	253.43 ^{CD}
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	200.00 ^D	203.27 ^E	201.63 ^{EF}
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	213.53 ^{CD}	210.67 ^E	212.10 ^{EF}
T ₇	Rec. FYM (10 t/ha) only	204.33 ^D	172.67 ^E	188.50 ^F
T ₈	Rec.NPK (160:80:80 kg /ha)	293.87 ^B	311.00 ^{AB}	302.43 ^{AB}
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	352.53 ^A	331.33 ^A	341.93 ^A
General Mean		246.59	259.40	253.00
CV		13.01	8.62	9.30
LSD		55.54	38.68	40.72

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

Table 3c. Effect of organic manure, bio-fertilizers and inorganic fertilizer on number of leaves per plant in basil (*Ocimum basilicum*) at harvest time

Treatments		2015		2016		Pooled	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	273.27 ^{BCD}	346.37 ^C	328.93 ^{BC}	297.30 ^{DE}	301.1 ^{CD}	321.84 ^D
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	309.60 ^{ABC}	376.73 ^B	380.77 ^{AB}	331.63 ^C	345.2 ^{BC}	354.2 ^C
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	255.80 ^{CD}	304.60 ^{DE}	304.73 ^{CD}	295.60 ^{DE}	280.3 ^{DE}	300.1 ^{EF}
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	278.03 ^{BCD}	316.70 ^D	329.40 ^{BC}	321.90 ^C	303.7 ^{CD}	319.30 ^D
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	234.50 ^D	287.30 ^E	233.20 ^E	284.20 ^E	233.70 ^{EF}	285.7 ^F
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	243.67 ^{CD}	305.83 ^{DE}	240.07 ^{DE}	304.03 ^D	241.9 ^{EF}	304.9 ^{DE}
T ₇	Rec. FYM (10 t/ha) only	232.53 ^D	248.47 ^F	208.5 ^E	254.47 ^F	220.5 ^F	251.47 ^G
T ₈	Rec.NPK (160:80:80 kg /ha)	341.50 ^{AB}	386.93 ^B	388.50 ^{AB}	365.70 ^B	365.0 ^{AB}	376.32 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	365.50 ^A	446.73 ^A	417.67 ^A	389.33 ^A	391.6 ^A	418.03 ^A
General Mean		280.49	335.52	313.49	316.02	297.94	325.77
CV(%)		14.21	4.84	11.52	3.21	9.99	3.36
LSD at 5%		68.99	28.10	62.75	17.55	51.52	18.88

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

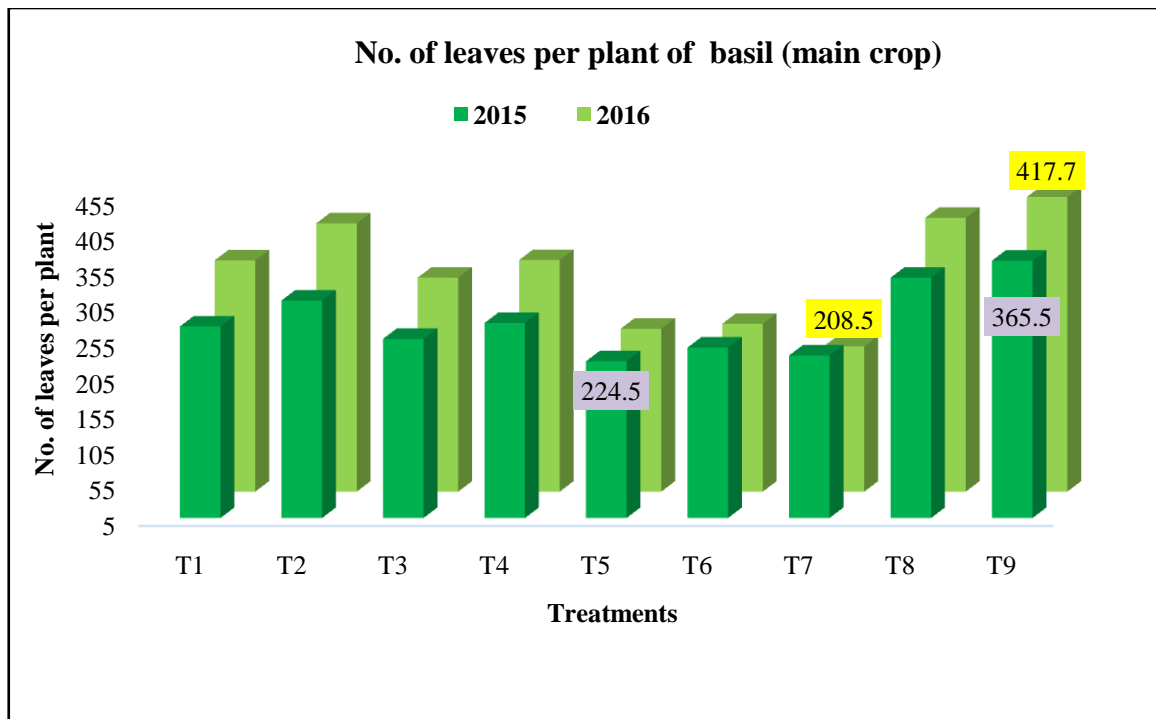


Fig. 5a: Effect of organic manure, bio-fertilizers and inorganic fertilizer on number of leaves per plant at harvest in basil (*Ocimum basilicum*) main crop

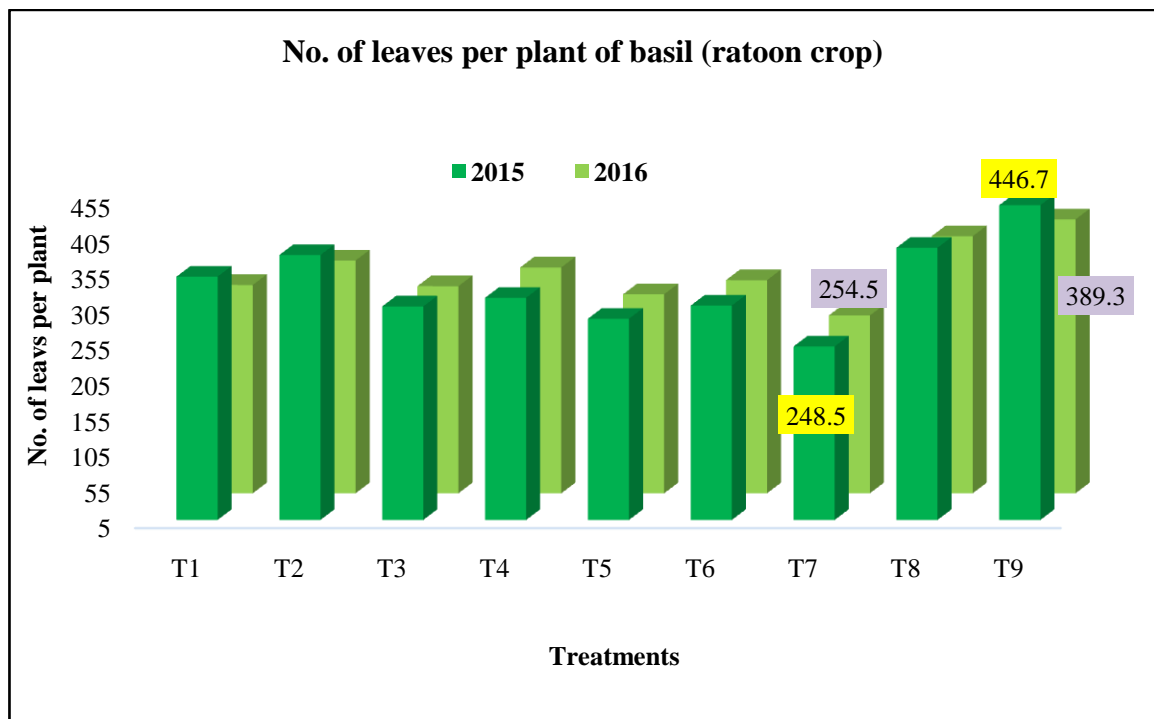


Fig. 5b: Effect of organic manure, bio-fertilizers and inorganic fertilizer on number of leaves per plant at harvest in basil (*Ocimum basilicum*) ratoon

No. of leaves per plant (main and ratoon crop)

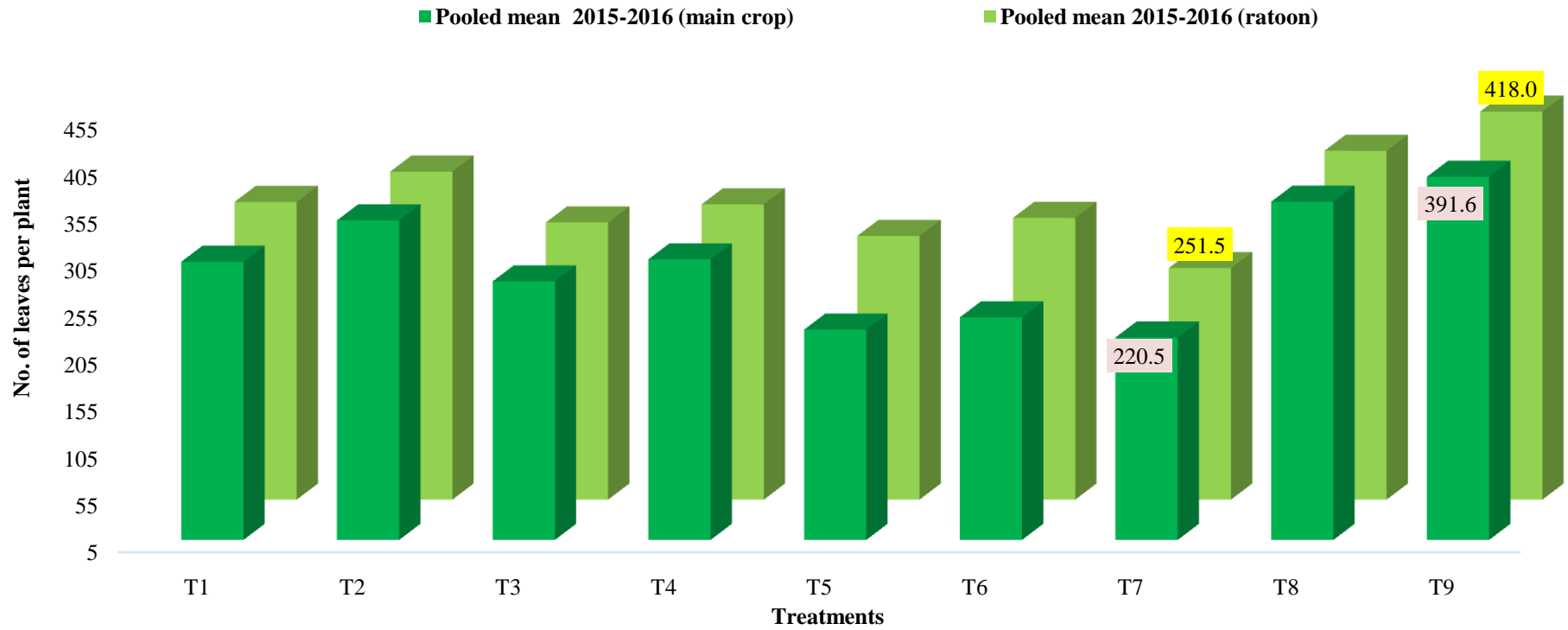


Fig. 5c: Effect of organic manure, bio-fertilizers and inorganic fertilizer on number of leaves per plant at harvest in basil (*Ocimum basilicum*) pooled data of main crop and ratoon

4.1.1.4. Leaf area (cm²)

A close look on data in Table 4. related to leaf area of basil as influenced by different levels of N through FYM along with and without biofertilizer and inorganic fertilizer indicated significant differences between the treatments. Application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ recorded maximum leaf area in the main crop (15.66, 17.04 and 16.35 cm²) and in ratoon (9.48, 10.11 and 9.79 cm²) during kharif 2015, 2016 and pooled data respectively. While, the minimum value was recorded in T₇ in the main crop (8.60 and 8.83 cm²), in ratoon (5 and 5.97 cm²) and (8.70 and 5.49 cm²) in pooled data during two years of the experiment respectively. Data pertaining to leaf area as influenced by different treatments is depicted in Figure (6)

4.1.1.5. Time taken for first flowering

Time taken for first flowering (day) is significantly influenced by different treatments in the main crop and ratoon during two years of experiment and presented in Table 5. The data revealed that maximum number of days till first flowering was recorded in with application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) *i.e.*, T₉ in the main crop (38.33, 35 and 36.67 day) and ratoon (26.67, 24.46 and 25.56 day) during kharif 2015, 2016 and in the pooled data respectively. Whereas, the minimum number was recorded in T₇ in the main crop (31, 22 and 26.50 day), and ratoon (16.67 and 16.33 day) during kharif 2015, 2016 respectively. Data on time taken for first flowering (day) for 2015 and 2016 were pooled and presented in Fig. 7.

4.1.1.6. Time taken for 50% flowering

Time taken for 50% of flowering (day) differed significantly among the treatments as shown in Table 6. and Fig. 8. Application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) *i.e.*, T₉ recorded the maximum number of days in the main crop (54.66, 48 and 51.33 day) and ratoon (39.80, 33.33 and 36.57 day) during kharif 2015, 2016 and pooled data respectively. Application of bio-fertilizer enhanced the duration of vegetative growth, and maximum days taken for 50% flowering was recorded with application of FYM (10 t/ha) +100% Rec. N through FYM + BF (T₂) during kharif 2015 and 2016 in the main crop (47.33 and 40.67 day), in ratoon (31.95 and 24.67 day), and in pooled data (44 and 28.31) respectively.

Table 4. Effect of organic manure, bio-fertilizers and inorganic fertilizer on average leaf area (cm²) in the main crop and ratoon of basil (*Ocimum basilicum*) during two years of the field experiment

Treatments		2015		2016		Pooled	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	12.80 ^B	7.15 ^C	13.73 ^C	7.45 ^D	13.27 ^C	7.30 ^D
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	14.53 ^A	7.67 ^B	15.51 ^B	8.23 ^C	15.01 ^B	7.95 ^C
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	11.73 ^B	6.09 ^E	12.29 ^D	6.89 ^{EF}	12.02 ^D	6.49 ^F
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	12.40 ^B	6.60 ^D	13.40 ^C	7.15 ^{DE}	12.93 ^C	6.87 ^E
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	11.2 ^{BC}	5.11 ^G	11.36 ^{DE}	6.47 ^G	11.30 ^E	5.79 ^G
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	10.12 ^C	5.64 ^F	10.63 ^E	6.77 ^{FG}	10.40 ^F	6.20 ^F
T ₇	Rec. FYM (10 t/ha) only	8.60 ^D	5.00 ^G	8.83 ^F	5.97 ^H	8.70 ^G	5.49 ^H
T ₈	Rec.NPK (160:80:80 kg /ha)	14.4 ^A	9.29 ^A	16.27 ^{AB}	9.47 ^B	15.33 ^B	9.38 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	15.66 ^A	9.48 ^A	17.04 ^A	10.11 ^A	16.35 ^A	9.80 ^A
General Mean		12.39	6.89	13.23	7.61	12.81	7.25
CV%		6.08	<.0001	<.0001	<.0001	3.31	<.0001
LSD at 5%		1.30	3.43	4.07	2.86	0.73	2.37

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

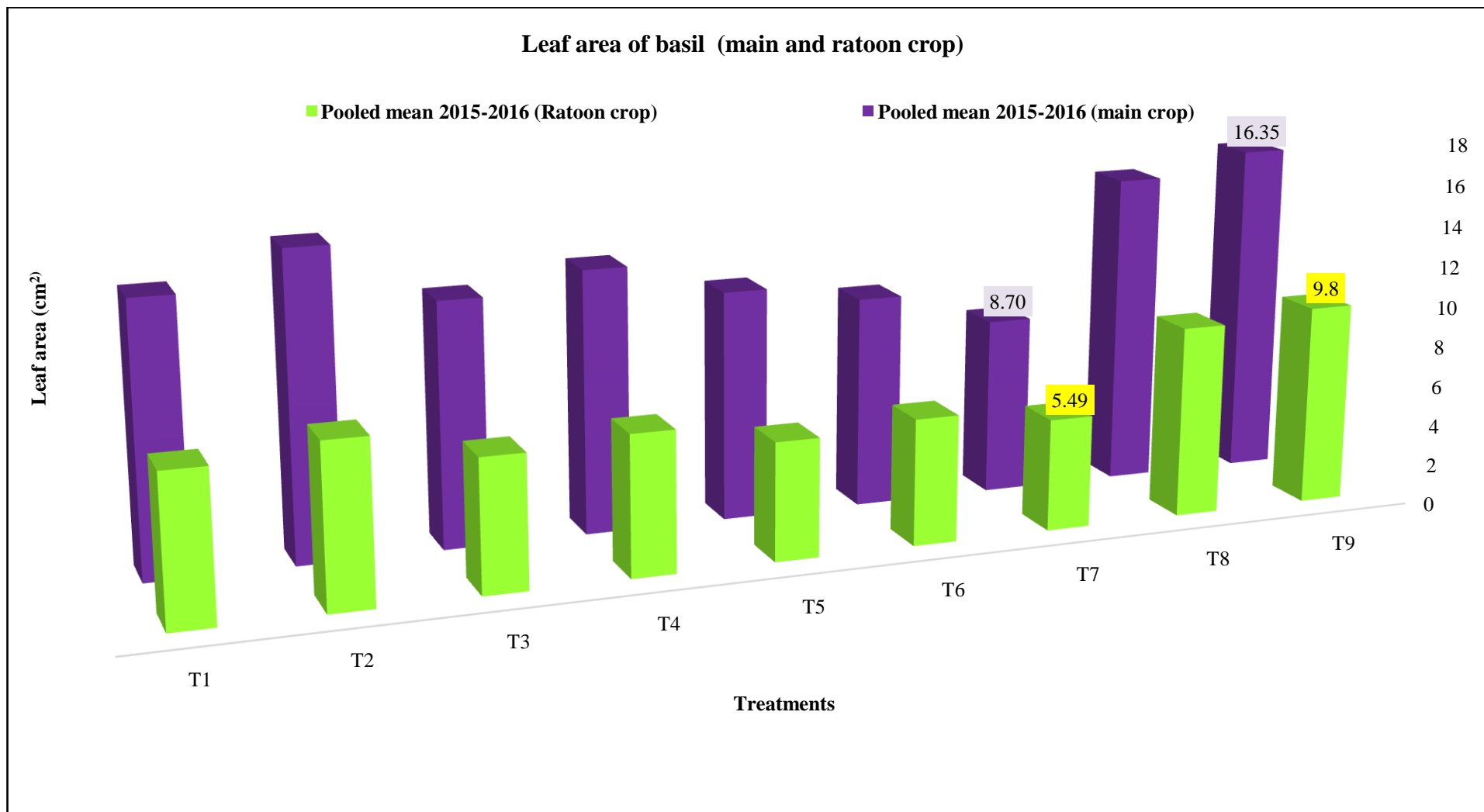


Fig. 6: Effect of organic manure, bio-fertilizers and inorganic fertilizer on average leaf area (cm²) of basil (*Ocimum basilicum*) pooled data of main crop and ratoon

Table 5. Effect of organic manure, bio-fertilizers and inorganic fertilizer on time taken for first flowering (day) in the main crop and ratoon of basil (*Ocimum basilicum*) during two years of the field experiment

Treatments		2015		2016		Pooled	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	34.67 ^C	22.00 ^{CD}	27.33 ^{BC}	19.67 ^{CD}	31.00 ^C	20.83 ^{CD}
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	36.33 ^B	20.67 ^{DE}	28.67 ^B	21.00 ^{BC}	32.50 ^B	20.83 ^{CD}
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	34.00 ^{CD}	20.67 ^{DE}	26.00 ^C	18.00 ^{DEF}	30.00 ^C	19.33 ^{DE}
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	35.67 ^B	23.00 ^{BC}	25.67 ^{CD}	19.00 ^{DE}	30.67 ^C	21.00 ^C
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	33.00 ^E	19.00 ^{EF}	23.33 ^{DE}	17.33 ^{EF}	28.17 ^D	18.17 ^E
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	33.33 ^{DE}	18.00 ^{FG}	26.17 ^C	17.67 ^{EF}	29.75 ^C	17.83 ^{EF}
T ₇	Rec. FYM (10 t/ha) only	31.00 ^F	16.67 ^G	22.00 ^E	16.33 ^F	26.50 ^E	16.50 ^F
T ₈	Rec.NPK (160:80:80 kg /ha)	37.67 ^A	24.67 ^B	34.67 ^A	22.33 ^B	36.17 ^A	23.50 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	38.33 ^A	26.67 ^A	35.00 ^A	24.67 ^A	36.67 ^A	25.67 ^A
General Mean		34.89	21.26	27.65	19.56	31.27	20.41
CV%		1.26	4.66	4.98	5.90	2.39	4.66
LSD at 5%		0.76	1.71	2.38	1.99	1.29	1.64

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

Table 6. Effect of organic manure, bio-fertilizers and inorganic fertilizer on time taken for 50% of flowering (day) of basil (*Ocimum basilicum*) main crop and ratoon during two years of the field experiment

Treatments		2015		2016		Pooled	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	45.67 ^{CD}	29.93 ^D	38.67 ^{DE}	23.33 ^{CD}	42.17 ^{DE}	26.63 ^C
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	47.33 ^C	31.95 ^C	40.67 ^C	24.67 ^B	44.00 ^C	28.31 ^B
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	44.33 ^{DE}	29.09 ^D	37.67 ^{EF}	22.67 ^{DEF}	41.00 ^F	25.88 ^{CD}
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	46.33 ^{CD}	31.59 ^C	39.67 ^{CD}	24.33 ^{BC}	43.00 ^{CD}	27.96 ^B
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	43.33 ^E	28.16 ^E	36.33 ^G	22.00 ^{EF}	39.83 ^G	25.08 ^{DE}
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	45.33 ^{CD}	29.73 ^D	38.33 ^E	23.00 ^{DE}	41.83 ^{EF}	26.37 ^C
T ₇	Rec. FYM (10 t/ha) only	39.00 ^F	27.67 ^E	37.00 ^{FG}	21.67 ^F	38.00 ^H	24.67 ^E
T ₈	Rec.NPK (160:80:80 kg /ha)	51.33 ^B	38.87 ^B	46.67 ^B	32.67 ^A	49.00 ^B	35.77 ^A
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	54.67 ^A	39.80 ^A	48.00 ^A	33.33 ^A	51.33 ^A	36.57 ^A
General Mean		46.37	31.87	40.33	25.30	43.35	28.58
CV%		2.04	4.66	4.98	5.90	2.39	4.66
LSD at 5%		1.64	1.54	1.52	2.97	1.35	1.80

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

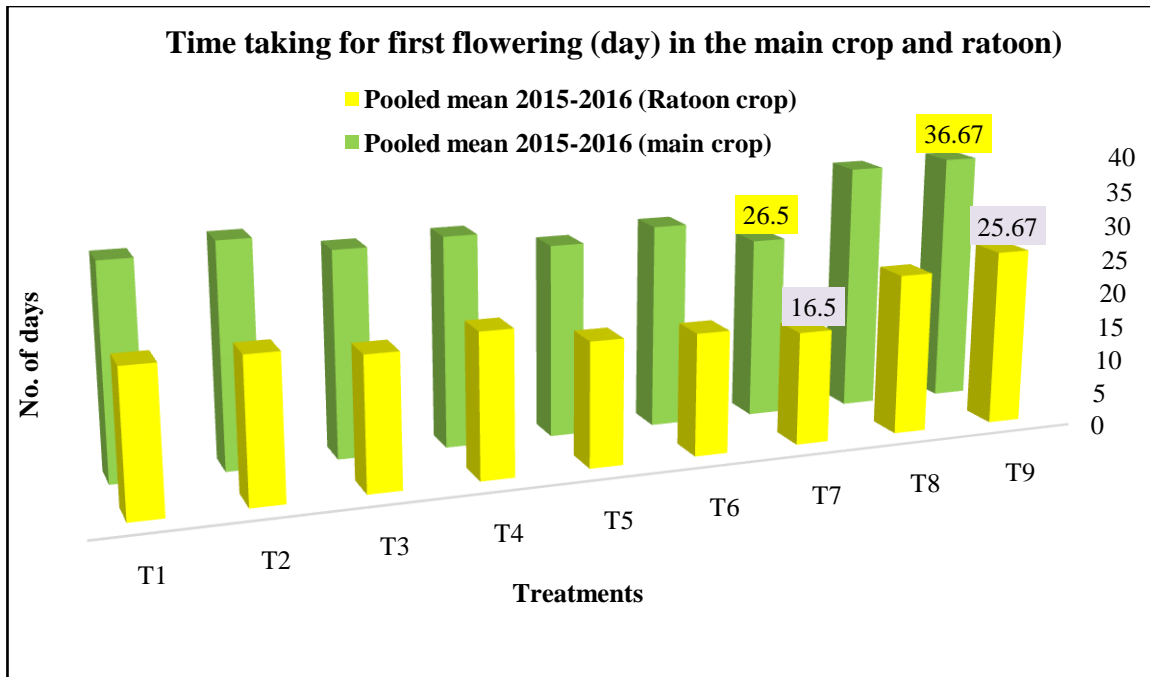


Fig. 7: Effect of organic manure, bio-fertilizers and inorganic fertilizer on time taken for first flowering (day) of basil (*Ocimum basilicum*) main crop and ratoon during two years of the field experiment

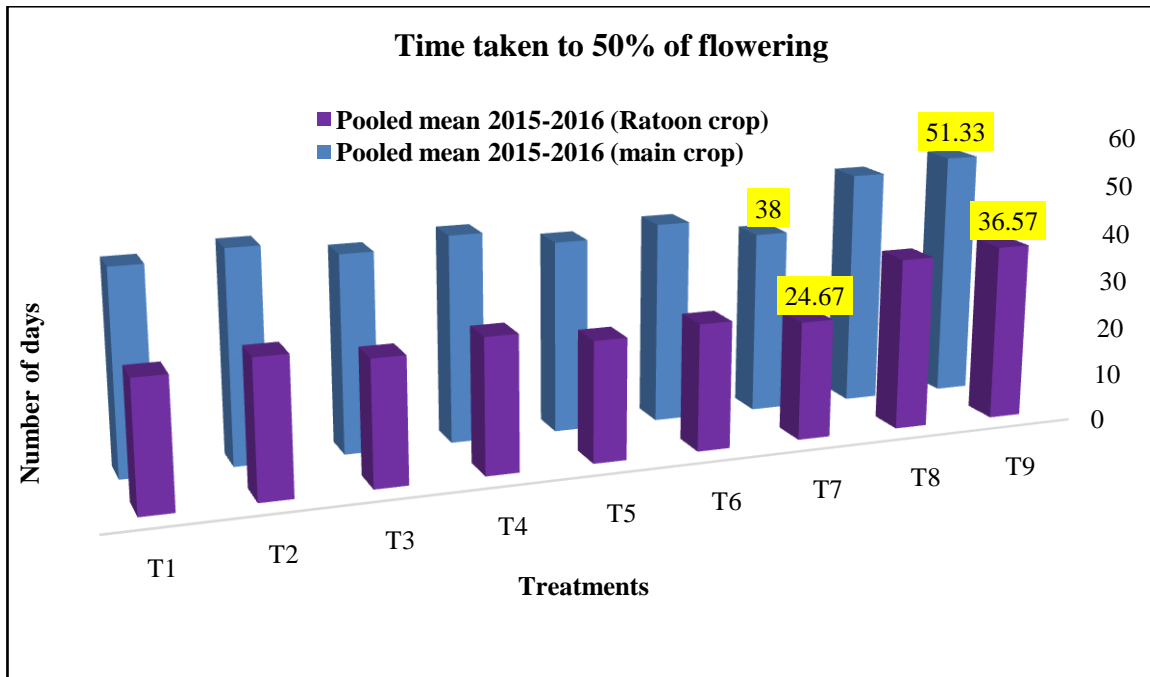


Fig. 8: Effect of organic manure, bio-fertilizers and inorganic fertilizer on time taken to 50% of flowering (day) of basil (*Ocimum basilicum*) main crop and ratoon during two years of the field experiment

4.1.2 YIELD PARAMETERS

4.1.2.1 Fresh weight of leaves (g/plant)

Data indicated significant differences among the treatments with respect to fresh weight of leaves per plant (g) in the main crop and ratoon during kharif 2015, 2016 and pooled data respectively. As it appears in Table 7. and Fig 9. Application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) *i.e.*, T₉ recorded the maximum fresh weight of leaves in the main crop during kharif 2015 (173.67 g/plant), (227.33 g/plant) during kharif 2016 and (200.5 g/plant) in the pooled data respectively. Different levels of N through FYM recorded significant differences in fresh weight of leaves, and the maximum value (108.67, 154 and 131.33 g/plant) was observed with application of FYM (10 t/ha) +100% Rec. N through FYM (T₁) whereas, the lowest was (90, 107.67 and 98.83 g/plant) in T₇ during kharif 2015, 2016 and pooled data respectively. Application of bio-fertilizer enhanced the fresh weight of leaves and the highest value (130.27, 167.33 and 148.80 g/plant) was observed with application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ during kharif 2015, 2016 and pooled data respectively. In the second harvest (ratoon) the treatments differed significantly in term of fresh weight of leaves per plant. Plants that manured with NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ recorded maximum fresh weight of leaves per plant (234.33, 209.66 and 221.99 g/plant) during kharif 2015, 2016 and pooled data respectively. Among different levels of N through FYM the fresh weight of leaves was maximum (166.20, 120.67 and 143.43 g/plant) with application of FYM (10 t/ha) +100% Rec. N through FYM (T₁) while, the minimum value was in T₇ (120, 90 and 105 g/plant) during kharif 2015, 2016 and pooled data respectively. Bio-fertilizer had a positive impact on the fresh weight of leaves in the second harvest, and maximum value (191.67, 132.33 and 162 g/plant) could be observed with application of FYM (10 t/ha) +100% Rec. N through FYM + BF (T₂) during kharif 2015, 2016 and pooled data respectively.

4.1.2.2. Fresh weight of stem (g/plant):

Data on fresh weight of stem as affected by different levels of N through FYM with and without bio-fertilizers and inorganic fertilization is given in the Table 8. and Fig. 10. There were significant differences between treatments. Application of NPK (160:80:80 kg /ha) *i.e.*, T₈ recorded the maximum fresh weight of stem in the main crop during kharif 2015 (730.40 g/plant) and it was *on par* with T₉ (698 g/plant). Different levels of N through FYM had significant influence on stem weight per plant and the maximum value (587.33 g/plant) was recorded in with application of FYM (10 t/ha) +100% Rec. N through FYM (T₁), while, the minimum value (509.33 g/plant) was observed in T₇. Application of bio-fertilizer enhanced the fresh weight of stem and the treatment (T₂) FYM (10 t/ha) +100% Rec. N through FYM + BF recorded the highest fresh stem weight (662 g/plant) among the bio-fertilizer applications. In Kharif 2016, the fresh weight of the stem was lower than what recorded during first season. While, the maximum value (582.27 g/plant) was recorded with application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉. Different levels of N through FYM did not differed significantly during the next season, and no significant trend could be observed for bio-fertilizer application. However, the treatment (T₂) FYM (10 t/ha) +100% Rec. N through FYM + BF recorded the maximum fresh stem weight (402.67 g/plant) among the other treatments. In the pooled data of the main crop, the highest value (640.13 g/plant) was recorded with application NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉. While, the minimum was observed in the lower level of organic manure in T₇ (368.20 g/plant).

At second harvest (ratoon) the fresh weight of stem was lower comparing with the main crop and there was significant differences between treatments. During kharif 2015, application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) *i.e.*, T₉ recorded the maximum fresh stem weight (186.67g/plant) and it was *on par* with T₈ (180 g/plant). Different levels of N through FYM had significant influence on stem weight in ratoon crop, and the treatment (T₁) FYM (10 t/ha) +100% Rec. N through FYM recorded the maximum fresh weight of stem (160.67 g/plant) while, the minimum value was observed in T₇ (116.67 g/plant). Application of bio-fertilizer had positive effect on increasing the fresh stem weight and the treatment (T₂) FYM (10 t/ha) +100% Rec. N through FYM + BF recorded the maximum value (170 g/plant). During kharif 2016, the plants that manured with (T₉) recorded the highest value (139.33 g/plant). While, there was no significant differences between different levels of N through FYM. However, application of bio-fertilizer along

Table 7. Fresh weight of leaves (g/plant) in basil (*Ocimum basilicum*) as influenced by organic manure, bio-fertilizers and inorganic fertilizer during two years of the field experiment

Treatments		2015		2016		Pooled	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	108.67 ^{CD}	166.20 ^C	154.00 ^{BC}	120.67 ^{CD}	131.33 ^{DE}	143.43 ^D
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	130.27 ^{BC}	191.67 ^B	167.33 ^B	132.33 ^C	148.80 ^C	162 ^C
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	100.33 ^D	150.67 ^{ED}	136.67 ^{CD}	108.66 ^{DE}	118.50 ^{EF}	129.00 ^{EF}
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	124.00 ^{BC}	159.33 ^{CD}	147.67 ^{BC}	116.67 ^{CDE}	135.83 ^{CD}	138.00 ^{DE}
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	96.33 ^D	132.00 ^F	120.33 ^{DE}	100.35 ^{EF}	108.33 ^{FG}	116.35 ^{GH}
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	99.67 ^D	144.67 ^E	135.00 ^{CD}	103.54 ^{DEF}	117.33 ^{EF}	124.00 ^{FG}
T ₇	Rec. FYM (10 t/ha) only	90.00 ^D	120.00 ^G	107.67 ^E	90.00 ^F	98.83 ^G	105 ^H
T ₈	Rec.NPK (160:80:80 kg /ha)	146.33 ^B	195.00 ^B	204.83 ^A	174.33 ^B	175.58 ^B	184.66 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	173.67 ^A	234.33 ^A	227.33 ^A	209.66 ^A	200.5 ^A	221.99 ^A
General Mean		118.81	166.99	155.46	128.40	137.22	147.19
CV (%)		10.86	4.07	9.35	8.33	7.35	2.25
LSD at 5%		22.334	11.69	25.21	18.52	20.839	13.38

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

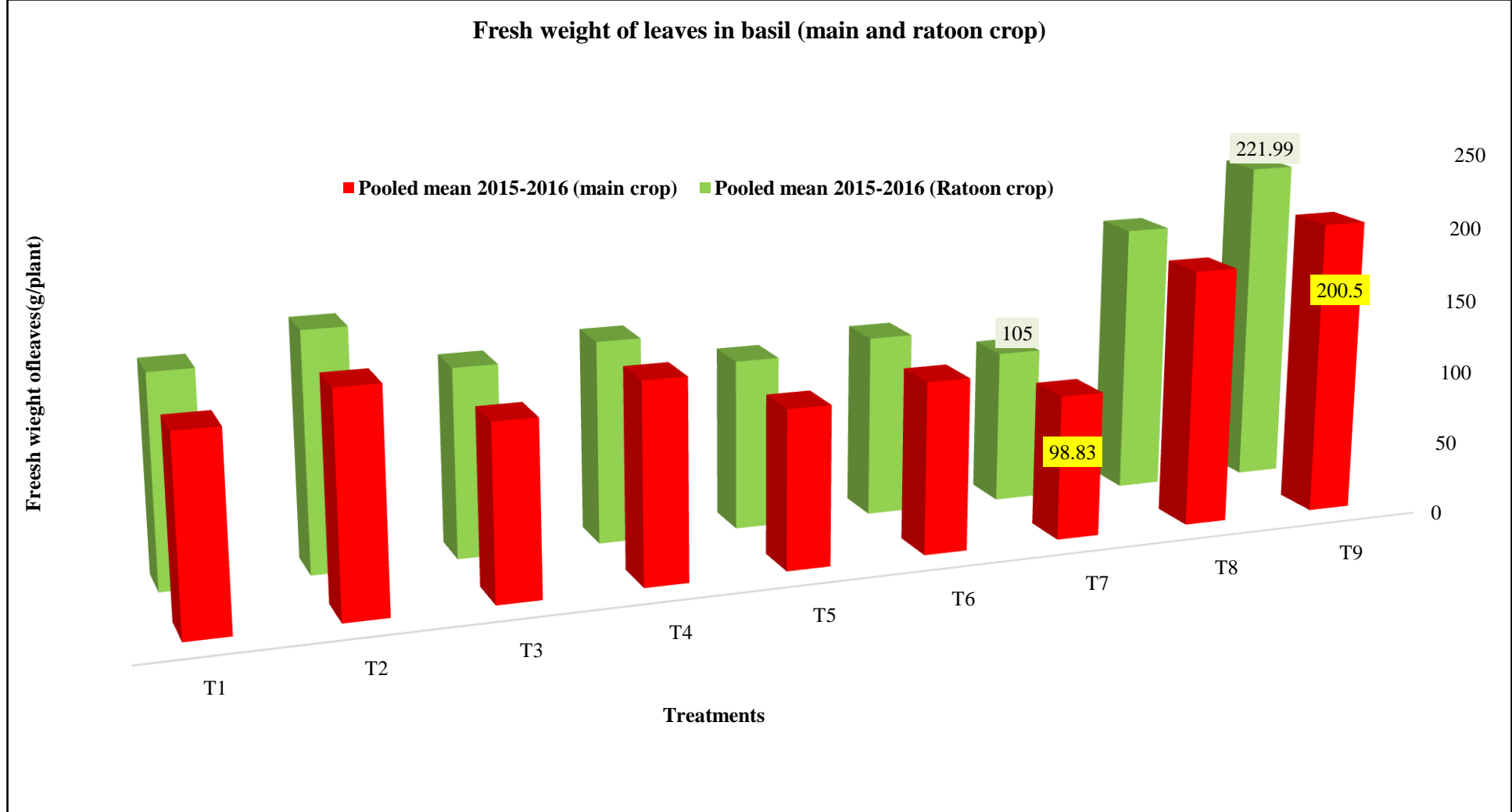


Fig. 9: Fresh weight of leaves (g/plant) in basil (*Ocimum basilicum*) as influenced by organic manure, bio-fertilizers and inorganic fertilizer during two years of the field experiment

Table 8. Fresh weight of stems (g/plant) in basil (*Ocimum basilicum*) as influenced by organic manure, bio-fertilizers and inorganic fertilizer during two years of the field experiment

Treatments		2015		2016		Pooled	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	587.33 ^C	160.67 ^C	381.27 ^C	94.67 ^C	484.30 ^D	127.67 ^{CD}
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	662.00 ^B	170.00 ^B	402.67 ^C	96.67 ^C	532.33 ^C	133.33 ^C
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	585.33 ^C	150.00 ^D	293.93 ^D	79.33 ^E	439.63 ^{EF}	114.67 ^E
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	648.67 ^B	158.67 ^C	301.67 ^D	91.33 ^{CD}	475.17 ^D	125.00 ^D
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	539.33 ^D	127.33 ^F	298.67 ^D	75.33 ^E	419.00 ^F	101.33 ^F
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	596.67 ^C	141.33 ^E	313.53 ^D	82.00 ^{DE}	455.10 ^{DE}	111.67 ^E
T ₇	Rec. FYM (10 t/ha) only	509.33 ^E	116.67 ^G	227.07 ^E	72.00 ^E	368.20 ^G	94.33 ^F
T ₈	Rec.NPK (160:80:80 kg /ha)	703.40 ^A	180.00 ^A	495.40 ^B	115.33 ^B	599.40 ^B	147.67 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	698.00 ^A	186.67 ^A	582.27 ^A	139.33 ^A	640.13 ^A	163.00 ^A
General Mean		614.45	154.59	366.27	94.00	490.36	124.30
CV (%)		2.32	3.22	8.92	6.77	3.45	3.46
LSD at 5%		24.65	8.61	56.56	11.01	29.29	7.43

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

Fresh weight of stems in basil (main and ratoon crop)

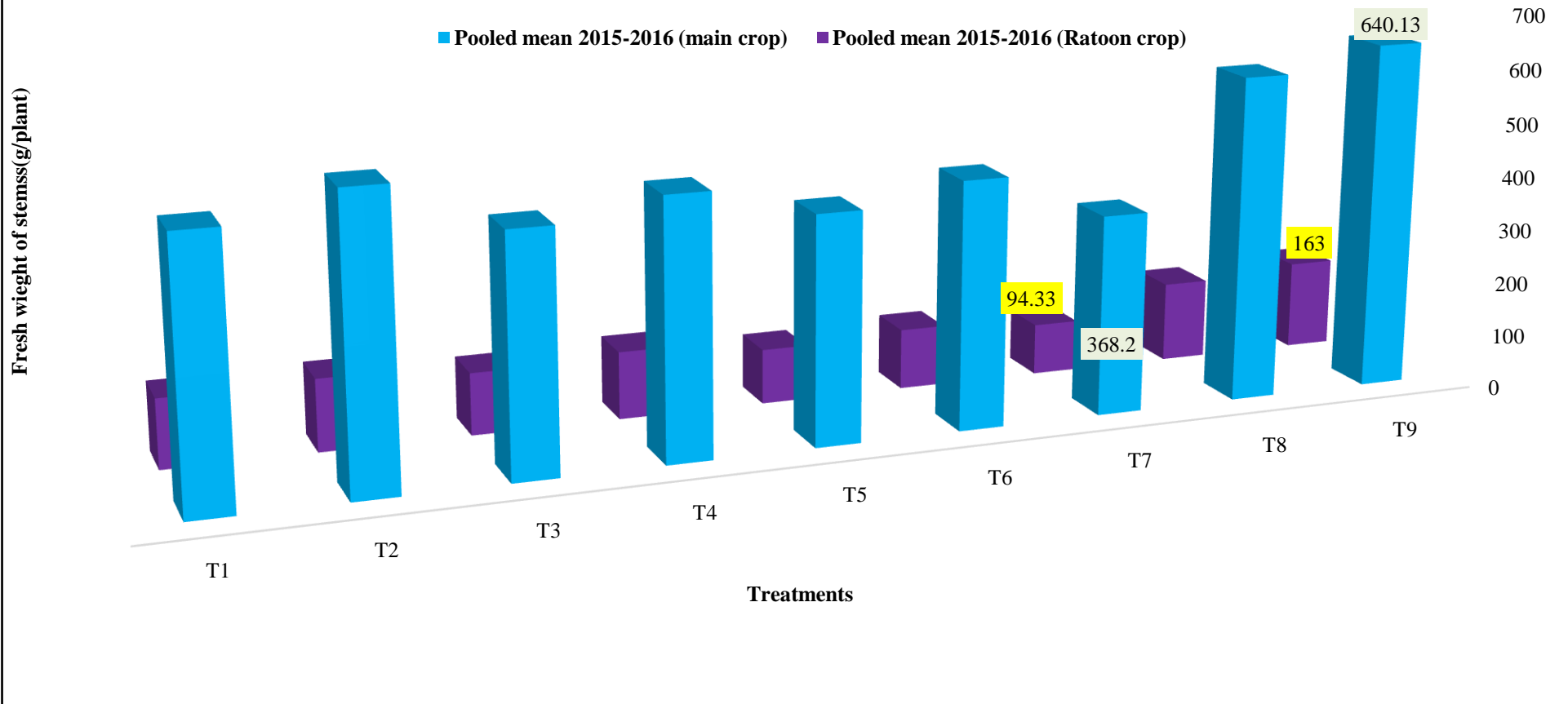


Fig.10: Fresh weight of stems (g/plant) in basil (*Ocimum basilicum*) as influenced by organic manure, bio-fertilizer and inorganic fertilizer during two years of the field experiment

with FYM recorded the highest value (96.67g/plant) with application of FYM (10 t/ha) +100% Rec. N through FYM + BF (T₂). In the pooled data of the ratoon the treatment differed significantly and the maximum fresh stem weight (163 g/plant) was recorded with application of NPK (160:80:80 Kg /ha) + FYM (10 t/ha) *i.e.*, T₉. While, the minimum value was observed in T₇ (94.33 g/plant).

4.1.2.3. Fresh weight of inflorescence (g/plant)

The data on effect of different levels of N through FYM with and without bio-fertilizers and inorganic fertilizer on fresh weight of inflorescence per plant are presented in Table 9. and Fig 11. As evident from the data, in the main crop during two years of the experimentation, there was significant difference between the treatments and the highest fresh inflorescence weight per plant was recorded with application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) *i.e.*, T₉ (168 and 138.33 g/plant) during kharif 2015, 2016 respectively, and it was found to be *on par* with T₈ (160 and 132 g/plant) and T₂ (153.67 and 123.33 g/plant) respectively. In the second harvest the fresh weigh of inflorescence was lower than the main crop and significant differences were observed between the treatments and application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) *i.e.*, T₉ recorded the highest fresh weight of inflorescence per plant (133.33 and 95.33 g/plant) during kharif 2015, 2016 respectively. Bio-fertilizer application effect could be observed with application of FYM (10 t/ha) +75% Rec. N through FYM + BF *i.e.*, T₄ during kharif 2015, it recorded the highest value (110 g/plant) between the bio-fertilizer treatments, While in the second year application of FYM (10 t/ha) +100% Rec. N through FYM + BF(T₂) recorded the highest value (78.67 g/pant).

In the pooled data of the main crop, significant differences between the treatments could be observed in respect to fresh weight of inflorescence per plant, the maximum value (153.17 g/plant) could be noticed with application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) *i.e.*, T₉. While, the minimum value was recorded in T₇ (106.17 g/plant). Similarly, in the second harvest (ratoon) maximum fresh weight of inflorescence was observed in T₉ (114.33 g/plant) and minimum value was in T₇ (69.67 g/plant) respectively.

Table 9. Fresh weight of inflorescence (g/plant) in basil (*Ocimum basilicum*) as influenced by organic manure, bio-fertilizers and inorganic fertilizer during two years of the field experiment

Treatments		2015		2016		Pooled	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	136.67 ^{BCD}	99.00 ^D	113.33 ^{CD}	68.67 ^{DE}	125.00 ^{BCD}	83.83 ^D
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	153.67 ^{ABC}	103.00 ^D	123.33 ^{ABC}	78.67 ^{BC}	138.50 ^{AB}	90.83 ^C
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	124.33 ^{DE}	90.00 ^E	112.67 ^{CD}	66.67 ^{DE}	118.50 ^{CDE}	78.33 ^E
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	132.00 ^{CDE}	110.00 ^C	121.83 ^{BC}	73.67 ^{CD}	126.92 ^{BC}	91.83 ^C
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	112.67 ^{DE}	80.00 ^F	106.53 ^D	62.00 ^E	109.60 ^{DE}	71.00 ^F
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	130.67 ^{CDE}	88.00 ^E	109.60 ^{CD}	67.33 ^{DE}	120.13 ^{CDE}	77.67 ^E
T ₇	Rec. FYM (10 t/ha) only	109.67 ^E	78.00 ^F	102.67 ^D	61.33 ^E	106.17 ^E	69.67 ^F
T ₈	Rec.NPK (160:80:80 kg /ha)	160.00 ^{AB}	114.67 ^B	132.00 ^{AB}	83.33 ^B	146.00 ^A	99.00 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	168.00 ^A	133.33 ^A	138.33 ^A	95.33 ^A	153.17 ^A	114.33 ^A
General Mean		136.41	99.56	117.81	73.00	127.11	86.28
CV%		10.92	2.33	7.45	7.30	7.66	3.44
LSD at 5%		25.78	4.00	15.18	9.21	16.86	5.14

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

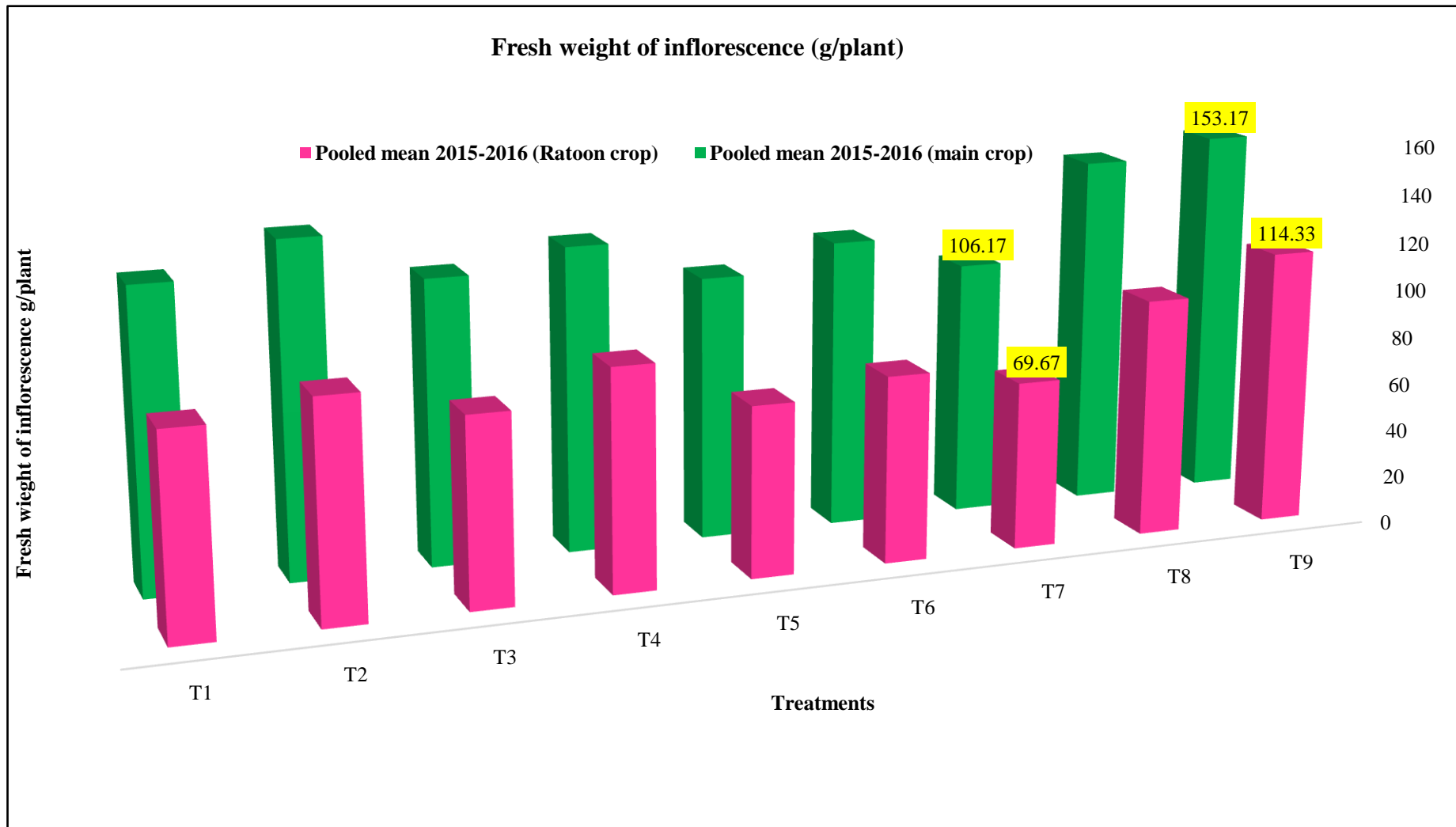


Fig. 11: Fresh weight of inflorescence (g/plant) in basil (*Ocimum basilicum*) as influenced by organic manure, bio-fertilizer and inorganic fertilizer during two years of the field experiment

4.1.2.4. Fresh herbage yield (g):

Application of different levels of N through FYM with and without bio-fertilizers and inorganic fertilizer differed significantly in respect to fresh weight of plant (g) in the main crop and ratoon during two years of the experiment as it presented in the Table 10. During kharif 2015, application of Rec. NPK (160:80:80 kg/ha) + FYM (10 t/ha) *i.e.*, T₉ recorded the maximum fresh weight (1039.67 g) and was statistically similar to T₈ NPK (160:80:80 kg /ha) as it recorded (1009.73 g) .Whereas, the treatment (T₂) recorded the highest value (945.93g) among the organic manure and biofertilizer applications. In the subsequent year the fresh weight of plant was lower, and the treatments differed significantly, the treatment T₉ significantly produced maximum fresh weight (957.93 g) when compared with rest of the treatments. Application of bio-fertilizer had positive impact and the treatment (T₂) FYM (10 t/ha) +100% Rec. N through FYM + BF produced maximum fresh herbage wieght (693.33g) when compared with other organic and biofertilizer treatments. However, in the pooled data application of Rec. NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ recorded the highest fresh weight (988.800 g) when compared with other treatments.While, the minimum value was recorded in T₇ (573.20 g).

Similarly, in ratoon application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ as soil fertilization significantly improved the fresh weight of plant over the other treatments (524.33, 444.32 and 484.33 g) during kharif 2015, 2016 and pooled data respectively. While, adoption of different levels of N through FYM differed significantly, and the treatment T₁ (425.87, 283.33 and 354.60 g) registered the highest value whereas the treatment T₇ had recorded the lowest one (314.67, 223.33 and 269 g) during kharif 2015, 2016 and pooled data respectively.

Table 10. Effect of organic manure, bio-fertilizers and inorganic fertilizer on fresh weight of whole plant (g) in the main crop and ratoon of basil (*Ocimum basilicum*) during two years of the field experimentation

Treatments		2015		2016		Pooled	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	832.67 ^C	425.87 ^D	648.00 ^C	283.33 ^C	740.45 ^D	354.63 ^D
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	945.93 ^B	464.67 ^C	693.33 ^C	307.66 ^B	819.63 ^C	386.16 ^C
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	810.00 ^C	390.67 ^E	543.26 ^D	254.66 ^D	676.33 ^{EF}	322.66 ^E
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	904.67 ^B	428.00 ^D	571.16 ^D	281.67 ^C	737.91 ^D	354.83 ^D
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	748.33 ^D	339.33 ^G	525.53 ^D	237.68 ^E	636.93 ^F	288.50 ^F
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	827.00 ^C	374.00 ^F	558.13 ^D	252.87 ^D	692.56 ^E	313.43 ^E
T ₇	Rec. FYM (10 t/ha) only	709.00 ^D	314.67 ^H	437.40 ^E	223.33 ^E	573.20 ^G	269 ^G
T ₈	Rec.NPK (160:80:80 kg /ha)	1009.73 ^A	489.67 ^B	823.23 ^B	372.99 ^B	920.98 ^B	431.33 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	1039.67 ^A	524.33 ^A	957.93 ^A	444.32 ^A	988.80 ^A	484.33 ^A
General Mean		869.67	416.80	640.85	295.93	753.94	365.09
CV%		3.15	2.21	5.75	3.83	3.09	1.67
LSD at 5%		47.45	15.91	63.87	17.91	40.49	9.93

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

4.1.2.5. Fresh herbage yield (kg)

The herbage yield (kg) as influenced by levels of N through FYM with and without bio-fertilizers and inorganic fertilizer applied during 2015 and 2016 is presented in Table 11. In the main crop as it is evident from data application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ recorded significantly the highest herbage yield between the other treatments (83.17 kg) while, and it was found to be *on par* with the treatment T₈ (80.78 kg) whereas, application of FYM (10 t/ha) +100% Rec. N through FYM + BF (T₂) recorded the highest value (75.67 kg) between the organic manure and bio-fertilizer treatments. During kharif 2016 same treatment *i.e.*, T₉ produced maximum herbage yield (76.63 kg) while, no positive trend could be observed due to bio-fertilizer application along with organic manure when compared with application of FYM alone. In the pooled data significant enhancement in the herbage yield could be observed in the treatment T₉ (79.90 kg) than rest of the other treatments, while the minimum value was recorded in T₇ (45.85 kg) with application of recommended dose of FYM only.

In the second harvest (ratoon) Addition of NPK (160:80:80 kg/ha) + FYM (10 t/ha) *i.e.*, T₉ significantly improved the herbage yield (41.95, 35.55 and 38.75 kg) than the rest of other treatments, while among biofertilizer applications, the treatment (T₂) FYM (10 t/ha) +100% Rec. N through FYM + BF recorded the maximum value (37.17, 24.61 and 30.89 kg) during kharif 2015, 2016 and pooled data respectively.

4.1.2.6. Fresh herbage yield (t/ha)

The fresh herbage yield in basil differed significantly due to application of different levels of N through FYM with and without bio-fertilizers and inorganic fertilizer in the main crop and ratoon during two years of the experiment as it is evident in Table 12. and Fig 12-15. application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) *i.e.*, T₉ recorded significantly the highest herbage yield in the main crop (41.59, 38.31 and 39.96 t/ha) during kharif 2015, 2016 and pooled data respectively. While, the treatment (T₂) FYM (10 t/ha) +100% Rec. N through FYM + BF recorded the maximum fresh herbage yield between the other organic and biofertilizer application (37.84, 27.73 and 32.78 t/ha) during kharif 2015, 2016 and pooled data respectively.

Table 11. Effect of organic manure, bio-fertilizers and inorganic fertilizer on fresh hrbage yield (kg) in the main crop and ratoon of basil (*Ocimum basilicum*) during two years of the field experiment

Treatments		2015		2016		Pooled	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	66.61 ^C	34.07 ^D	51.88 ^C	22.67 ^C	59.25 ^D	28.37 ^D
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	75.67 ^B	37.17 ^C	55.46 ^C	24.61 ^B	65.57 ^C	30.89 ^C
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	64.80 ^C	31.25 ^E	43.46 ^D	20.37 ^D	54.13 ^{EF}	25.81 ^E
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	72.37 ^B	34.24 ^D	48.69 ^D	22.53 ^C	59.03 ^D	28.39 ^D
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	59.87 ^D	27.15 ^G	42.04 ^D	19.01 ^E	50.95 ^F	23.08 ^F
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	66.16 ^C	29.92 ^F	44.65 ^D	20.23 ^D	55.40 ^E	25.07 ^E
T ₇	Rec. FYM (10 t/ha) only	56.72 ^D	25.17 ^H	33.99 ^E	17.87 ^E	45.85 ^G	21.52 ^G
T ₈	Rec.NPK (160:80:80 kg /ha)	80.78 ^A	39.17 ^B	66.57 ^B	29.84 ^B	73.67 ^B	34.51 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	83.17 ^A	41.95 ^A	76.63 ^A	35.55 ^A	79.90 ^A	38.75 ^A
General Mean		69.57	33.34	51.27	23.67	60.42	28.51
CV%		3.15	2.21	5.72	3.83	3.07	1.67
LSD at 5%		3.79	1.27	5.08	1.43	3.21	0.79

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

Table 12. Fresh herbage yield (t/ha) of basil (*Ocimum basilicum*) as influenced by organic manure, bio-fertilizers and inorganic fertilizer

Treatments	2015			2016			Pooled		
	Main crop	Ratoon	Cumulative yield	Main crop	Ratoon	Cumulative yield	Main crop	Ratoon	Cumulative yield
T ₁	33.31 ^C	17.03 ^D	50.34 ^E	25.94 ^C	11.33 ^C	37.27 ^C	29.62 ^D	14.18 ^D	43.8 ^E
T ₂	37.84 ^B	18.59 ^C	56.43 ^C	27.73 ^C	12.31 ^B	40.04 ^C	32.78 ^C	15.45 ^C	48.2 ^C
T ₃	32.40 ^C	15.63 ^E	48.03 ^E	21.73 ^D	10.19 ^D	31.92 ^{DE}	27.06 ^{EF}	12.91 ^E	40.0 ^E
T ₄	36.19 ^B	17.12 ^D	53.31 ^D	22.84 ^D	11.27 ^C	34.11 ^D	29.51 ^D	14.19 ^D	43.7 ^D
T ₅	29.93 ^D	13.57 ^G	43.47 ^F	21.02 ^D	9.51 ^E	30.53 ^E	25.47 ^F	11.54 ^F	37.0 ^F
T ₆	33.08 ^C	14.96 ^F	48.04 ^E	22.32 ^D	10.11 ^D	32.43 ^{DE}	27.70 ^E	12.54 ^E	40.2 ^E
T ₇	28.36 ^D	12.59 ^H	40.95 ^G	17.49 ^E	8.93 ^E	26.42 ^F	22.92 ^G	10.76 ^G	33.7 ^G
T ₈	40.39 ^A	19.59 ^B	59.98 ^B	33.28 ^B	14.92 ^B	48.2 ^B	36.83 ^B	17.25 ^B	54.1 ^B
T ₉	41.59 ^A	20.97 ^A	62.56 ^A	38.31 ^A	17.77 ^A	56.08 ^A	39.95 ^A	19.37 ^A	59.3 ^A
General Mean	34.79	16.67	51.46	27.05	10.82	37.44	30.21	14.25	44.45
CV%	3.15	2.21	2.19	5.72	3.83	4.58	3.07	1.67	3.38
LSD at 5%	1.89	0.63	1.95	2.54	0.71	2.88	1.61	0.39	2.41

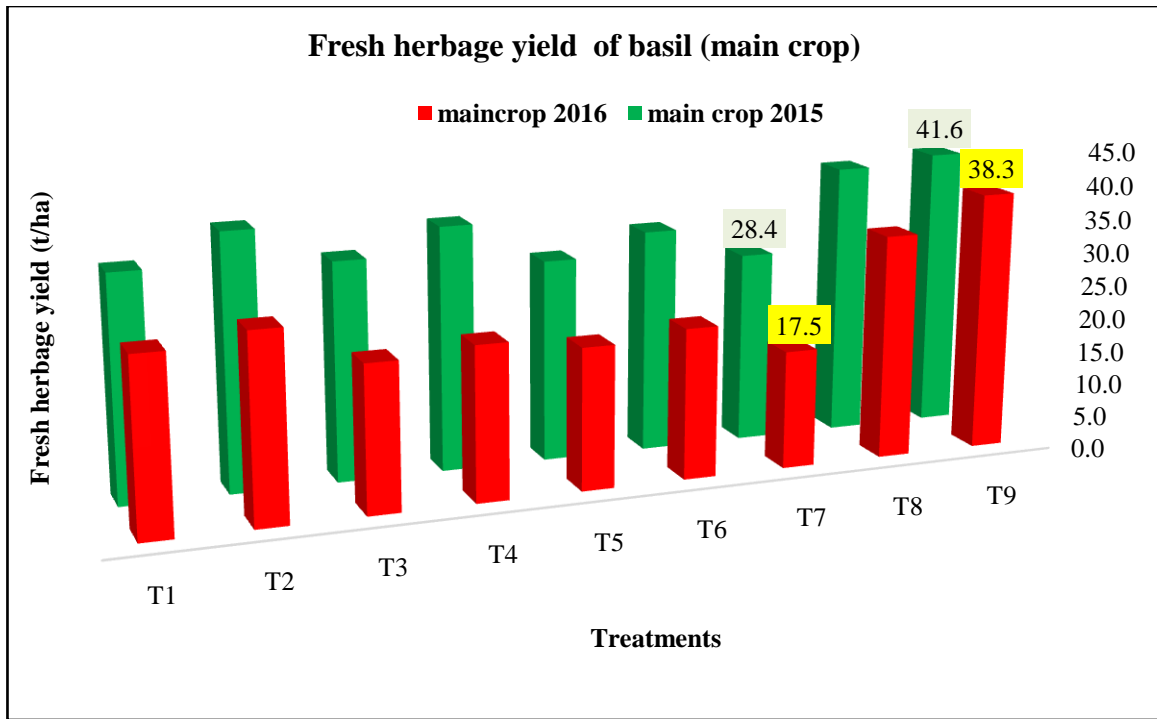


Fig. 12: Fresh herbage yield (t/ha) in basil main crop as influenced by organic manure, bio-fertilizer and inorganic fertilizer

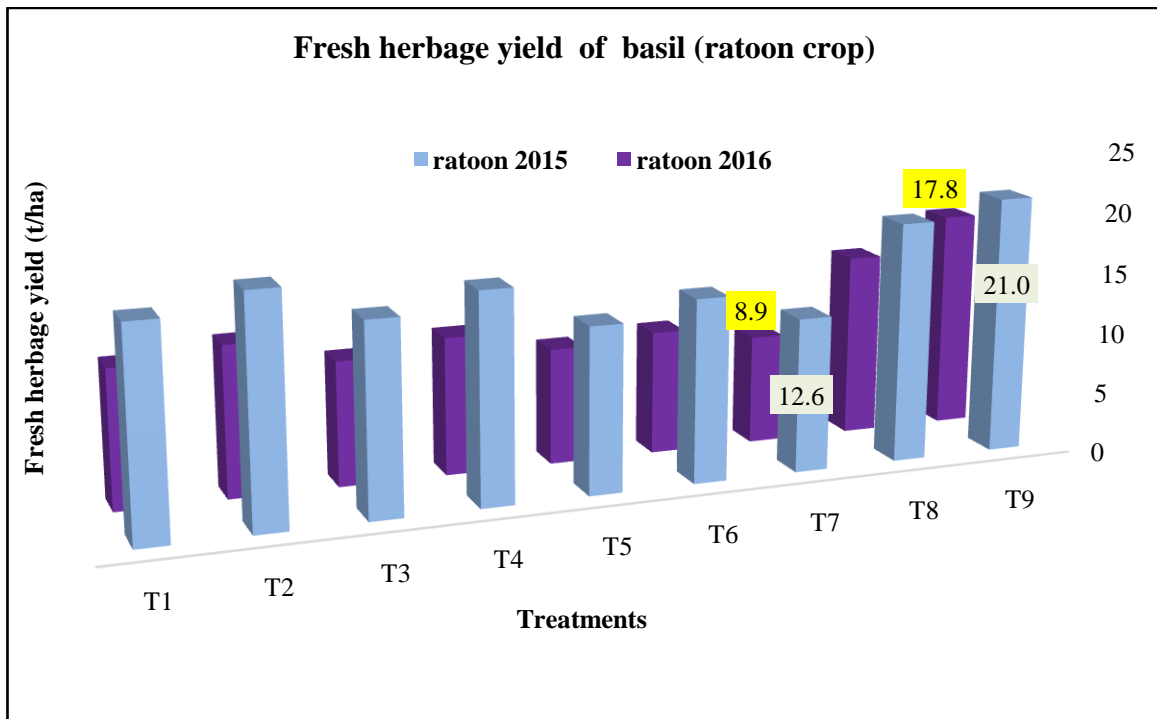


Fig. 13: Fresh herbage yield (t/ha) in basil ratoon crop as influenced by organic manure, bio-fertilizer and inorganic fertilizer

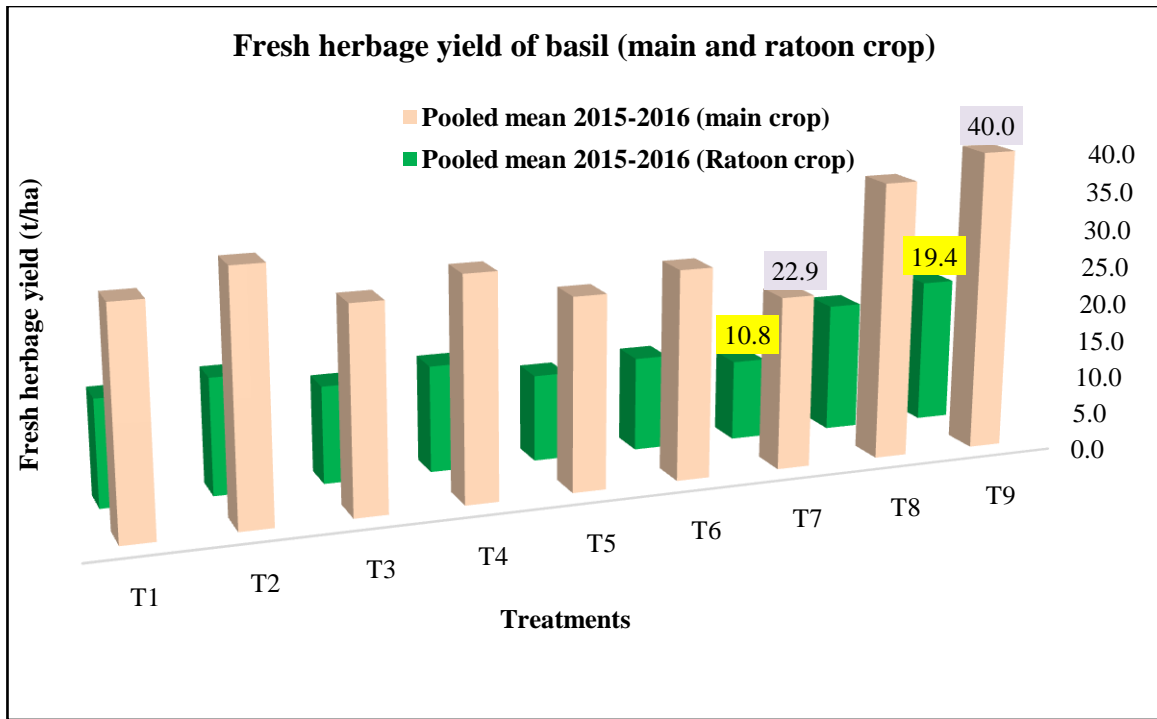


Fig. 14: Fresh herbage yield (t/ha) of basil pooled data of main crop and ratoon as influenced by organic manure, bio-fertilizer and inorganic fertilizer

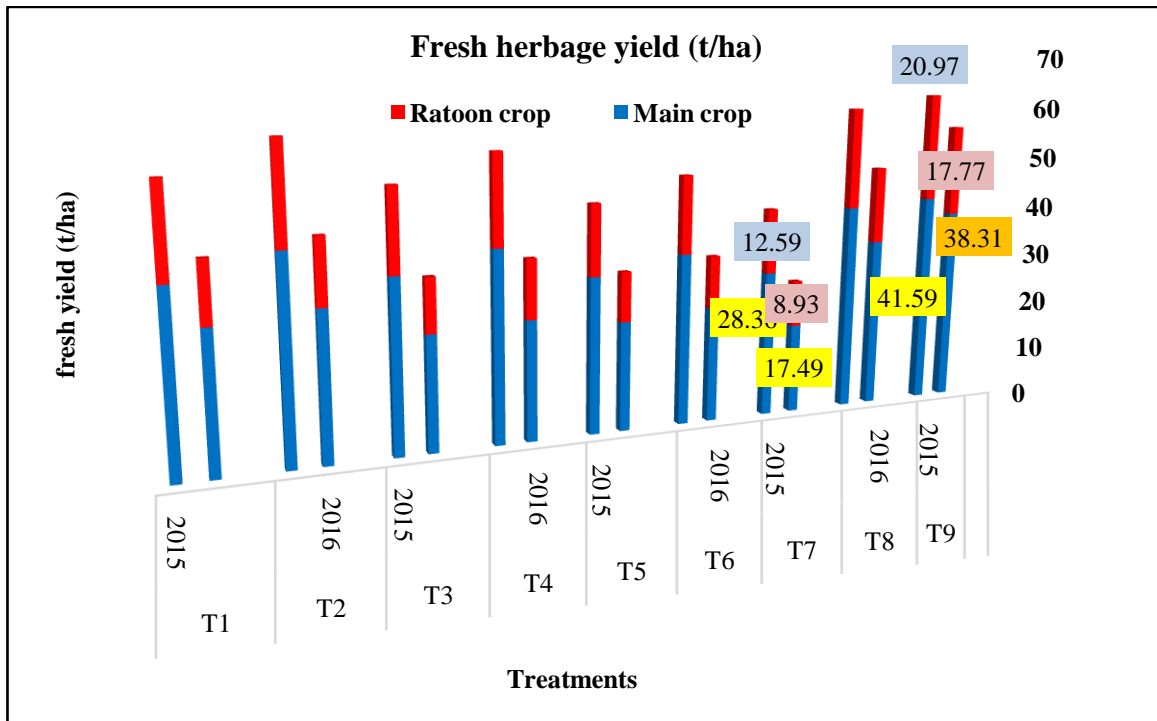


Fig. 15: Cumulative fresh herbage yield (t/ha) of basil (*Ocimum basilicum*) as influenced by organic manure, bio-fertilizer and inorganic fertilizer

The fresh herbage yield in the second harvest was lower than the first one and the treatment (T₉) NPK (160:80:80 kg/ha) + FYM (10 t/ha) recorded significantly the highest value (20.97, 17.77 and 19.37 t/ha) during kharif 2015, 2016 and pooled data respectively. Whereas, the treatment (T₂) FYM (10 t/ha) +100% Rec. N through FYM + BF registered significantly the highest value between the other applied levels (18.59, 12.31 and 15.45 t/ha) during kharif 2015, 2016 and pooled data respectively. For cumulative herbage yield application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ recorded significantly the highest cumulative herbage yield (62.56, 56.08 and 59.3 t/ha) while, the minimum value (40.95, 26.42 and 33.7 t/ha) was recorded in T₇ during 2015 and 2016 and the pooled data respectively.

4.1.2.7. Dry weight of leaves (g/plant):

The data on dry weight of leaves per plant as affected by application of different levels of N through FYM with and without bio-fertilizers and inorganic fertilizer is given table 13. The plant that manured NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ recorded the maximum dry weight of leaves in the main crop (34.67, 45.60 and 40.14 g/plant) and ratoon (40.80, 39.46 and 40.13 g/plant) during kharif 2015, 2016 and pooled data respectively. There were no significant differences between different levels of N through FYM in respect to dry weight of leaves. And no significant trend could be observed due to application of bio-fertilizer. However the treatment (T₂) FYM (10 t/ha) +100% Rec. N through FYM + BF recorded the highest dry weight in the main crop and ratoon during kharif 2015 (26.11 and 36.87 g/plant), (39.47 and 24.80 g/plant) during kharif 2016 and (32.79 and 30.83 g/plant) in the pooled data respectively.

4.1.2.8. Dry weight of stem (g/plant):

The information pertaining to dry weight of stem is presented in Table 14. It was significantly influenced with application of different levels of N through FYM with and without bio-fertilizers and inorganic fertilizer in the main crop and ratoon during two years of the experiment.

Table 13. Dry weight of leaves (g/plant) in basil (*Ocimum basilicum*) as influenced by organic manure, bio-fertilizers and inorganic fertilizer during two years of the field experiment

Treatments		2015		2016		Pooled	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	21.8 ^{CD}	28.8 ^{BC}	32.20 ^{CD}	22.67 ^{CD}	27.02 ^{DE}	25.73 ^{DE}
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	26.1 ^{BC}	36.87 ^A	39.47 ^{BC}	24.80 ^C	32.79 ^{BC}	30.83 ^C
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	19.7 ^D	27.3 ^{BC}	28.53 ^D	21.40 ^{DE}	24.10 ^{DEF}	24.33 ^{DE}
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	25.1 ^{BC}	29.8 ^B	31.27 ^{CD}	22.73 ^{CD}	28.21 ^{CD}	26.30 ^D
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	19.4 ^D	24.6 ^{CD}	25.93 ^D	18.53 ^{EF}	22.67 ^{EF}	21.60 ^{FG}
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	20.2 ^D	27.0 ^{BC}	29.07 ^D	20. ^{DEF}	24.63 ^{DEF}	23.50 ^{EF}
T ₇	Rec. FYM (10 t/ha) only	18.3 ^D	22.13 ^D	23.53 ^D	17.73 ^F	20.91 ^F	19.93 ^G
T ₈	Rec.NPK (160:80:80 kg /ha)	29.8 ^B	38.67 ^A	39.60 ^{AB}	33.53 ^B	34.7 ^{AB}	36.01 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	34.6 ^A	40.80 ^A	45.60 ^A	39.46 ^A	40.14 ^A	40.13 ^A
General Mean		23.91	30.67	33.91	24.54	28.91	26.64
CV%		11.49	9.07	15.51	7.79	10.48	5.14
LSD at 5%		4.75	4.81	8.84	3.30	5.24	2.37

Legend: FYM- Farm Yard Manure

Rec. – Recommended

BF – Bio- fertilizer

During kharif 2015, in the main crop application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ recorded the highest dry weight of stem (135.07 g/plant) and it was *on par* with T₈ (128.43 g/plant) among different levels of N through organic manure treatments, the highest level of N in (T₁) FYM (10 t/ha) +100% Rec. N through FYM recorded the highest dry weight of stem (111.22 g/plant) while the minimum was recorded in T₇ (93.19 g/plant). Application of bio-fertilizer along with organic manure had increased the dry weight of stem and that was noticed in T₂ and T₄ (125.75 and 121.95 g/plant), respectively and was on par with T₈ (128.34g/plant). In the second harvest (ratoon) of the same year the dry weight of stem was lower than the main crop Similarly, application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ recorded the maximum value (35.07 g/plant). However the minimum value was recorded in T₇ (19.67g/plant) with application of Rec. FYM alone. While the bio-fertilizer application increased the dry weight comparing with FYM alone, and the highest value could be observed in (T₂) FYM (10 t/ha) +100% Rec. N through FYM + BF (29.20 g/plant) among the other bio-fertilizer applications. During Kharif 2016, in the main crop, the dry weight of stem was lower comparing with the first year. The treatments differed significantly and maximum dry weight of stem (107.94 g/plant) was observed in T₉ with application of NPK (160:80:80 kg/ha) + FYM (10 t/ha). No significant trend could be observed due to bio-fertilizer application when it was applied along with organic manure when compared with application of FYM alone. However, the maximum level of N through rganic manure in (T₁) FYM (10 t/ha) +100% Rec. N through FYM recorded the maximum dry weight of stem (69.40 g/plant) among the other treatments. In the second harvest (ratoon), the treatment (T₉) was significantly different from the other treatment, and it recorded the highest value (27.08 g/plant) while, no significant trend could be observed due to application of bio-fertilizer. However between different levels of N through organic manure, the maximum level of N through FYM in (T₁) FYM (10 t/ha) +100% Rec. N recorded the highest dry weight of stem (17.04 g/plant) while the minimum was recorded in T₇ (13.67g/plant). In the pooled data of the main crop and ratoon, maximum dry weight of stem (121.51 and 31.07 g/plant) could be observed with application of Rec. NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ followed by T₈ (109.72, 27.69 g/plant) while, the minimum value was in T₇ (67.26 and 16.67 g/plant) respectively.

Table 14. Dry weight of stems (g/plant) in basil (*Ocimum basilicum*) as influenced by organic manure, bio-fertilizers and inorganic fertilizer during two years of the field experiment

Treatments		2015		2016		Pooled	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	111.22 ^C	27.60 ^{CD}	69.40 ^C	17.04 ^C	90.31 ^D	22.32 ^{CD}
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	125.75 ^B	29.20 ^C	73.29 ^C	17.16 ^C	99.52 ^C	23.18 ^C
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	109.87 ^C	24.60 ^{EF}	53.26 ^D	14.64 ^{DE}	81.57 ^{EF}	19.62 ^{EF}
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	121.95 ^B	27.20 ^{CD}	55.82 ^D	16.43 ^{CD}	88.89 ^D	21.81 ^{CD}
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	101.92 ^D	22.87 ^F	55.46 ^D	13.94 ^E	78.69 ^F	18.40 ^{FG}
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	113.37 ^C	26.37 ^{DE}	57.91 ^D	15.5 ^{CDE}	85.64 ^{DE}	20.95 ^{DE}
T ₇	Rec. FYM (10 t/ha) only	93.19 ^E	19.67 ^G	41.34 ^E	13.67 ^E	67.26 ^G	16.67 ^G
T ₈	Rec.NPK (160:80:80 Kg /ha)	128.43 ^{AB}	32.47 ^B	91.01 ^B	22.92 ^B	109.72 ^B	27.69 ^B
T ₉	Rec. NPK (160:80:80 Kg /ha)+ Rec. FYM (10 t/ha)	135.07 ^A	35.07 ^A	107.94 ^A	27.08 ^A	121.51 ^A	31.07 ^A
General Mean		115.64	27.23	67.27	17.60	91.46	22.41
CV%		3.39	5.38	8.36	7.13	3.50	5.21
LSD at 5%		6.78	2.53	9.73	2.17	5.54	2.01

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

4.1.2.9. Dry weight of inflorescence (g/plant)

The data pertaining to dry weight of inflorescence per plant as influenced by different levels of N through FYM with and without bio-fertilizers and inorganic fertilizer applied during 2015 and 2016 is presented in Table 15 and fig. 14. In the main crop, during 2015, there was significant differences between the treatments, Application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) i.e., T₉ significantly increased the dry weight of inflorescence per plant (47.93 g/plant) over the other treatments. While in the second year there was no significant differences in respect to dry weight of inflorescence among the treatments. In the second harvest (ratoon) the treatment T₉ recorded the highest value (32 and 23.80 g/plant) during kharif 2015, 2016 respectively. While the treatment T₂ recorded maximum dry weight of inflorescence per plant among biofertilizer along with organic manure applications (25.33 and 19.20 g/plant) during kharif 2015, 2016 respectively. In the pooled data, application of recommended dose of chemical fertilizers along with FYM (10 t/ha) i.e., T₉ recorded significantly highest value in respect to dry weight of inflorescence per plant (47.21 and 27.90 g/plant) in the main crop and ratoon respectively. While, the lowest value was observed in T₇ (28.75 and 15.37 g/plant) respectively.

4.1.2.10. Dry weight of whole plant (g)

The data pertaining to dry yield (g/plant) as influenced by different of levels of N through FYM with and without bio-fertilizers and inorganic fertilizer applied during 2015 and 2016 is presented in Table 16. Among the different treatments, application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) i.e., T₉ significantly recorded the highest dry herbage per plant in the main crop (217.67, 204.04 and 210.85 g) and in ratoon (107.87, 80.34 and 94.11 g) While, application of bio-fertilizer recorded the maximum dry herbage yield in (T₂) FYM (10 t/ha) +100% Rec. N through FYM + BF in the main crop (192.80, 155.89 and 174.34g) and ratoon (91.40, 61.16 and 76.28g) during kharif 2015, 2016 and pooled data respectively. Whereas, the treatment with recommended dose of FYM alone (T₇) registered the lowest dry herbage yield (g/plant) among the all treatments in the main crop (138.51, 101.34 and 119.92 g) and in ratoon (58.47, 45.47 and 51.97g) during kharif 2015, kharif 2016 and in pooled data respectively.

Table 15. Dry weight of inflorescence (g/plant) in basil (*Ocimum basilicum*) as influenced by organic manure, bio-fertilizers and inorganic fertilizer during two years of the field experiment

	Treatments	2015		2016		Pooled	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	33.67 ^{BC}	22.33 ^D	36.00	17.87 ^{BC}	34.83 ^{CD}	20.10 ^{CD}
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	40.93 ^{AB}	25.33 ^C	43.13	19.20 ^B	42.03 ^{ABC}	22.27 ^{BC}
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	29.94 ^C	20.33 ^{DE}	36.53	15.67 ^{CD}	33.24 ^D	18.00 ^{DE}
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	36.08 ^{BC}	26.00 ^{BC}	36.87	17.20 ^{BCD}	36.48 ^{BCD}	21.60 ^C
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	28.19 ^C	18.67 ^{EF}	31.37	15.40 ^{CD}	29.78 ^D	17.03 ^{EF}
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	34.10 ^{BC}	18.33 ^{EF}	31.60	17.13 ^{BCD}	32.85 ^D	17.73 ^E
T ₇	Rec. FYM (10 t/ha) only	27.03 ^C	16.67 ^F	30.47	14.07 ^D	28.75 ^D	15.37 ^F
T ₈	Rec.NPK (160:80:80 kg /ha)	41.71 ^{AB}	27.67 ^B	45.33	20.00 ^B	43.52 ^{AB}	23.83 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	47.93 ^A	32.00 ^A	46.50	23.80 ^A	47.21 ^A	27.90 ^A
General Mean		35.51	23.04	38.20	17.81	36.85	20.43
CV%		15.19	5.18	21.60	10.66	0.0012	6.22
LSD at 5%		9.33	2.06	NS	3.28	11.51	2.2

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

Table 16. Effect of organic manure, bio-fertilizers and inorganic fertilizer on dry herbage yield (g/plant) in the main crop and ratoon of basil during two years of the field experiment

Treatments		2015		2016		Pooled	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	166.73 ^D	78.73 ^D	137.60 ^{CD}	57.57 ^{CD}	152.16 ^{CD}	68.15 ^D
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	192.80 ^{BC}	91.40 ^C	155.89 ^C	61.16 ^C	174.35 ^C	76.28 ^C
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	159.47 ^{DE}	72.20 ^E	118.3 ^{DEF}	51.71 ^{FG}	138.9 ^{DEF}	61.95 ^E
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	183.20 ^C	83.07 ^D	123.95 ^{DE}	56.36 ^{DE}	153.58 ^{DE}	69.71 ^D
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	149.52 ^{EF}	66.20 ^F	112.76 ^{EF}	47.87 ^{GH}	131.14 ^{EF}	57.03 ^F
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	167.66 ^D	71.70 ^{EF}	118.6 ^{DEF}	52.67 ^{EF}	143.12 ^{DEF}	62.19 ^E
T ₇	Rec. FYM (10 t/ha) only	138.51 ^F	58.47 ^G	101.34 ^F	45.47 ^H	119.9 ^F	51.97 ^G
T ₈	Rec.NPK (160:80:80 kg /ha)	199.99 ^B	98.80 ^B	181.94 ^B	69.12 ^B	119.9 ^B	83.96 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	217.67 ^A	107.87 ^A	204.04 ^A	80.34 ^A	210.85 ^A	94.11 ^A
General Mean		175.06	80.94	139.38	58.03	157.22	69.48
CV%		4.09	4.15	8.79	4.26	3.98	3.32
LSD at 5%		12.39	5.81	21.20	4.27	10.83	3.99

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

4.1.2.11. Dry herbage yield (kg)

Application of different levels of N through FYM with and without bio-fertilizers and inorganic fertilization significantly influenced the dry herbage yield (kg/m^2) in the main crop and ratoon during both years of the experiment as shown in the Table 17. In the main crop, application of inorganic fertilizer NPK (160:80:80 kg /ha) along with organic manure FYM (10 t/ha) i.e., T_9 recorded significantly the maximum dry herbage yield (17.41, 16.32 and 16.87 kg/m^2) during kharif 2015, 2016 and pooled data respectively. In the next harvest (ratoon) the dry herbage yield was lower compared with the main crop, and the treatment (T_9) NPK (160:80:80 Kg /ha) + FYM (10 t/ha) recorded the maximum dry herbage yield (8.63, 6.43 and 7.53 kg/m^2) during kharif 2015, 2016 and pooled data respectively. Application of bio-fertilizer along with organic manure significantly influenced the dry herbage yield in the main crop (15.42, 12.47 and 13.95 kg/m^2) and in ratoon (7.31, 4.89 and 6.10 kg/m^2) during kharif 2015, 2016 and pooled data respectively. Whereas, application of Rec. FYM alone recorded significantly the lowest dry herbage yield in the main crop (11.08 and 8.11 kg/m^2) and in ratoon (4.68 and 3.64 kg/m^2) during two years of the experiments.

4.1.2.12. Dry herbage yield (t/ha):

The data pertaining to dry herbage yield (t/ha) as influenced by different levels of N through FYM with and without bio-fertilizers and inorganic fertilizer is shown in the Table 18. and Fig 16-17The treatment (T_9) NPK (160:80:80 Kg /ha) + FYM (10 t/ha) registered the maximum value in the main crop (8.71, 8.16 and 8.43 t/ha) and ratoon (4.31, 3.21 and 3.76 t/ha) during kharif 2015, 2016 and pooled data respectively. Among the biofertilizer treatments application of FYM (10 t/ha) +100% Rec. N through FYM + BF i.e., T_2 recorded maximum dry herbage yield in the main (7.71, 6.24 and 6.97 t/ha) and in ratoon (3.66, 2.45 and 3.05 t/ha) during kharif 2015, 2016 and pooled data respectively. For cumulative dry herbage yield application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) i.e., T_9 recorded significantly the highest value (13.02, 11.37 and 12.19 t/ha) while, the minimum one (7.88, 5.87 and 6.87 t/ha) was recorded in T_7 during 2015, 2016 and in the pooled data respectively.

Table 17. Effect of organic manure, bio-fertilizers and inorganic fertilizer on dry herbage yield (kg) in the main crop and ratoon of basil (*Ocimum basilicum*) during two years of the field experiment

Treatments		2015		2016		Pooled	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	13.34 ^D	6.30 ^D	11.01 ^{CD}	4.61 ^{CD}	12.17 ^D	5.45 ^D
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	15.42 ^{BC}	7.31 ^C	12.47 ^C	4.89 ^C	13.95 ^C	6.10 ^C
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	12.76 ^{DE}	5.78 ^E	9.47 ^{DEF}	4.14 ^{FG}	11.11 ^{EF}	4.96 ^E
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	14.66 ^C	6.65 ^D	9.92 ^{DE}	4.51 ^{DE}	12.29 ^D	5.58 ^D
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	11.96 ^{EF}	5.30 ^F	9.02 ^{EF}	3.83 ^{GH}	10.49 ^F	4.56 ^F
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	13.41 ^D	5.74 ^{EF}	9.49 ^{DEF}	4.21 ^{EF}	11.45 ^{DE}	4.97 ^E
T ₇	Rec. FYM (10 t/ha) only	11.08 ^F	4.68 ^G	8.11 ^F	3.64 ^H	9.59 ^G	4.16 ^G
T ₈	Rec.NPK (160:80:80 kg /ha)	16.00 ^B	7.90 ^B	14.56 ^B	5.53 ^B	15.28 ^B	6.72 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	17.41 ^A	8.63 ^A	16.32 ^A	6.43 ^A	16.87 ^A	7.53 ^A
General Mean		14.00	6.47	11.15	4.64	12.58	5.56
CV%		4.09	4.15	8.79	4.26	3.98	3.32
LSD at 5%		0.99	0.46	1.69	0.34	0.86	0.31

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

Table 18. Dry herbage yield (t/ha) of basil (*Ocimum basilicum*) as influenced by organic manure, bio-fertilizers and inorganic fertilizer

Treatments	2015			2016			Pooled		
	Main crop	Ratoon	Cumulative yield	Main crop	Ratoon	Cumulative yield	Main crop	Ratoon	Cumulative yield
T ₁	6.67 ^D	3.15 ^D	9.82 ^E	5.50 ^{CD}	2.30 ^{CD}	7.8 ^{CD}	6.09 ^D	2.73 ^D	8.81 ^E
T ₂	7.71 ^{BC}	3.66 ^C	11.37 ^C	6.24 ^C	2.45 ^C	8.69 ^C	6.97 ^C	3.05 ^C	10.03 ^C
T ₃	6.38 ^{DE}	2.89 ^E	9.27 ^E	4.73 ^{DEF}	2.07 ^{FG}	6.8 ^{DEF}	5.56 ^{EF}	2.48 ^E	8.03 ^E
T ₄	7.33 ^C	3.32 ^D	10.65 ^D	4.96 ^{DE}	2.25 ^{DE}	7.21 ^{DE}	6.14 ^D	2.79 ^D	8.93 ^D
T ₅	5.98 ^{EF}	2.65 ^F	8.63 ^F	4.51 ^{EF}	1.91 ^{GH}	6.42 ^{EF}	5.25 ^F	2.28 ^F	7.52 ^F
T ₆	6.71 ^D	2.87 ^{EF}	9.58 ^E	4.74 ^{DEF}	2.11 ^{EF}	6.85 ^{DEF}	5.72 ^{DE}	2.49 ^E	8.21 ^E
T ₇	5.54 ^F	2.34 ^G	7.88 ^G	4.05 ^F	1.82 ^H	5.87 ^F	4.80 ^G	2.08 ^G	6.87 ^G
T ₈	8.00 ^B	3.95 ^B	11.95 ^B	7.28 ^B	2.76 ^B	10.04 ^B	7.64 ^B	3.36 ^B	10.99 ^B
T ₉	8.71 ^A	4.31 ^A	13.02 ^A	8.16 ^A	3.21 ^A	11.37 ^A	8.43 ^A	3.76 ^A	12.19 ^A
General Mean	7.00	3.24	10.24	5.58	2.32	7.89	6.29	2.78	9.0
CV%	4.09	4.15	2.91	8.79	4.26	6.63	3.98	3.32	4.77
LSD at 5%	0.49	0.23	0.51	0.84	0.17	0.90	0.43	0.15	0.7

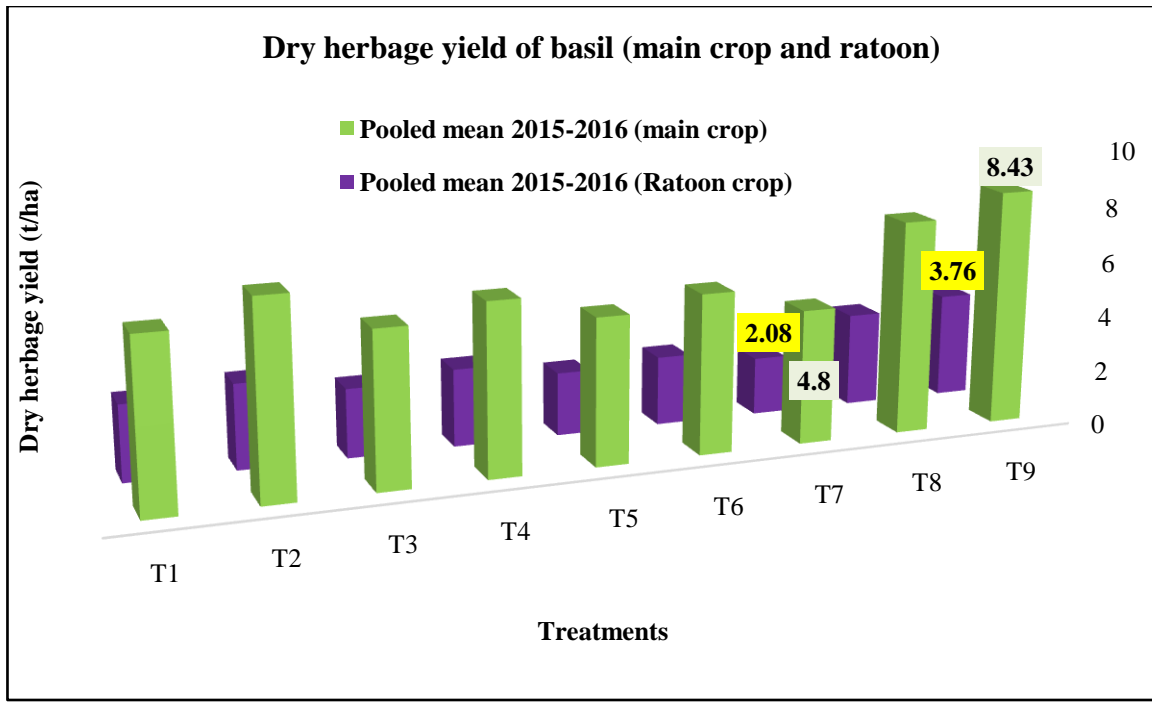


Fig. 16: Dry herbage yield (t/ha) in basil (*Ocimum basilicum*) main crop and ratoon as influenced by organic manure, bio-fertilizer and inorganic fertilizer during two years of the field experiment.

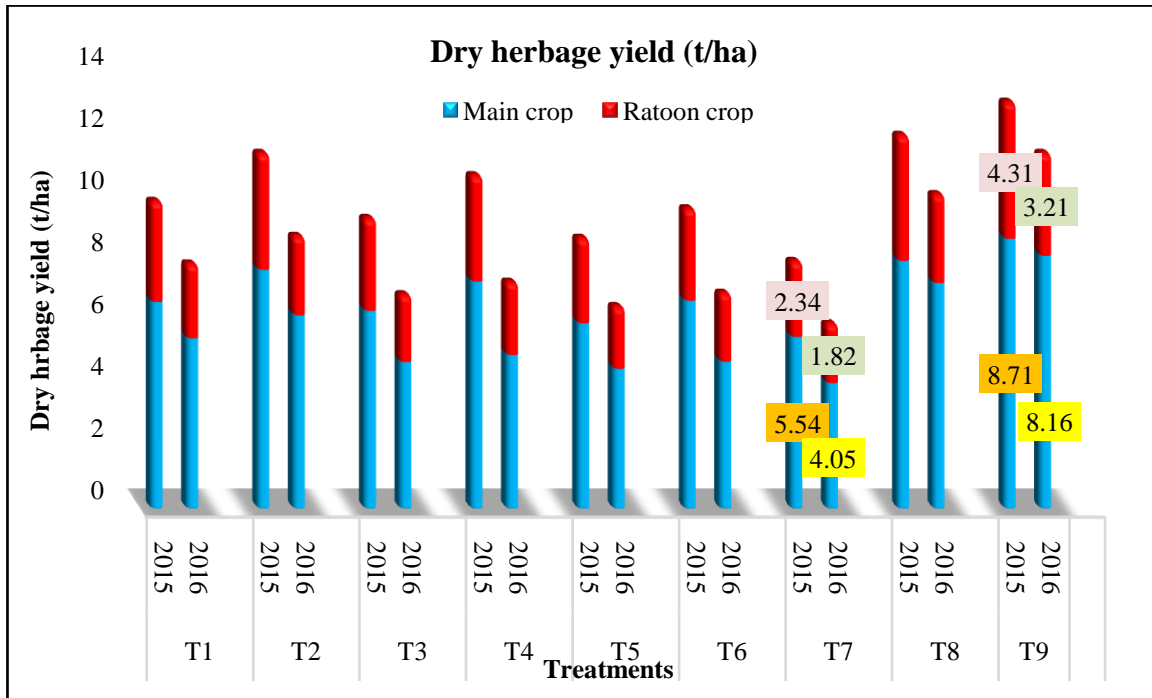


Fig. 17: Cumulative dry herbage yield (t/ha) of basil as influenced by organic manure, bio-fertilizer and inorganic fertilizer

4.1.2.13. Oil per cent (%)

Oil per cent (%) as affected by different levels of N through FYM with and without bio-fertilizers and inorganic fertilization is presented in Table 19. and fig.18. Application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ recorded highest oil percent among the treatments in the main crop (0.50, 0.46 and 0.48%) and in ratoon (0.40, 0.50 and 0.45%) during 2015, 2016 and pooled data respectively. While, minimum value was observed in T₇ in the main crop (0.33 and 0.28%), in ratoon (0.17 and 0.18%) and in pooled data (0.31 and 0.17%) during 2015 and 2016 respectively.

4.1.2.14. Oil yield (l/ha)

Oil yield per hectare differed significantly among the treatments as shown in Table 20, and fig. 19. a to 19. d. Application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ recorded highest oil yield among the treatments in the main crop (211.94, 187.46 and 199.7 l/ha) and in ratoon (144.36, 70.81 and 107.58 l/ha) during 2015, 2016 and pooled data respectively. Whereas, lowest oil yield per hectare was recorded with recommended dose of FYM alone in T₇ in the main crop (95.13 and 52.40 l/ha) in ratoon (38.52 and 15.36 l/ha) during 2015 and 2016 respectively, and in the pooled data (73.8 and 26.94 l/ha). Application of bio-fertilizer along with FYM increased the oil yield, and the treatment T₂ FYM (10 t/ha) + 100% Rec. N through FYM + BF registered significantly the highest value between the other applied levels in the main crop (182.04, 123.13 and 152.6 l/ha) and ratoon (111.96, 56.07 and 84.02 l/ha) during kharif 2015, 2016 and pooled data respectively. For cumulative oil yield application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ recorded significantly the highest value (356.3, 258.27 and 307.28 l/ha) while, the minimum value (133.65, 67.76 and 100.70 l/ha) was recorded in T₇ during 2015, 2016 and pooled data respectively.

Table 19. Effect of organic manure, bio-fertilizers and inorganic fertilizer on oil per cent (%) in the main crop and ratoon of basil (*Ocimum basilicum*) during two years of the field experiment

Treatments		2015		2016		Pooled	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	0.45 ^B	0.31 ^C	0.38 ^C	0.33 ^C	0.42 ^C	0.32 ^D
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	0.47 ^B	0.35 ^B	0.42 ^B	0.47 ^B	0.45 ^B	0.41 ^C
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	0.35 ^C	0.21 ^D	0.35 ^D	0.25 ^E	0.35 ^D	0.23 ^F
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	0.45 ^B	0.22 ^D	0.36 ^D	0.28 ^D	0.40 ^C	0.25 ^E
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	0.35 ^C	0.20 ^D	0.34 ^D	0.23 ^{EF}	0.35 ^D	0.22 ^{FG}
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	0.35 ^C	0.20 ^D	0.34 ^D	0.22 ^F	0.34 ^D	0.21 ^G
T ₇	Rec. FYM (10 t/ha) only	0.33 ^C	0.17 ^E	0.28 ^E	0.18 ^G	0.31 ^E	0.17 ^H
T ₈	Rec.NPK (160:80:80 kg /ha)	0.47 ^B	0.39 ^A	0.46 ^A	0.47 ^B	0.46 ^{AB}	0.43 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	0.50 ^A	0.40 ^A	0.46 ^A	0.50 ^A	0.48 ^A	0.45 ^A
	General Mean	0.41	0.27	0.38	0.33	0.39	0.30
	CV %	4.63	5.94	3.87	4.42	2.75	3.41
	LSD at 5%	0.03	0.02	0.02	0.02	0.018	0.017

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

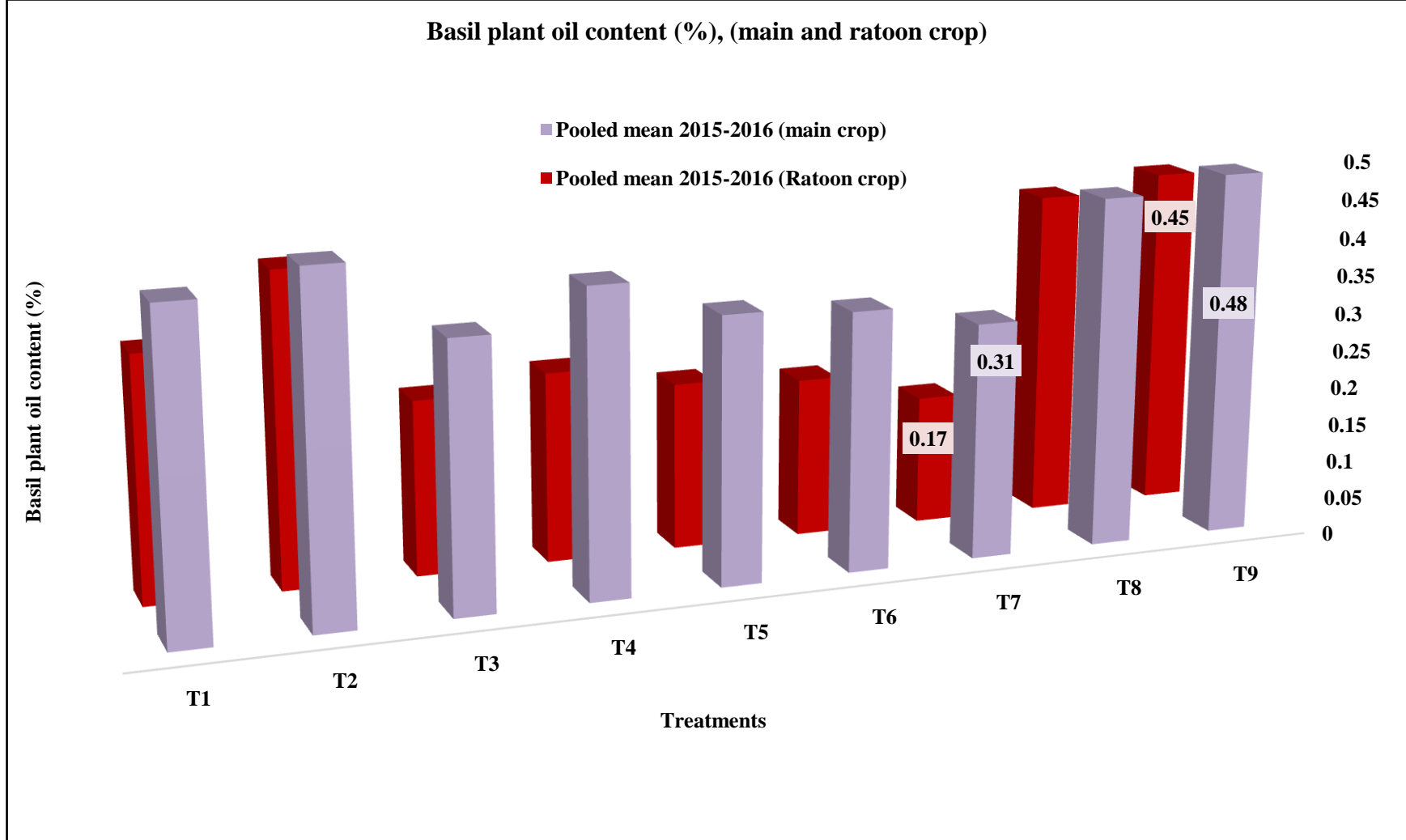


Fig. 18: Effect of organic manure, bio-fertilizer and inorganic fertilizer on oil content (%) in the main and ratoon crop of basil during the two years of the field experiment

Table 20. Oil yield per hectare (l/ha) of basil (*Ocimum basilicum*) as influenced by organic manure, bio-fertilizers and inorganic fertilizer

Treatments	2015			2016			Pooled		
	Main crop	Ratoon	Cumulative yield	Main crop	Ratoon	Cumulative yield	Main crop	Ratoon	Cumulative yield
T ₁	151.96 ^E	86.41 ^D	238.37 ^D	105.47 ^D	35.79 ^D	141.26 ^A	128.7 ^D	61.10 ^D	189.81 ^D
T ₂	182.04 ^C	111.96 ^C	294 ^C	123.13 ^C	56.07 ^C	179.2 ^C	152.6 ^C	84.02 ^C	236.6 ^C
T ₃	115.81 ^F	56.95 ^F	172.76 ^E	78.99 ^F	24.85 ^F	103.84 ^F	97.4 ^E	40.90 ^F	138.3 ^F
T ₄	166.42 ^D	65.79 ^E	232.21 ^D	86.05 ^E	30.77 ^E	116.82 ^E	126.2 ^D	48.28 ^E	174.51 ^E
T ₅	106.44 ^G	51.14 ^G	157.58 ^F	73.90 ^F	20.48 ^G	94.38 ^G	90.2 ^F	35.81 ^G	125.98 ^G
T ₆	116.50 ^F	56.41 ^F	172.91 ^E	78.70 ^F	21.41 ^G	100.11 ^{FG}	97.6 ^E	38.91 ^F	136.51 ^F
T ₇	95.13 ^H	38.52 ^H	133.65 ^G	52.40 ^G	15.36 ^H	67.76 ^H	73.8 ^G	26.94 ^H	100.70 ^H
T ₈	194.06 ^B	133.45 ^B	327.51 ^B	161.66 ^B	58.81 ^B	220.47 ^B	177.9 ^B	96.13 ^B	273.99 ^B
T ₉	211.94 ^A	144.36 ^A	356.3 ^A	187.46 ^A	70.81 ^A	258.27 ^A	199.7 ^A	107.58 ^A	307.28 ^A
General Mean	148.92	82.77	231.69	105.31	37.15	141.45	127.1	59.96	187.08
CV %	2.74	2.89	2.78	2.85	2.96	2.86	2.77	2.91	2.81
LSD at 5%	16.63	4.10	11.06	5.14	1.89	6.95	6.05	2.99	9.02

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

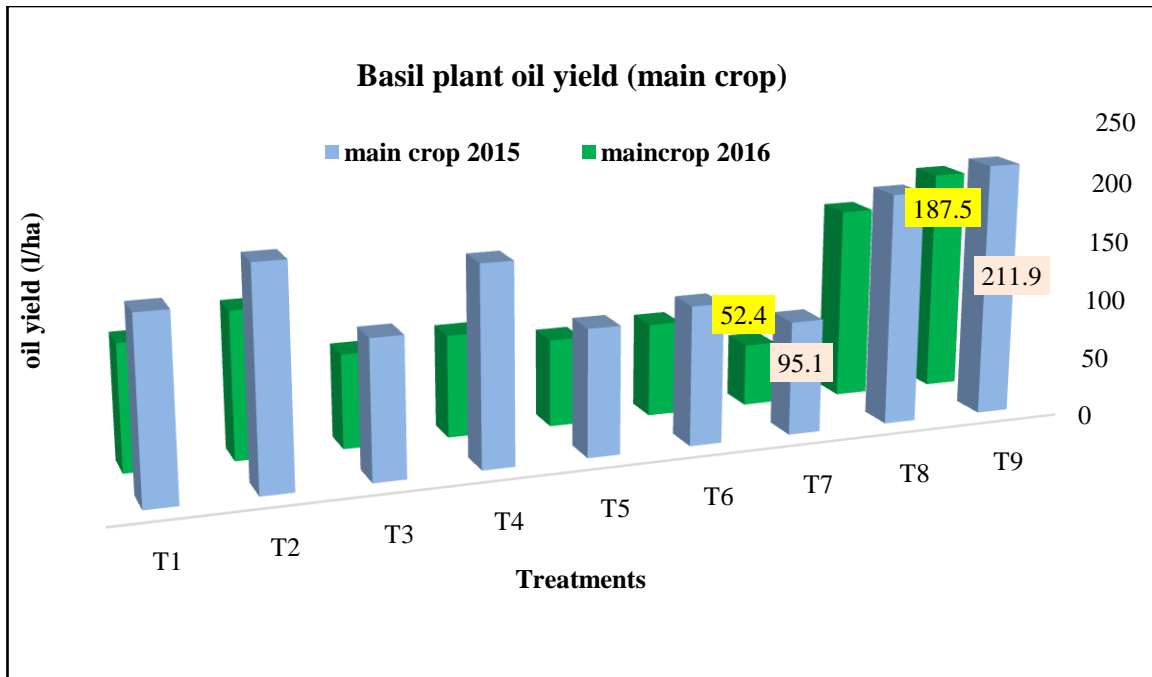


Fig. 19a: Oil yield per hectare (l/ha) in basil (*Ocimum basilicum*) main crop as influenced by organic manure, bio-fertilizer and inorganic fertilizer during two years of the field experiment

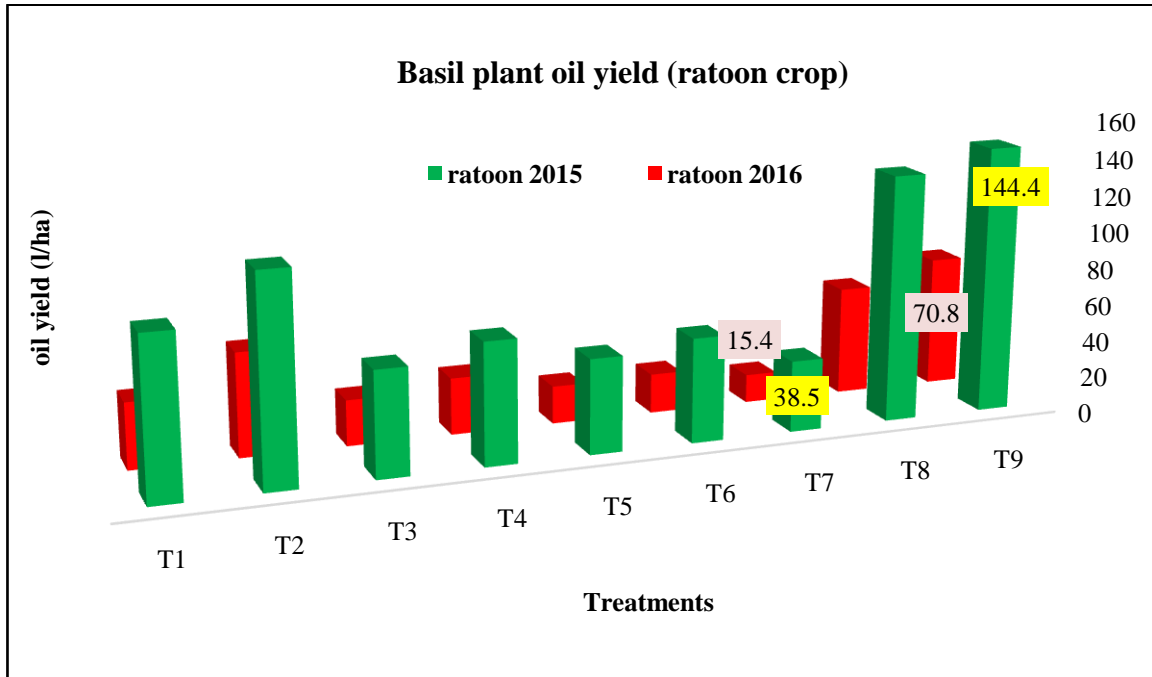


Fig. 19b: Oil yield per hectare (l/ha) in basil (*Ocimum basilicum*) ratoon crop as influenced by organic manure, bio-fertilizer and inorganic fertilizer during two years of the field experiment crop during two years of the field experiment

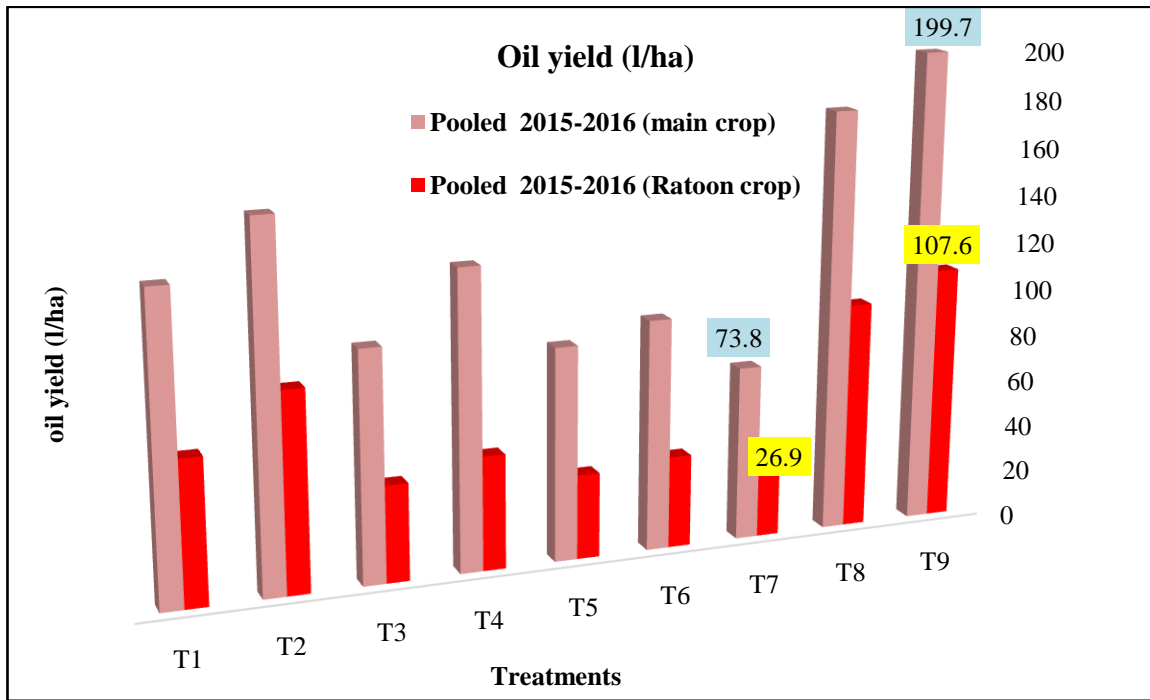


Fig. 19c: Oil yield per hectare (l/ha) in pooled data of main crop and ratoon in basil (*Ocimum basilicum*) as influenced by organic manure, bio-fertilizer and inorganic fertilizer during two years of the field experiment crop during two years of the field experiment

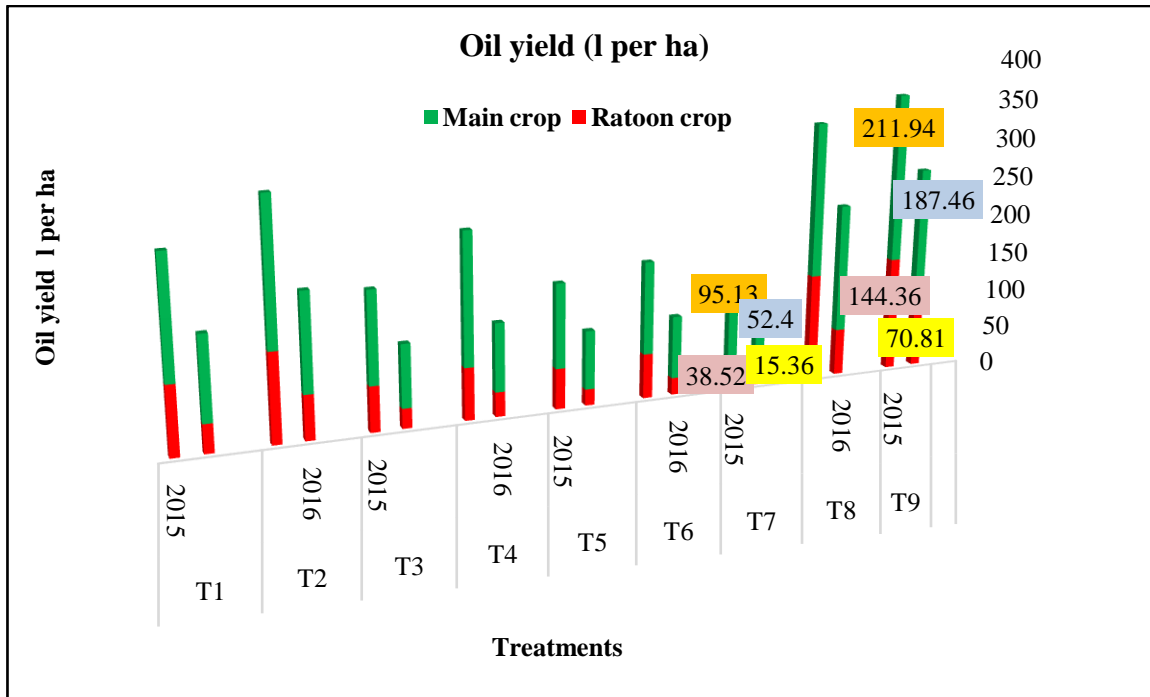


Fig. 19d: Cumulative oil yield per hectare (l/ha) of basil as influenced by organic manure, bio-fertilizer and inorganic fertilizer

4.1.3 Quality parameters

The data on chemical composition of essential oil of basil as influenced by different levels of N through FYM with and without bio-fertilizers and inorganic fertilizer are presented in Table 20 to 21d. To look forward for any possible influence of the main crop or ratoon on the composition of basil oil, the oils got from the plants in tow different harvesting time (main crop and ratoon) and were accounted for GC analysis. Major components are given in figures 20.a to 20.d.

Methyl chavicol percentage in the oil affected by application of different treatments, and the treatment T₉ with application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) recorded the highest percentage in the main crop of 2015 (52.3%) while, in the second season application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ recorded maximum Methyl chavicol percentage (63.78%). Whereas, the lowest percentage was recorded in T₇ (40.05 and 46.2%) during 2015, and 2016, respectively. In the second harvest (ratoon) application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ recorded the highest percentage (59.39 and 59.67%) whereas, the lowest percentage (40.22 and 41.49%) was observed in T₇ during 2015 and 2016 respectively. Methyl chavicol percentage are given in figure 20.

The treatment T₉ with application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) recorded the highest percentage of Linalool in the main crop (25.29 and 22.88%) and ratoon (26.59 and 25.19%). Whereas, the lowest percentage was recorded in T₇ of the main crop (19.20 and 15.20%) and ratoon (15.28 and 16.25%) during 2015, and 2016, respectively.

The Eugenol content was highest with application of NPK (160:80:80 Kg /ha) in T₈ in the main crop (2.48 and 1.34 %) and ratoon (1 and 3.20%) during 2015 and 2016 respectively. While, the lowest percentage was recorded in T₁ in the main crop (0.01 and 0.02%) and ratoon (0.02 and 0.01%) respectively.

The concentration of α -Pinene varied from 0.10 to 1.74 per cent in the main crop during kharif 2015. Whereas, it varied from 0.09 to 0.23 per cent in the main crop during kharif 2016. In the second harvest (ratoon) during first year of the experiment (2015) the percentage of α -Pinene varied from 0.13 to 0.24. While, it ranges between 0.18 to 0.09 percent in the ratoon of kharif 2016. Treatment (T₂) with application of FYM (10 t/ha) +100% Rec. N through FYM + BF recorded maximum α -Pinene percentage in the main crop (1.74 and 0.23%) and ratoon (0.24 and 0.99%) during 2015 and 2016 respectively. While, a low percentage was recorded in T₈ (0.10 and 0.09%) of the main crop and in ratoon (0.13 and 0.18%) during 2015 and 2016 respectively.

Percentage of Limonene differed significantly between the treatments in the main crop and ratoon during two years of the experiment. In the main crop, application of NPK (160:80:80 Kg /ha) + FYM (10 t/ha) *i.e.*, T₉ recorded the highest percentage (1.24 and 1.02%) while, the lowest parentage was observed in T₇ (0.37 and 0.24%) during 2015 and 2016 respectively. Whereas, in the second harvest (ratoon) application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ recorded the highest limonene percentage (1.75 and 2.70%) and the lowest was recorded in T₇ (1.75 and 0.20%) during 2015 and 2016 respectively.

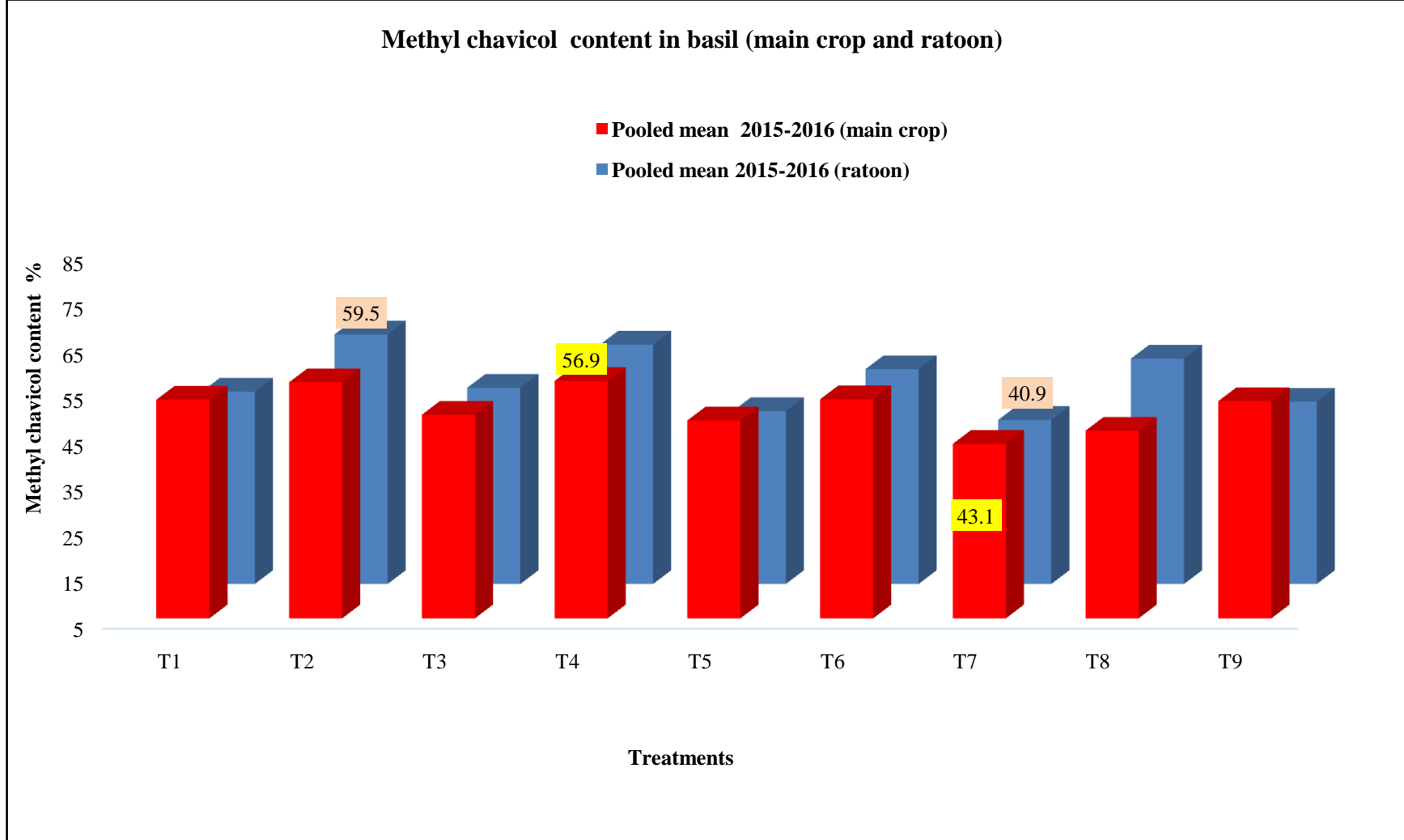


Fig. 20: Methyl chavicol percentage in the oil of basil (*Ocimum basilicum*) affected by application of organic manure bio-fertilizers and inorganic fertilizer

Table 21a. Effect of organic manure with and without biofertilizer and inorganic fertilizer on major essential oil components of basil main crop 2015

Co. No.	Essential oil components	Percentage of components (%)								
		T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉
1	α -Pinene	0.40	1.74	0.28	0.30	0.29	0.31	0.13	0.10	0.20
2	β -Ocimene	0.98	0.59	0.78	0.42	1.10	0.45	0.62	0.89	0.21
3	Linalol	20.01	22.3	20.7	21.13	19.56	20.49	19.20	23.44	25.29
4	Eugenol	0.01	0.02	0.03	0.04	0.10	0.13	0.21	2.48	0.73
5	Camphor	0.16	0.22	0.20	0.02	0.20	0.55	2.02	0.30	0.88
6	α -Terpinen	0.35	5.75	0.38	6.76	2.00	5.24	3.09	0.05	0.12
7	Limonene	0.42	0.48	0.39	0.40	0.37	0.40	0.37	0.9	1.24
8	Methyl chavicol	45.49	49.39	41.42	50.83	40.39	46.06	40.05	42.5	52.31
9	β -Elemene	0.88	0.65	0.64	2.20	1.93	0.31	0.49	0.23	1.87
10	Cubenol	2.99	1.01	1.92	0.22	0.76	1.19	1.88	1.35	1.22
11	Camphene	1.34	1.31	1.33	0.41	0.51	0.74	1.05	0.71	1.12
12	α -Humulene	1.04	0.03	1.30	0.40	0.48	0.43	0.64	0.29	0.49
13	Germacrene D	1.48	0.76	2.56	1.07	0.60	0.38	0.42	0.21	1.28
14	β -Cadinene	3.32	3.24	3.45	6.16	0.34	1.41	1.90	1.26	1.47

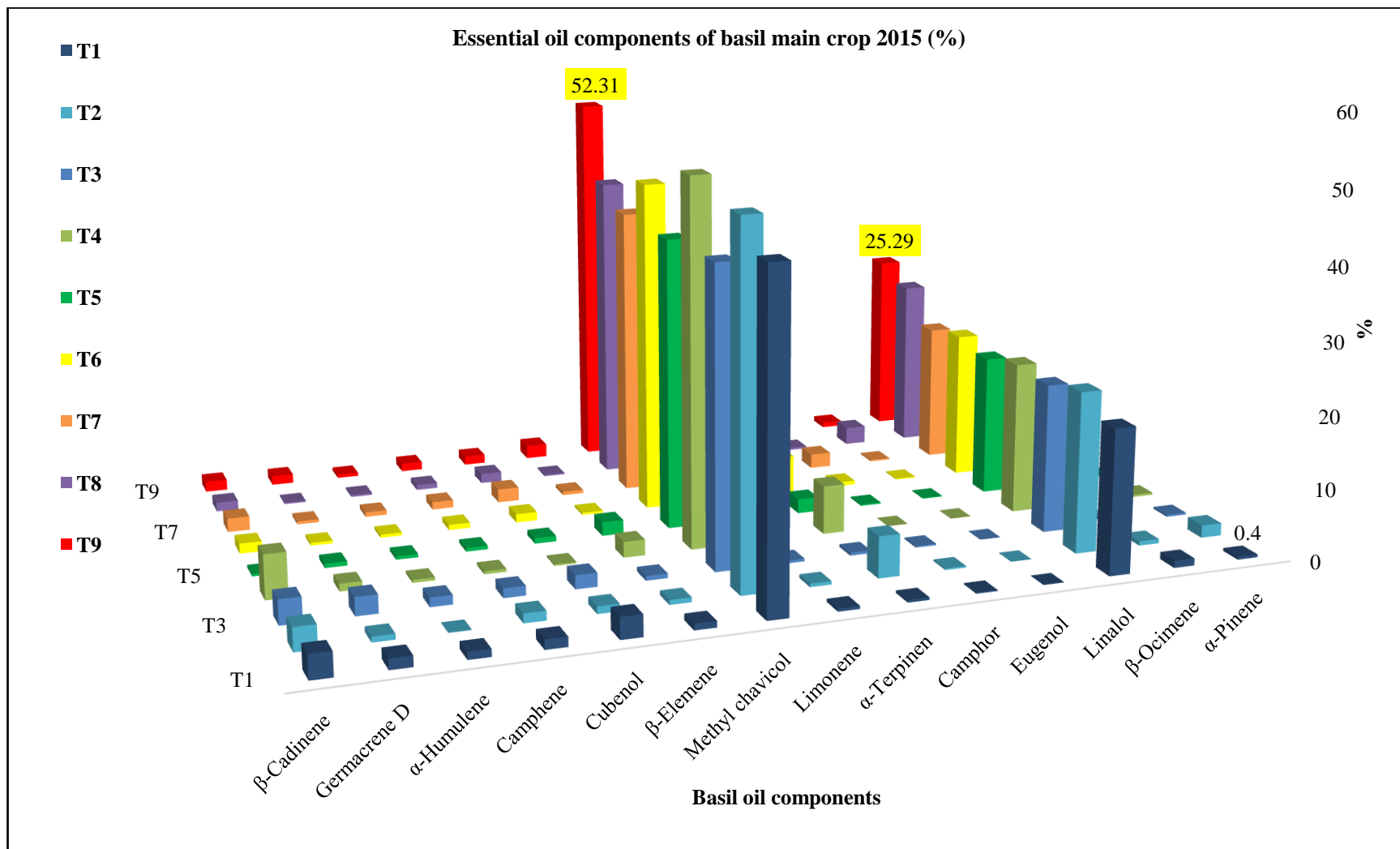


Fig. 21a: Effect of organic manure with and without bio-fertilizer and inorganic fertilizer on major essential oil components of basil main crop 2015

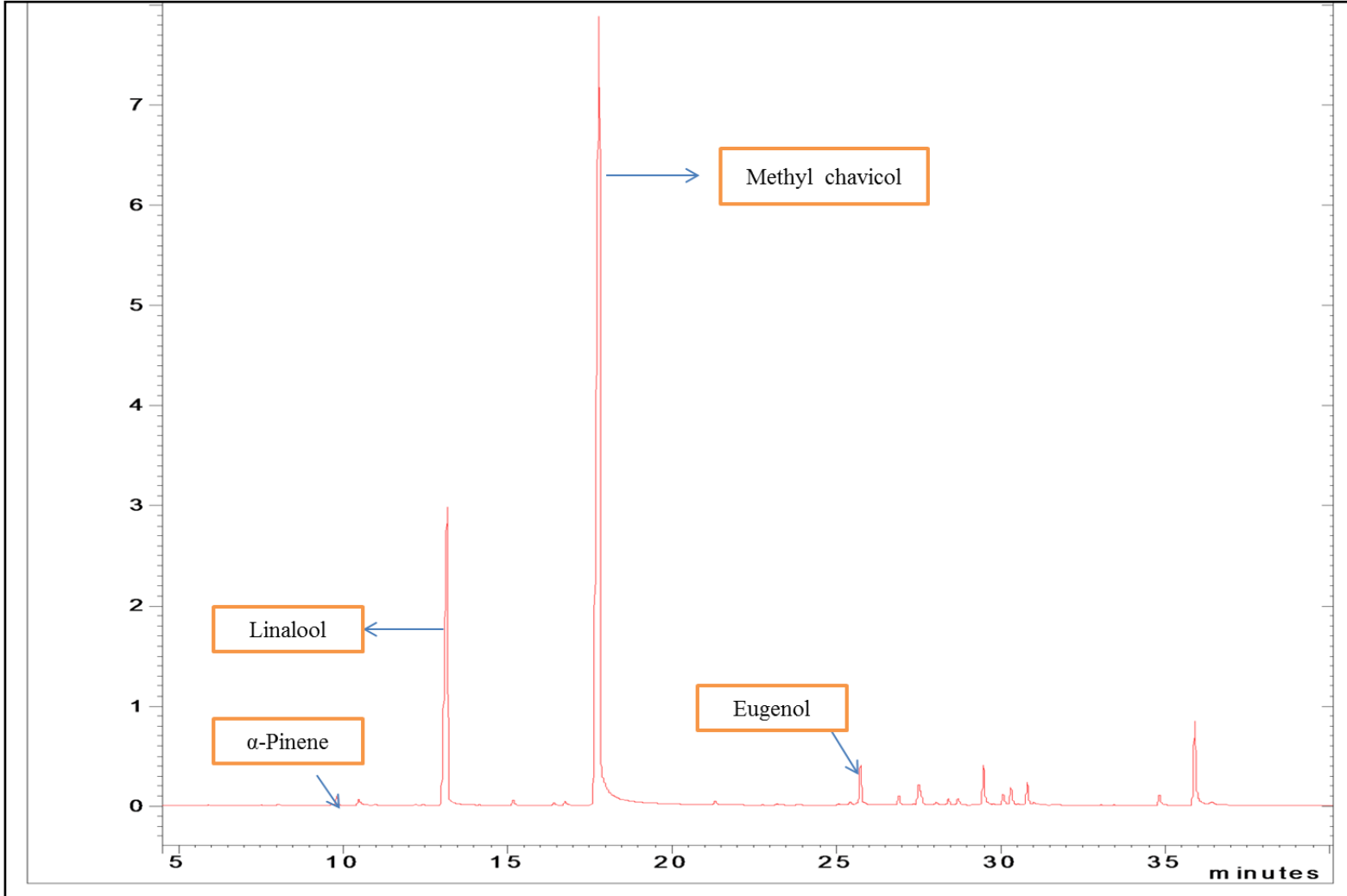


Fig. 22a: GC of major components of basil essential oil of T₉ main crop 2015as influenced by organic manure, bio fertilizer and inorganic fertilizer

Table 21b. Effect of organic manure with and without biofertilizer and inorganic fertilizer on on major essential oil components of basil ratoon crop 2015

Co.No.	Essential oil components	Percentage of components (%)								
		T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉
1	α -Pinene	0.19	0.24	0.18	0.17	0.17	0.20	0.15	0.13	0.20
2	β -Ocimene	0.71	0.18	1.20	0.37	0.30	0.86	0.58	0.86	0.89
3	Linalol	23.06	20.07	19.08	20.14	19.81	21.16	15.28	22.22	26.59
4	Eugenol	0.02	0.03	0.04	0.18	0.90	0.10	0.37	1.00	0.33
5	Camphor	8.83	0.13	0.18	0.46	0.48	0.42	0.51	0.47	0.63
6	α -Terpinen	1.33	1.39	1.56	3.68	1.40	0.88	1.30	0.63	1.58
7	Limonene	0.37	1.75	0.23	0.33	0.27	0.38	0.20	0.27	0.49
8	Methyl chavicol	43.84	59.39	45.60	59.23	42.28	52.66	40.22	54.60	45.50
9	β -Elemene	2.07	0.80	2.75	3.75	2.48	1.56	3.01	2.01	2.90
10	Cubenol	0.83	0.72	0.99	2.20	0.86	0.68	0.89	0.63	0.82
11	Camphene	1.34	1.31	1.33	0.41	0.51	0.74	1.05	0.71	1.12
12	α -Humulene	0.35	0.33	0.51	0.80	0.40	0.33	0.40	0.43	0.47
13	Germacrene D	1.15	1.35	0.95	1.24	0.73	0.04	0.08	0.55	0.80
14	β -Cadinene	0.12	0.05	0.13	0.28	0.16	0.04	0.12	0.09	0.06

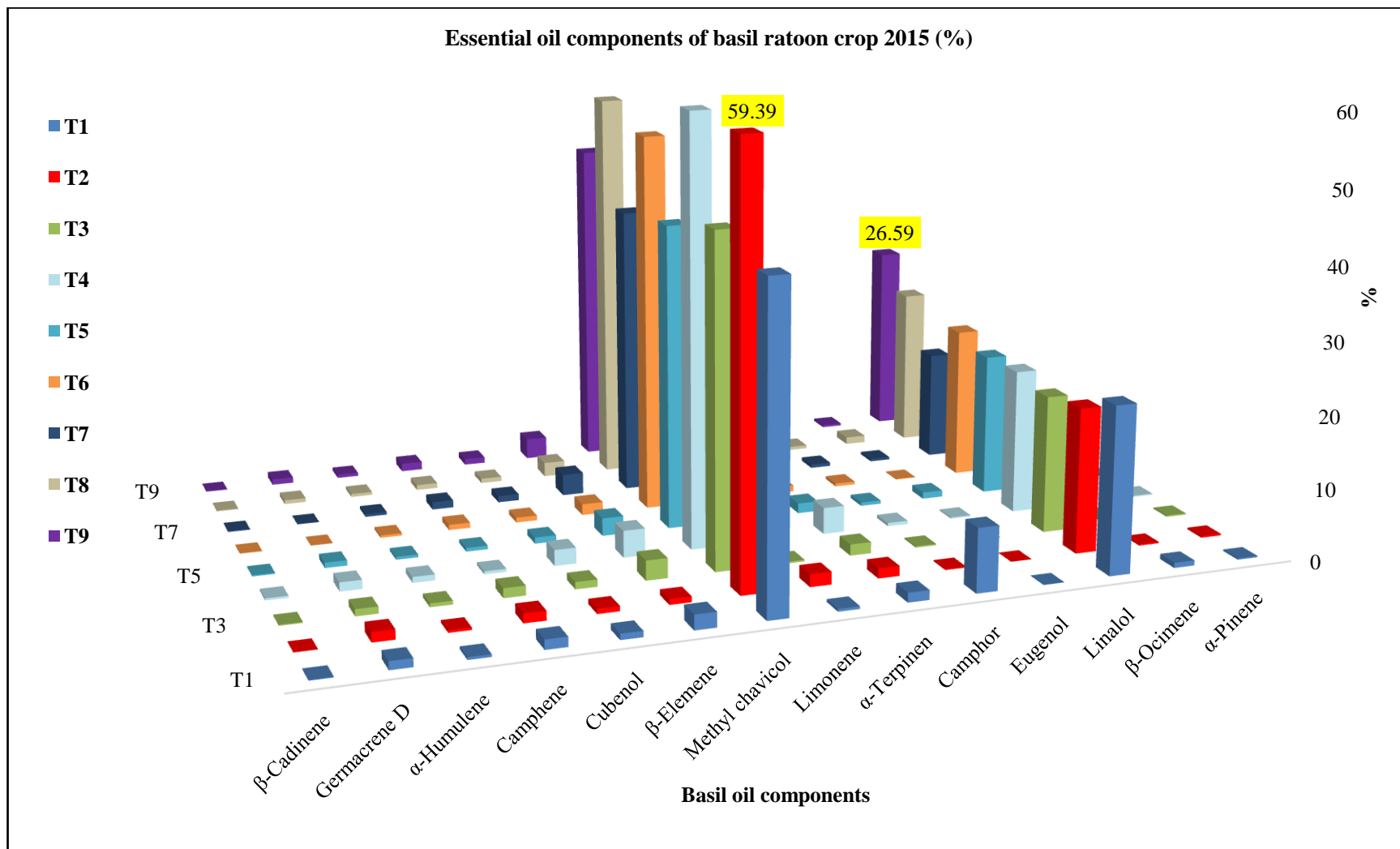


Fig. 21b: Effect of organic manure with and without bio-fertilizer and inorganic fertilizer on major essential oil components of basil ratoon crop 2015

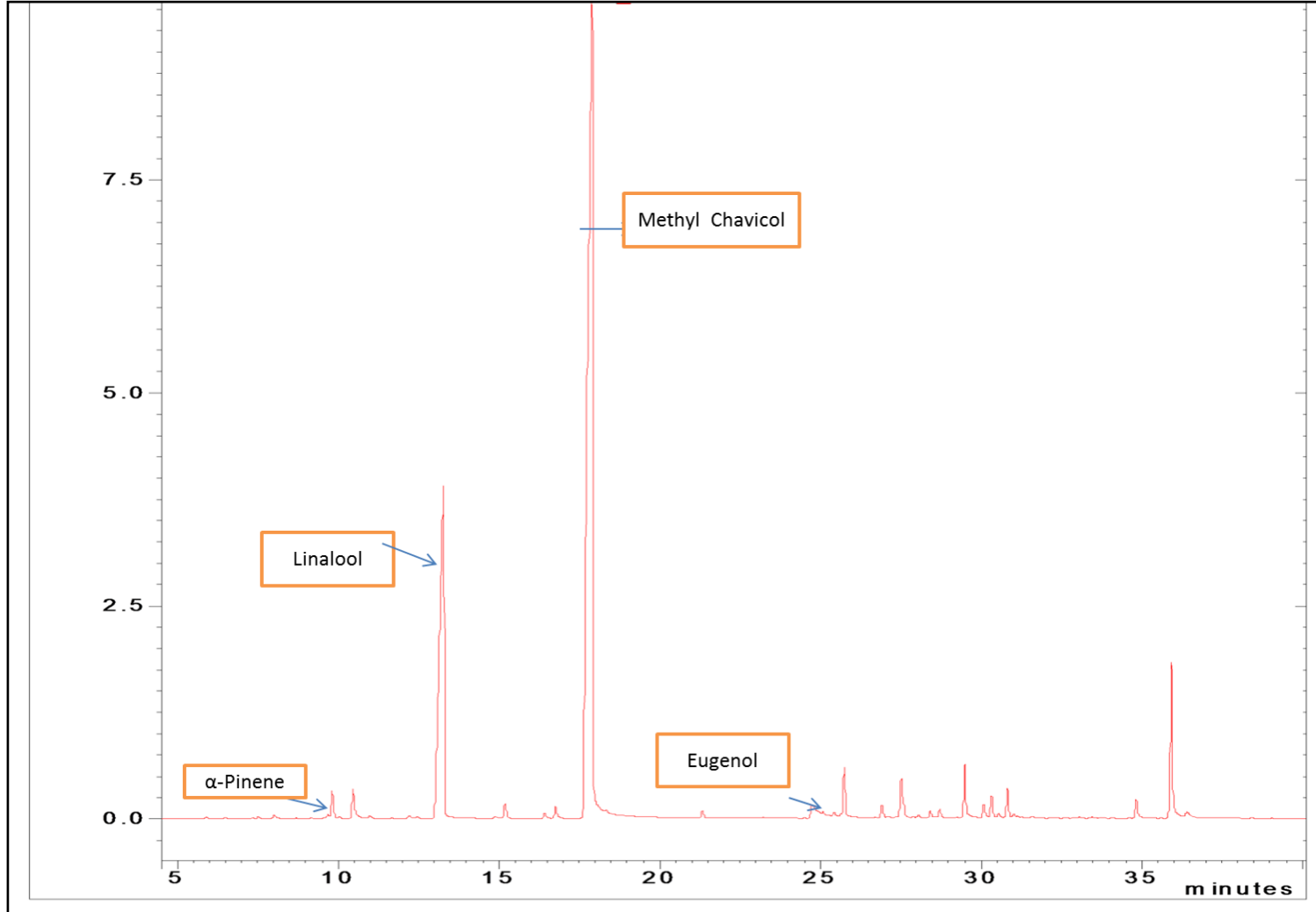


Fig. 22b: GC of major components of basil essential oil of T₂ ratoon crop 2015 as influenced by organic manure, bio -fertilizer and inorganic fertilizer

Table 21c. Effect of organic manure with and without biofertilizer and inorganic fertilizer on major essential oil components of basil main crop 2016

Co.No.	Essential oil components	Percentage of components (%)								
		T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉
1	α -Pinene	0.15	0.23	0.14	0.21	0.10	0.17	0.10	0.09	0.13
2	β -Ocimene	0.51	0.35	0.63	0.76	0.46	0.77	0.49	0.71	0.58
3	Linalool	21.46	21.37	20.76	21.11	18.43	17.59	15.20	21.74	22.88
4	Eugenol	0.02	0.07	0.05	0.06	0.04	0.06	0.03	1.34	1.10
5	Camphor	0.44	0.55	0.48	0.54	0.43	0.47	0.35	0.55	0.55
6	α -Terpinen	0.07	1.13	0.06	0.07	0.06	0.06	0.02	0.08	0.54
7	Limonene	0.46	0.40	0.89	0.76	0.57	0.72	0.24	0.73	1.02
8	Methyl chavicol	60.07	63.78	57.57	62.92	56.08	59.67	46.20	49.52	52.62
9	β -Elemene	0.16	0.14	0.16	1.04	2.06	2.05	2.94	1.42	2.32
10	Cubenol	0.58	0.46	0.59	0.37	0.82	0.75	0.66	0.57	0.74
11	Camphene	0.19	0.16	0.16	0.16	0.12	0.19	0.16	0.19	0.31
12	α -Humulene	0.15	0.84	0.50	0.82	0.42	1.09	0.41	0.24	0.45
13	Germacrene D	0.63	1.22	1.64	1.11	2.62	2.39	2.77	1.79	1.72
14	β -Cadinene	2.38	1.42	1.98	1.04	0.32	0.41	0.39	1.10	1.57

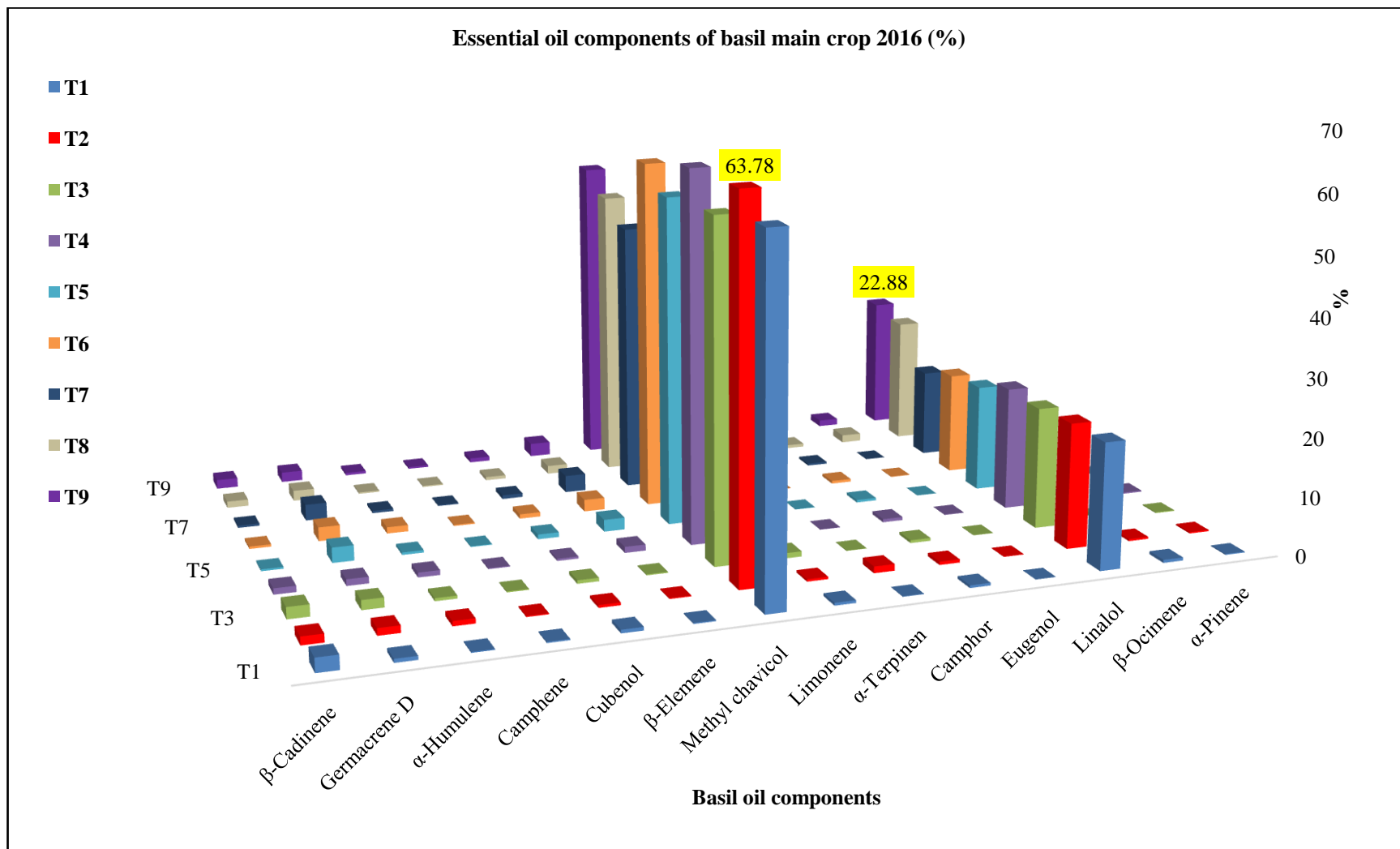


Fig. 21c: Effect of organic manure with and without bio-fertilizer and inorganic fertilizer on major essential oil components of basil main crop 2016

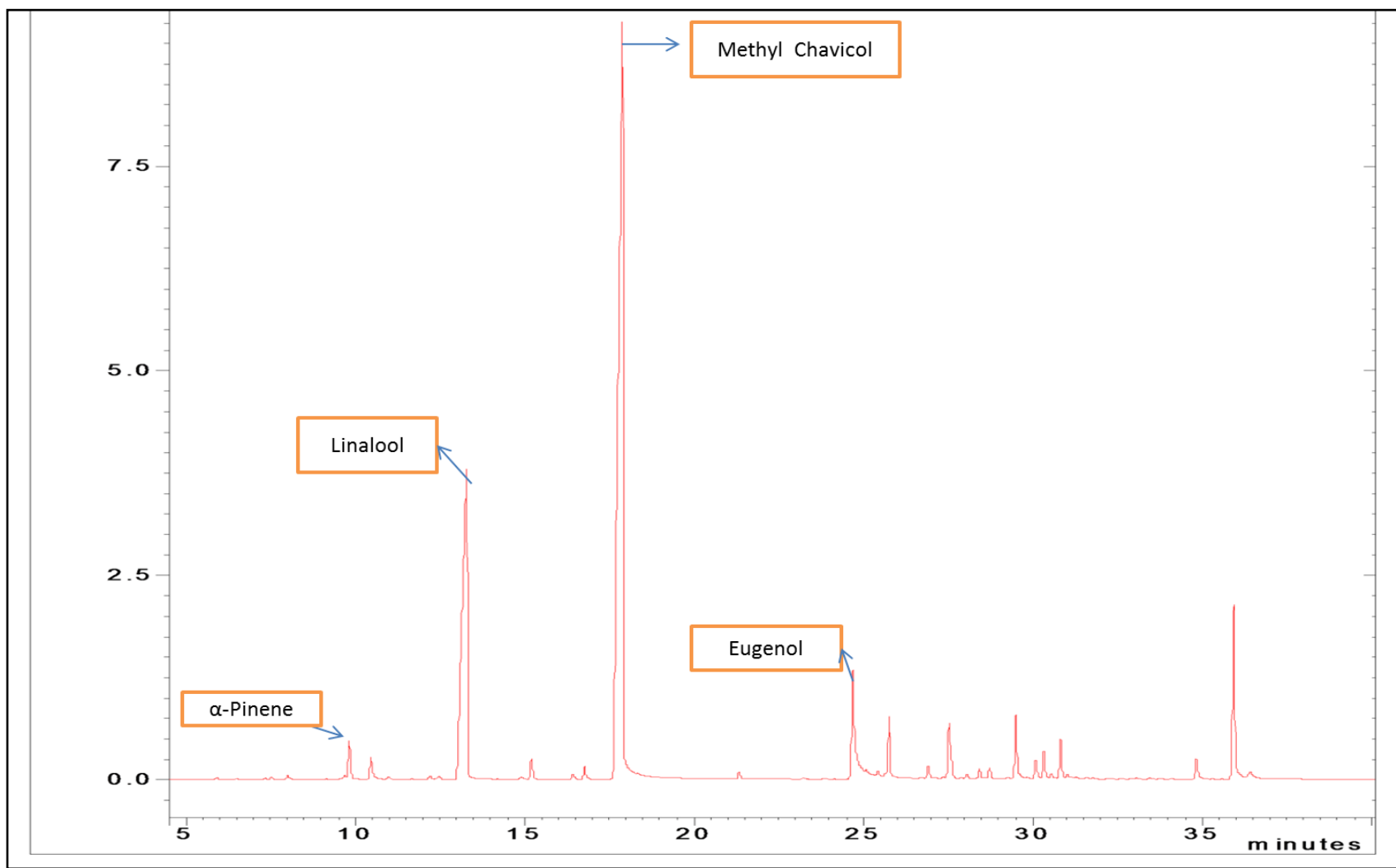


Fig. 22c: GC of major components of basil essential oil of T₂ main crop 2016 as influenced by organic manure, bio fertilizer and inorganic fertilizer

Table 21d. Effect of organic manure with and without biofertilizer and inorganic fertilizer on major essential oil components of basil ratoon 2016

Co.No.	Essential oil components	Percentage of components (%)								
		T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉
1	α -Pinene	0.26	0.99	0.24	0.89	0.20	0.79	0.20	0.18	0.21
2	β -Ocimene	0.66	0.82	3.68	0.62	0.92	0.54	0.49	0.76	0.80
3	Linalol	20.19	23.48	19.60	22.71	17.67	20.25	16.25	24.22	25.19
4	Eugenol	0.01	0.03	0.06	0.05	0.10	0.13	0.19	3.20	0.53
5	Camphor	0.04	2.29	9.73	0.41	1.54	0.26	0.88	0.06	0.64
6	α -Terpinen	0.01	0.02	0.01	0.04	0.45	0.07	0.11	0.09	0.16
7	Limonene	0.33	2.70	0.01	0.45	0.32	0.36	0.12	1.06	1.60
8	Methyl chavicol	50.23	59.67	50.15	55.38	43.28	51.22	41.49	53.90	44.17
9	β -Elemene	2.01	7.13	2.61	4.66	1.28	0.26	0.29	0.42	2.68
10	Cubenol	0.02	0.03	0.13	0.04	0.86	0.44	0.67	0.27	0.91
11	Camphene	0.05	0.75	3.23	0.92	0.29	0.51	0.81	0.22	0.40
12	α -Humulene	0.35	1.15	5.85	0.97	0.20	0.47	0.59	0.04	0.47
13	Germacrene D	0.35	2.46	16.72	2.37	0.05	0.08	0.15	0.66	1.39
14	β -Cadinene	0.96	0.41	2.41	0.35	2.81	1.58	2.44	0.66	1.56

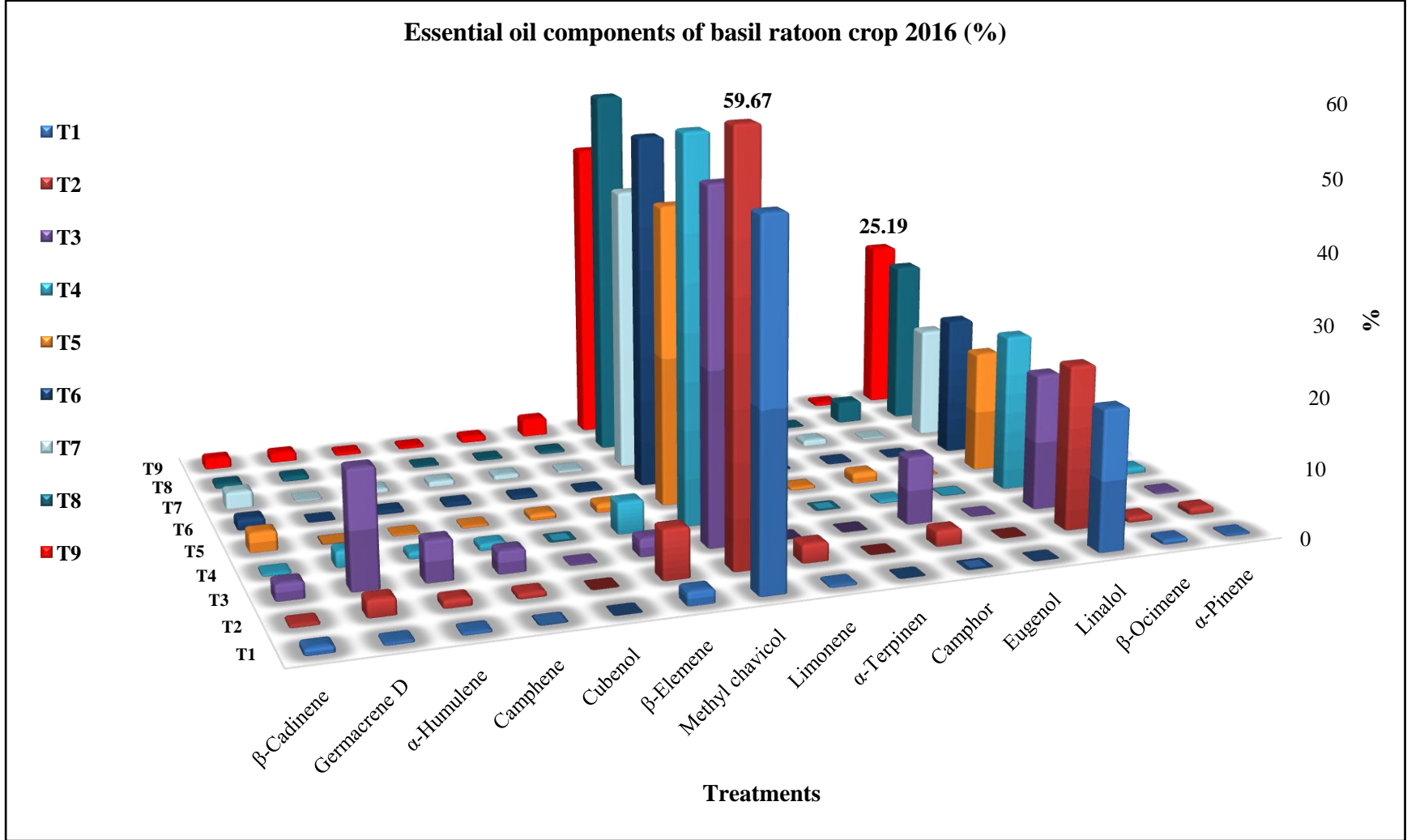


Fig. 21d: Effect of organic manure with and without bio-fertilizer and inorganic fertilizer on major essential oil components of basil ratoon crop 2016

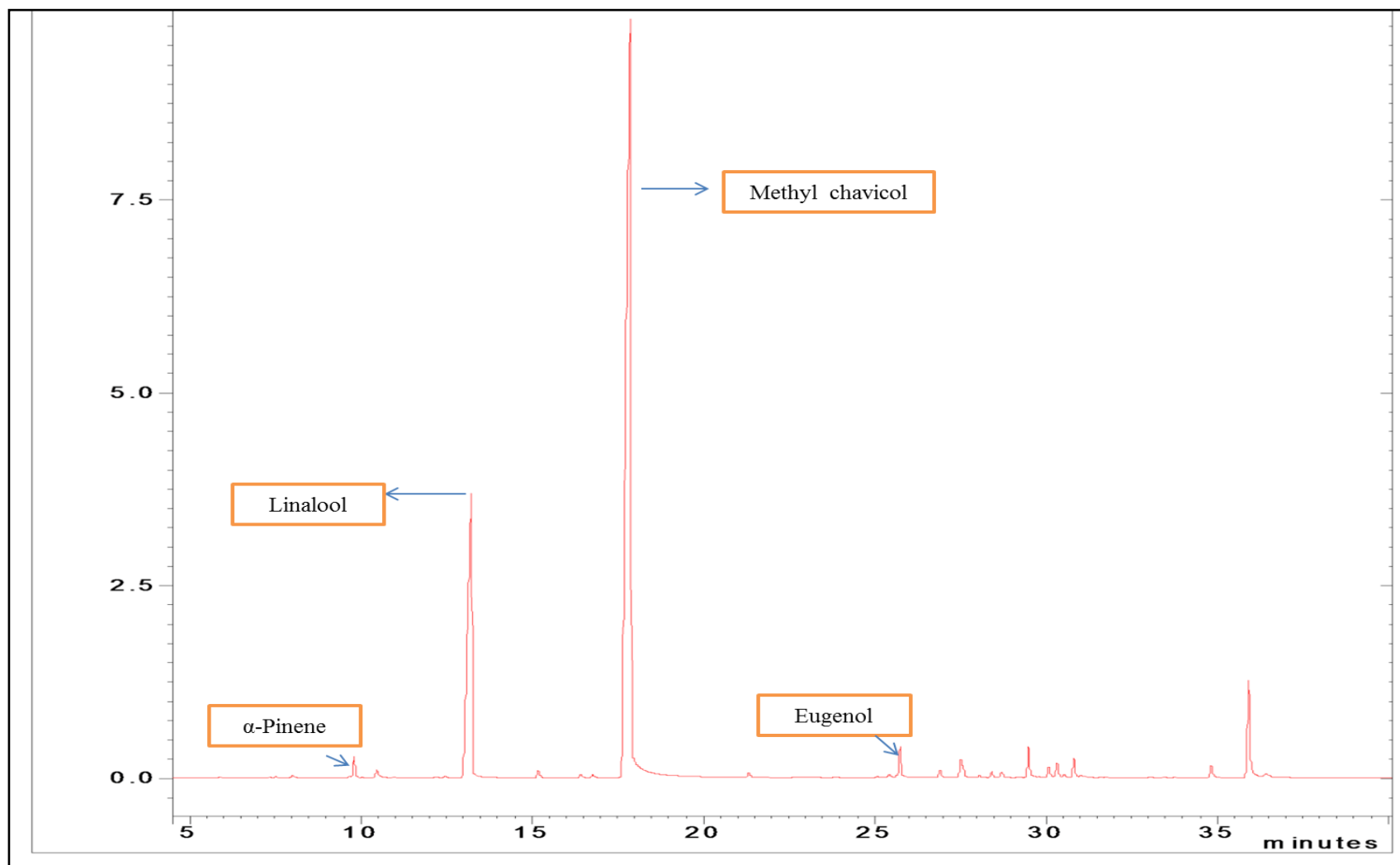


Fig. 22d: GC of major components of basil essential oil of T₂ ratoon crop 2016 as influenced by organic manure, bio - fertilizer and inorganic fertilizer



Plate 1. General view of the field 2015



Plate 2. General view of the field 2016



Plate 3. Preparation of seedlings



Plate 4. recommended dose of FYM



Plate 5. (T₉) NPK+ Recommended dose of FYM 2015



Plate 6. T₉ Recommended dose of FYM+NPK 2016



Plate 7. T₁ 100% N through FYM



Plate 8. T₂ 100% N through FYM + Bio



Plate 9. T₈ NPK Treatment



Plate 10. T₂ 50% Rec. N through FYM+BF

4.1.4. Soil parameters

4.1.4.1. Physical proprieties

Data on influence of different levels of N through FYM with and without bio-fertilizer and inorganic fertilizer on soil physical proprieties during two years of the experiment was presented in Table 22.

4.1.4.1.1. Bulk density

Soil bulk density differed between the treatments without significant differences as shown in Table 22. There was decrease in bulk density of the soil after imposition of the treatments. However, the highest bulk density (1.23 and 1.24 Mg m^{-3}) was recorded with 100% Rec. of NPK (160:80:80 kg /ha) *i.e.*, T_8 in 2015 and, 2016, respectively. Whereas, the lowest bulk density of the soil (1.18 and 1.17 Mg m^{-3}) was recorded with application of FYM (10 t/ha) +100% Rec. N through FYM + BF (T_2) in 2015 and, 2016 respectively.

4.1.4.1.2. Porosity

The porosity of soil after cropping was affected by the different treatments without significant differences as shown in Table 22. Among the different treatments, application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T_2 recorded the maximum porosity (44.5 and 44.87%) While, the minimum value (41.40 and 41.29%) was recorded in T_8 with 100% RFD of NPK (160:80:80 kg /ha) in 2015 and 2016, respectively.

4.1.4.1.3. Particle density

There was no significant differences among the treatments in respect to particle density as shown in Table 22. Application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T_2 recorded the minimum particle density (2.65 and 2.61 g/cm^3). While, the maximum value (2.83 and 2.83 g/cm^3) was recorded with application of recommended dose of NPK *i.e.*, T_8 in 2015 and, 2016, respectively.

Table 22. Bulk density (Mg m^{-3}), porosity (%) and particle density (g/cm^3) of the soil as influenced by organic manure, bio-fertilizers and inorganic fertilizer

Treatments		Bulk density (Mg m^{-3})		Porosity (%)		Particle density (g/cm^3)	
		2015	2016	2015	2016	2015	2016
After the experiment		2015	2016	2015	2016	2015	2016
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	1.19	1.18	44.28	44.5	2.78	2.62
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	1.18	1.17	44.5	44.87	2.65	2.61
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	1.21	1.20	43.08	43.36	2.79	2.69
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	1.19	1.17	43.46	43.98	2.78	2.73
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	1.21	1.20	42.27	42.60	2.80	2.80
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	1.22	1.20	43.08	43.15	2.80	2.73
T ₇	Rec. FYM (10 t/ha) only	1.20	1.18	42	42.91	2.82	2.82
T ₈	Rec.NPK (160:80:80 kg /ha)	1.23	1.24	41.40	41.29	2.83	2.83
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	1.22	1.21	43.24	43.15	2.79	2.78
	General Mean	1.21	1.18	43.03	43.31	2.78	2.73
	CV%	2.4	2.39	5.96	4.09	4.08	4.33
	LSD at 5%	NS	NS	0.05	NS	NS	NS

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

4.1.4.2. Chemical proprieties

Data on influence of different levels of N through FYM with and without bio-fertilizer and inorganic fertilizer on soil chemical proprieties during two years of the experiment was presented in Table 23.

4.1.4.2.1. Soil pH

A perusal of the data given in Table 23. showed that soil pH is affected by the treatments involving different levels of N through organic manure with and without bio-fertilizers and inorganic fertilizer during two years of the experiment without significant differences. Highest soil pH after cropping (8.01 and 8) was recorded with application of 100% RFD of NPK *i.e.*, T₈ in 2015 and, 2016, respectively. While, the lowest soil pH (7.76 and 7.71) was recorded with application of FYM (10 t/ha) +100% Rec. N through FYM + BF (T₂), respectively.

4.1.4.2.2. Electrical conductivity (dS m⁻¹)

The data pertaining to electrical conductivity of the soil after cropping (dS m⁻¹) as influenced by different levels of N through organic manure with and without bio-fertilizers and inorganic fertilizer is shown in the Table 23.

Maximum electrical conductivity of soil after cropping (0.37 and 0.39 dS m⁻¹) was observed in T₈ (160:80:80 kg /ha) during 2015 and 2016 respectively. The minimum electrical conductivity in the soil (0.34 and 0.27 dS m⁻¹) was observed with application FYM (10 t/ha) +100% Rec. N through FYM + BF (T₂), respectively.

4.1.4.2.3 Organic carbon (%)

The treatments effect on organic carbon per cent in the soil have been presented in Table 23. Application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ recorded the maximum organic carbon (0.63 and 0.66 %) in the in the post harvest soil samples collected during 2015 and, 2016, respectively. While, the minimum value (0.52 and 0.53%) was recorded in T₈ with application the recommended dose of inorganic fertilizer (160:80:80 kg /ha) during 2015 and, 2016, respectively.

Table 23. pH, Electrical conductivity (dS m⁻¹) and organic carbon content (%) in the soil as influenced by organic manure, bio-fertilizers and inorganic fertilizer

Treatments		pH		Electrical conductivity (dS m ⁻¹)		Organic carbon (%)	
Before the experiment		7.75		0.36		0.5	
After the experiment		2015	2016	2015	2016	2015	2016
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	7.83	7.72	0.35	0.33 ^{AB}	0.61 ^{AB}	0.65 ^A
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	7.76	7.71	0.34	0.27 ^B	0.63 ^A	0.66 ^A
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	7.81	7.73	0.37	0.32 ^{AB}	0.58 ^{ABC}	0.62 ^A
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	7.77	7.60	0.36	0.28 ^B	0.61 ^{AB}	0.65 ^A
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	7.84	7.69	0.37	0.32 ^{AB}	0.56 ^{ABC}	0.60 ^{AB}
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	7.79	7.69	0.35	0.28 ^B	0.58 ^{ABC}	0.64 ^A
T ₇	Rec. FYM (10 t/ha) only	7.83	7.70	0.36	0.30 ^{AB}	0.55 ^{ABC}	0.57 ^{ABC}
T ₈	Rec.NPK (160:80:80 kg /ha)	8.01	8.00	0.37	0.39 ^A	0.52	0.53 ^C
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	7.87	7.77	0.35	0.38 ^A	0.54	0.54 ^{BC}
General Mean		7.84	7.74	0.36	0.32	0.58	0.60
CV%		1.64	2.12	18.13	10.45	5.09	6.13
LSD at 5%		NS	NS	NS	0.05	0.02	0.03

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

4.1.4.2.4. Available Macronutrient in the soil:

Data on available nitrogen, phosphorus and potassium in the soil (kg/ha) as influenced by different levels of N through FYM with and without bio-fertilizer and inorganic fertilizer are presented in Table 24.

4.1.4.2.4.1. Available Nitrogen (kg/ha)

Available nitrogen (kg/ha) in the soil after cropping differed significantly among different treatments as it shown in Table 24. Highest available nitrogen in the soil after cropping (227.40 and 277 kg/ha) was recorded with application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ during 2015 and, 2016, respectively. While, it was significantly lowest (189.91 and 201.40 kg/ha) in soils treated by T₇ with application of recommended dose of FYM during 2015 and, 2016, respectively.

4.1.4.2.4.2. Available Phosphorus (kg/ha)

Available phosphorus in the soil differed significantly among the treatments as shown in Table 24. Application of (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ recorded the highest value (42.31 and 58.15 kg/ha) in 2015 and, 2016, respectively. Whereas, the lowest value (27.33 and 34.17 kg/ha) was observed in T₇ in the soil after cropping, respectively.

4.1.4.2.4.3. Available Potassium (kg/ha)

Significant differences were observed with respect to available potassium in the soil after cropping among the treatments during two years of the experiment (Table 24).

Wherein, the treatment T₂ with application of FYM (10 t/ha) +100% Rec. N through FYM + BF recorded the highest available potassium in the soil after cropping (296.80 and 340.60 kg/ha) in 2015 and 2016, respectively. While, the lowest available potassium in the soil after cropping was observed in T₇ (212.8 and 234.90 kg /ha) during 2015 and, 2016, respectively.

Table 24. Macro nutrient content of soil (kg/ha) as influenced by organic manure, bio-fertilizers and inorganic fertilizer

Treatments		Available Nitrogen (kg/ha)		Available Phosphor (kg/ha)		Available Potassium (kg/ha)	
Before the experiment		185kg/ha		28 kg/ha		200kg/ha	
After the experiment		2015	2016	2015	2016	2015	2016
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	220.15 ^{AB}	262.10	36.91 ^{ABC}	46.37 ^{ABC}	268.80 ^{ABC}	281.66 ^{ABC}
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	227.40 ^A	277.00	42.10 ^A	47.98 ^{ABC}	296.80 ^{ABC}	340.60 ^A
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	211.68 ^{ABC}	246.00	33.33 ^{ABC}	45.58 ^{ABC}	242.67 ^{ABC}	275.67 ^{ABC}
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	222.57 ^{AB}	266.70	38.74 ^{AB}	46.25 ^{ABC}	265.07 ^{ABC}	315.86 ^{AB}
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	203.21 ^{ABC}	228.00	30.33 ^{BC}	39.29 ^{BC}	250.13 ^{BC}	261.00 ^{BC}
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	211.68 ^{ABC}	246.40	36.41 ^{ABC}	43.25 ^{ABC}	259.47 ^{ABC}	324.53 ^{AB}
T ₇	Rec. FYM (10 t/ha) only	189.91 ^C	201.40	27.33 ^C	34.17 ^C	212.80 ^C	234.90 ^C
T ₈	Rec.NPK (160:80:80 kg /ha)	195.96 ^{BC}	214.20	40.40 ^{AB}	53.26 ^{AB}	229.60 ^{AB}	323.22 ^{AB}
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	199.58 ^{ABC}	222.00	42.31 ^A	58.15 ^A	235.20 ^A	333.33 ^A
General Mean		209.13	240.42	36.42	46.03	251.17	298.97
CV%		5.09	5.20	11.54	11.08	8.49	8.46
LSD at 5%		10.46	20.04	4.19	13.91	36.92	43.94

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

4.1.4.2.5. Exchangeable Secondary nutrient in the soil

Effect of different treatments on exchangeable secondary nutrient in the soil are shown in Table.25

4.1.4.2.5.1. Exchangeable calcium

The plot treated with (160:80:80 kg/ha) + FYM (10 t/ha) *i.e.*, T₉ recorded significantly higher exchangeable calcium content in the soil (1278.78 and 1368.33 ppm) in 2015 and 2016, respectively are shown in Table.25. Soil application of recommended dose of FYM in T₇ registered least exchangeable calcium content of soil after cropping (617.78 and 985.75 ppm) during both the years.

4.1.4.2.5.2. Exchangeable magnesium:

As shown in Table.25 Application of FYM (10 t/ha)+100% Rec. N through FYM + BF *i.e.*, T₂ enhanced the exchangeable magnesium content (200 and 225 ppm) of the post-harvest soil samples during 2015 and 2016, respectively compared to rest of the treatments. Recommended dose of FYM treated plot (T₇) recorded least exchangeable magnesium content in the soil after cropping (153.3and 176.67 ppm) during the year 2015 and, 2016, respectively.

4.1.4.2.6. Available micronutrients in the soil

Effect of different treatments on available micronutrients in the soil are shown in Table.26

4.1.4.2.6.1. Available Iron

Significant differences were observed among the treatments in respect to available iron of the soil after cropping in two years of the experimnt. Whereien, the treatment T₂ with application of FYM (10 t/ha) +100% Rec. N through FYM along with bio-fertilizer recorded the highest iron content in the soil after cropping (4.92 and 6.50 ppm) in 2015 and 2016, respectively. While, the plots treated T₇ registered the lowest iron content in the soil (3.08 and 3.75 ppm) during 2015 and, 2016, respectively.

4.1.4.2.6.2. Available Manganese

The available manganese in the soil after cropping showed significant differences due to vairous treatments wherien , application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ resulted in the highest available manganese in the soil (3.40 and 5.30 ppm) in 2015 and 2016 respectively. While, the treatment T₇ resulted in lowest available manganese content in the soil (1.37 and 2.49 ppm) during 2015 and, 2016, respectively.

4.1.4.2.6.3. Available Zinc

The available zinc in the soil after cropping differed significantly among the treatments, and was highest in the plots supplied with FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ (2.71 and 3.06 ppm) in 2015 and, 2016, respectively. While, the lowest was recorded with application of recommended dose of FYM (10 t/ha) in T₇ (1.51 and 1.85 ppm) during respective year.

4.1.4.2.6.4. Available Copper

Different levels of N through FYM with and without fertilizer and inorganic fertilizer had a significant impact on the available copper. Application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ recorded the highest value (2.78 and 4.16 ppm) in 2015 and/ 2016, respectively. While, the lowest value was noticed in T₇ (1.34 and 2.58 ppm) in 2015 and 2016, respectively.

4.1.4.3. Soil biological proprieties

4.1.4.3.1. Population of heterotrophic free-living N₂ fixers (CFU ×10³/ g of oven dry soil)

Data indicated significant differences among the treatments with respect to population of heterotrophic free-living N₂ fixers (CFU ×10³/ g of oven dry soil) as shown in Table 27. While, maximum population of the colonies in the soil after cropping (40.66 and 63.33 CFU ×10³/ g) was recorded with application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ during 2015 and, 2016, respectively. Whereas, T₇ recorded the lowest number (26.13 and 34 CFU ×10³/ g) in 2015 and, 2016, respectively.

Table 25. Secondary nutrients content of soil as influenced by organic manure, bio-fertilizers and inorganic fertilizer

Treatments		Exchangeable calcium (ppm)		Exchangeable Magnesium (ppm)	
Before the experiment		1050		100	
After the experiment		2015	2016	2015	2016
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	1026.89 ^B	1205.00 ^{AB}	187.50 ^{AB}	200.33 ^{AB}
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	1041.11 ^B	1212.50 ^{AB}	200 ^A	225.00 ^A
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	974.44 ^{BC}	1082.50 ^{AB}	172.50 ^{AB}	186.67 ^{BC}
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	967.78 ^{BC}	1177.50 ^{AB}	175.00 ^{AB}	195.00 ^{BC}
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	790.00 ^C	1048.50 ^B	167.50 ^{AB}	180.00 ^C
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	965.56 ^{BC}	1162.50 ^{AB}	165.00 ^{AB}	198.33 ^{BC}
T ₇	Rec. FYM (10 t/ha) only	617.78 ^D	985.75 ^B	153.33 ^B	176.67 ^C
T ₈	Rec.NPK (160:80:80 kg /ha)	1170.00 ^{AB}	1209.17 ^{AB}	172.50 ^{AB}	200.00 ^{BC}
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	1278.78 ^A	1368.33 ^A	177.50 ^{AB}	205.00 ^{ABC}
General Mean		981.37	1161.31	173.43	194.44
CV%		8.29	9.06	9.2	5.35
LSD at 5%		140.89	182.15	28.21	18.33

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

Table 26. Micro nutrient content of soil (ppm) as influenced by organic manure, bio-fertilizers and inorganic fertilizer

Treatments		Available Iron (ppm)		Available Manganese (ppm)		Available Zinc (ppm)		Available Copper (ppm)	
Before the experiment		3		1.3		1.3		1.3	
After the experiment		2015	2015	2015	2016	2015	2016	2015	2016
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	3.10 ^{AB}	3.10 ^{AB}	3.10 ^{AB}	3.83 ^{AB}	1.94 ^{AB}	2.27 ^{AB}	2.05 ^{AB}	3.87 ^{AB}
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	3.40 ^A	3.40 ^A	3.40 ^A	5.30 ^A	2.71 ^A	3.06 ^A	2.78 ^A	4.16 ^A
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	3.17 ^{AB}	3.17 ^{AB}	3.17 ^{AB}	3.35 ^{AB}	1.80 ^{AB}	2.00 ^{BC}	1.74 ^{AB}	3.11 ^B
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	2.71 ^B	2.71 ^B	2.71 ^B	4.42 ^{AB}	1.84 ^{AB}	2.01 ^{BC}	2.00 ^{AB}	3.90 ^{AB}
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	2.85 ^{AB}	2.85 ^{AB}	2.85 ^{AB}	4.08 ^{AB}	1.72 ^{AB}	1.92 ^{BC}	1.74 ^{AB}	3.02 ^B
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	2.99 ^{AB}	2.99 ^{AB}	2.99 ^{AB}	4.00 ^{AB}	1.81 ^{AB}	1.97 ^{BC}	1.80 ^{AB}	3.36 ^B
T ₇	Rec. FYM (10 t/ha) only	1.37 ^C	1.37 ^C	1.37 ^C	2.49 ^B	1.51 ^B	1.85 ^{BC}	1.34 ^B	2.58 ^B
T ₈	Rec.NPK (160:80:80 Kg /ha)	2.44 ^B	2.44 ^B	2.44 ^B	3.69 ^{AB}	1.63 ^{AB}	1.9 ^C	1.49 ^{AB}	2.80 ^B
T ₉	Rec. NPK (160:80:80 Kg /ha)+ Rec. FYM (10 t/ha)	2.50 ^B	2.50 ^B	2.50 ^B	4.16 ^{AB}	1.84 ^{AB}	1.95 ^{AB}	1.77 ^{AB}	3.50 ^B
General Mean		3.98	2.72	2.72	3.93	1.82	2.02	1.84	3.37
CV%		15.08	11.71	11.71	22.11	22.61	18.31	24.89	21.40
LSD at 5%		1.062	0.55	0.55	1.50	0.74	0.63	0.82	0.68

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

4.1.4.3.2. Population of phosphate solubilising bacteria (CFU $\times 10^3$ / g of oven dry soil)

The perusal of data on the population of phosphate solubilizing bacteria (CFU $\times 10^3$ / g of oven dry soil after cropping Table 27. indicated that there was no significant differences between the treatments in 2016. However, application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ recorded the maximum value (5.6 CFU $\times 10^3$ / g) while, the lowest value (3 CFU $\times 10^3$ / g) was recorded in (T₈).

During 2016, there were significant differences among the treatments in respect to population of phosphate solubilising bacteria in the soil. In similar trend, application of FYM (10 t/ha) +100% Rec. N through FYM + BF (T₂) recorded the highest population (6.6 CFU $\times 10^3$ / g) while, T₈ recorded the lowest population (3.9 CFU $\times 10^3$ / g).

4.1.4.3.3. Population of fungal (CFU $\times 10^3$ / g of oven dry soil)

Fungal population in the soil after cropping in two years of the experiment was affected significantly by the treatments involving different levels of organic manure with and without bio-fertilizers and inorganic fertilization as shown in Table 27. Application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ recorded the maximum fungal population (6.4 and 5.33 CFU $\times 10^3$ /g) in the soil after cropping in 2015 and, 2016, respectively. While, T₈ recorded the lowest fungal population (3.6 and 2.5 CFU $\times 10^3$ / g) in the soil after cropping in 2015 and, 2016, respectively.

4.1.4.3.4. Population of Actinomycetes (CFU $\times 10^3$ / g of oven dry soil)

The data on Actinomycetes Population in the soil after cropping (CFU $\times 10^3$ / g of oven dry soil) during two years of the experiment indicted significant differences between the treatments as shown in Table 27. The highest Population of Actinomycetes (29.93 and 44.56 was recorded in T₉ with application of NPK (160:80:80 Kg /ha) + FYM (10 t/ha) during 2015 and 2016 respectively, while application of recommended dose of FYM (10 t/ha) in T₇ resulted in minimum population (20 and 30.5 CFU $\times 10^3$ /g of oven dry soil) during 2015 and 2016 respectively.

Table 27. Soil microbial population (CFU $\times 10^3$ / g of oven dry soil) as influenced by organic manure, bio-fertilizers and inorganic fertilizer

Treatments		Soil microbial population							
		Heterotrophic free living N ₂ fixer		phosphate solubilising bacteria		Fungal		Actinomyceteyes	
After the experiment		2015	2016	2015	2016	2015	2016	2015	2016
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	34.96 ^{ABC}	41 ^C	4	5.48 ^{ABC}	6.26 ^{AB}	5.16 ^{AB}	24.33	34.00 ^{AB}
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	40.66 ^A	63.33 ^A	5.6	6.6 ^A	6.4 ^A	5.33 ^A	26.67	36.33 ^{AB}
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	31.83 ^{BCD}	36.83 ^C	3.6	4.8 ^{BCD}	4.1 ^{CD}	3 ^{CD}	22.67	31.67 ^B
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	36.42 ^{ABC}	54.5 ^B	4.5	5.6 ^{AB}	4.7 ^{CD}	3.65 ^{CD}	25.85	35.07 ^{AB}
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	29.5 ^{CD}	39.4 ^C	3.3	4.08 ^{CD}	4.3 ^{CD}	3 ^{CD}	21.67	30.67 ^B
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	34 ^{ABC}	40 ^C	4	4.9 ^{BCD}	5.3 ^{BC}	4 ^{BC}	24.67	32.50 ^B
T ₇	Rec. FYM (10 t/ha) only	26.13 ^D	34 ^C	3.7	4.06 ^{CD}	3.7 ^D	2.66 ^D	20.00	30.50 ^B
T ₈	Rec.NPK (160:80:80 Kg /ha)	36.26 ^{AB}	35 ^C	3	3.9 ^D	3.6 ^D	2.5 ^D	28.33	41.83 ^{AB}
T ₉	Rec. NPK (160:80:80 Kg /ha)+ Rec. FYM (10 t/ha)	39 ^A	55 ^B	4.5	5.32 ^{ABC}	5.1 ^{BC}	4 ^{BC}	29.93	44.56 ^A
General Mean		34.26	44.67	4.04	4.99	4.80	3.70	24.33	35.24
CV%		10.99	10.33	26.54	17.07	1.26	1.26	16.74	12.5
LSD at 5%		6.52	7.99	NS	1.47	15.20	19.72	NS	7.47

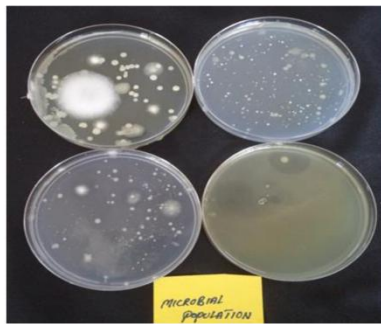
Legend: FYM- Farm Yard Manure

Rec. - Recommended

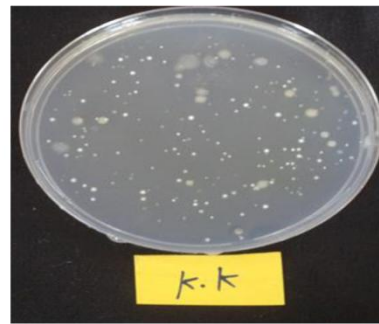
BF – Bio-fertilizer



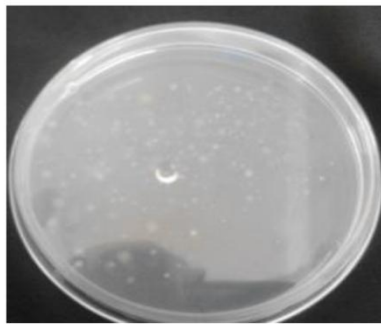
Media preparation



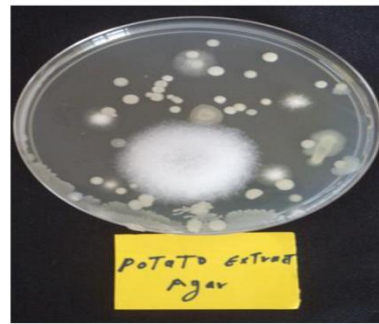
Microbial population



Population of Actinomycetes (CFU $\times 10^3$ / g of oven dry soil)



Population of heterotrophic free-living N₂ fixers (CFU $\times 10^3$ / g of oven dry soil)



Population of fungal (CFU $\times 10^3$ / g of oven dry soil)

Plate 11: Soil microbial population

4.1.5. Nutrient uptake by plant

Nitrogen, phosphorus, potassium, secondary and micronutrient uptake by the plant tissue as affected by application of different levels of nitrogen through FYM with and without bio-fertilizer and inorganic fertilizer as showed in Table (28. to 33.)

4.1.5.1. Nitrogen uptake (kg/ha)

Different levels of N through FYM with and without bio-fertilizer and inorganic fertilizer had profound and significant influence on plant nitrogen uptake during the two years of the experiment as shown in Table 28.

Where the highest nitrogen uptake was recorded in the plants applied with NPK (160:80:80 kg/ha) + FYM (10 t/ha) *i.e.*, T₉ in the main crop (155.67 and 113.19 kg/ha) and ratoon (56.43 and 26.65 kg/ha) during 2015 and 2016, respectively. In contrast, the lowest nitrogen uptake was recorded in T₇ in the main crop (55.92 and 53.81 kg/ha) and ratoon (15.95 and 13.16 kg/ha) during 2015 and 2016, respectively.

4.1.5.2. Phosphorus uptake (kg/ha)

Data in Table 29. Indicated that there was significant differences in phosphorus uptake by the plant of the main crop and ratoon among the treatments. While, The highest phosphorous uptake was recorded in T₉ with application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) in the main crop (43.80 and 32.43 kg/ha) and ratoon (16.14 and 14.01 kg/ha) during 2015 and 2016, respectively. Whereas, the minimum value was recorded in T₇ of the main crop (20.54 and 14.22kg/ha) and ratoon (6.97 and 5.28 kg/ha) during 2015 and 2016, respectively.

4.1.5.3. Potassium uptake (kg/ha)

Significant differences could be observed among the treatments in Table 30. in respect to of potassium uptake by plant tissue among the treatments. Wherese, potassium uptake was highest with application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) in T₉ in the main crop (163.33 and 116.16 kg/ha) and ratoon (55.56 and 39.27 kg/ha) in 2015 and 2016, respectively. While, the lowest value was recorded in T₇ in the main crop (79.55 and 51.92 kg/ha) and ratoon (24.67 and 19.10 kg/ha) in 2015 and 2016, respectively.

Table 28. Nitrogen uptake (kg/ha) in basil (*Ocimum basilicum*) as influenced by organic manure, bio-fertilizers and inorganic fertilizer

Treatments		2015		2016	
		Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	82.63 ^{CD}	27.06 ^D	69.66 ^{CD}	17.33 ^D
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	112.69 ^B	40.24 ^C	84.80 ^B	19.44 ^C
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	82.88 ^{CD}	26.96 ^D	64.04 ^{CD}	15.29 ^E
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	95.72 ^C	32.92 ^D	68.15 ^C	17.57 ^D
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	68.50 ^{DE}	20.84 ^D	61.36 ^{DE}	13.80 ^F
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	82.23 ^{CD}	25.96 ^D	63.83 ^{CD}	15.80 ^E
T ₇	Rec. FYM (10 t/ha) only	55.92 ^E	15.95 ^D	53.81 ^E	13.16 ^F
T ₈	Rec.NPK (160:80:80 kg /ha)	123.52 ^B	41.95 ^B	97.35 ^B	21.69 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	155.67 ^A	56.43 ^A	113.19 ^A	26.65 ^A
General Mean		83.07	32.04	75.13	17.86
CV%		9.15	12.32	8.15	3.74
LSD at 5%		15.13	6.83	10.6	1.15

Legend: FYM- Farm Yard Manure **Rec. -** Recommended **BF** – Bio-fertilizer

Table 29. Phosphorus uptake (kg/ha) in basil (*Ocimum basilicum*) as influenced by organic manure, bio-fertilizers and inorganic fertilizer

Treatments		2015		2016	
		Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	29.85 ^{BC}	12.87 ^B	24.07 ^{BC}	8.65 ^{BC}
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	36.76 ^{AB}	14.53 ^B	27.17 ^{AB}	12.54 ^B
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	27.21 ^{BC}	10.47 ^C	17.74 ^{CD}	7.60 ^{CD}
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	32.49 ^{ABC}	13.67 ^B	19.95 ^D	7.79 ^B
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	22.16 ^C	8.77 ^D	15.63 ^D	5.09 ^{CD}
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	28.36 ^{BC}	8.14 ^D	17.27 ^D	9.41 ^{CD}
T ₇	Rec. FYM (10 t/ha) only	20.54 ^C	6.97 ^D	14.22 ^D	5.28 ^D
T ₈	Rec.NPK (160:80:80 kg /ha)	35.47 ^{AB}	12.58 ^B	25.36 ^{ABC}	10.27 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	43.80 ^A	16.14 ^A	32.43 ^A	14.01 ^A
General Mean		29.00	11.57	21.32	8.96
CV%		16.05	7.63	12.14	12.29
LSD at 5%		8.54	1.52	4.47	1.66

Legend: FYM- Farm Yard Manure **Rec. -** Recommended **BF** – Bio-fertilizer

Table 30. Potassium uptake (kg/ha) in basil (*Ocimum basilicum*) as influenced by organic manure, bio-fertilizers and inorganic fertilizer

Treatments		2015		2016	
		Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	99.16 ^{CD}	33.80 ^{DE}	77.64 ^{CD}	24.88 ^{CDE}
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	124.97 ^B	44.05 ^{BC}	85.23 ^C	29.44 ^{BC}
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	108.55 ^{BC}	33.65 ^{DE}	62.31 ^{DE}	22.07 ^{DE}
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	122.89 ^B	38.94 ^{CD}	68.69 ^{CDE}	26.63 ^{BCD}
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	87.02 ^{DE}	27.56 ^E	57.20 ^E	20.02 ^{DE}
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	115.35 ^{BC}	30.14 ^{DE}	63.03 ^{DE}	23.40 ^{CDE}
T ₇	Rec. FYM (10 t/ha) only	79.55 ^E	24.67 ^E	51.92 ^E	19.10 ^E
T ₈	Rec.NPK (160:80:80 kg /ha)	125.19 ^B	49.15 ^{AB}	99.33 ^B	31.37 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	163.33 ^A	55.56 ^A	116.16 ^A	39.27 ^A
General Mean		114.00	37.50	75.72	26.24
CV%		7.31	10.43	10.56	10.53
LSD at 5%		14.43	4.03	13.84	4.80

Legend: FYM- Farm Yard Manure

Rec. – Recommended

BF – Bio-fertilizer

4.1.5.4 Secondary nutrient uptake

The data on secondary nutrient uptake by the plant tissue as influenced by different levels of N through FYM with and without bio-fertilizer and inorganic fertilizer are presented in Table 31.

4.1.5.4.1. Calcium (Ca)

Calcium uptake by the tissue of the main crop and ratoon of basil has significant differences due to varied treatments in the main and ratoon during during two years of the experimentas presented in Table 31. Wherein, the treatment T₈ with application of NPK (160:80:80 kg /ha) registered the highest calcium uptake in the main crop (190.53) during 2015. Wherese application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ recorded highest Ca uptake (162.99 kg/ha) during 2016. While, in ratoon the treatment T₉ recorded highest Ca uptake (67.44 and 42.33 kg/ha) during 2015 and 2016, respectively. Whereas, the treatment T₇ recorded the lowest value in the main crop (106.07 and 67.97 kg/ha) and ratoon (42.74 and 17.33 kg/ha) during 2015 and 2016, respectively.

4.1.5.4.2. Magnesium (Mg)

The data on Mg uptake by the plant tissue of the main crop and ratoon in Table31. indicted that there was significant differences between the treatments. While, The highest Mg uptake of the main crop (34.52 and 32.28 kg/ha) and ratoon (13.96 and 11.45 kg/ha) was recorded in T₉ with application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) in 2015 and 2016, respectively, while, the lowest content was recorded in T₇ in the main crop (19.49 and 15.26 kg/ha) and ratoon (7.13 and 5.31 kg/ha) in 2015 and 2016, respectively.

4.1.5.5. Micronutrient uptake by the plant (Fe, Mn, Zn and Cu kg/ha)

The data on micronutrient uptake by the plant tissue as influenced by different levels of N through FYM with and without bio-fertilizer and inorganic fertilizer are presented in Table 32 and 33.

Table 31. Secondary nutrient uptake (kg/ha) in basil (*Ocimum basilicum*) as influenced by organic manure, bio-fertilizers and inorganic fertilizer

Treatments		Ca				Mg			
		2015		2016		2015		2016	
		Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	140.04 ^{BCD}	45.60 ^B	123.08 ^{BC}	29.6 ^{ABC}	24.77 ^{CDE}	10.27 ^C	22.94 ^{BCD}	8.23
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	156.43 ^{ABC}	52.05 ^B	147.91 ^{AB}	31.66 ^{ABC}	28.72 ^{BC}	12.28 ^{AB}	26.48 ^{ABC}	9.63
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	142.84 ^{BCD}	43.50 ^B	83.95 ^D	25.03 ^{ABC}	23.26 ^{DEF}	9.44 ^{CD}	19.61 ^{BCD}	7.53
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	159.03 ^{ABC}	47.3 ^{AB}	105.99 ^{CD}	27.57 ^{BC}	27.17 ^{CD}	10.91 ^{BC}	20.64 ^{BCD}	8.09
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	119.76 ^{CD}	43.42 ^B	76.04 ^D	20.68 ^{BC}	21.05 ^{EF}	8.27 ^{DE}	17.88 ^{CD}	6.53
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	157.83 ^{ABC}	44.85 ^B	84.35 ^D	22.95 ^{BC}	24.04 ^{CDEF}	9.05 ^{CD}	18.87 ^{CD}	6.97
T ₇	Rec. FYM (10 t/ha) only	106.07 ^D	42.74 ^B	67.97 ^D	17.33 ^C	19.49 ^F	7.13 ^E	15.26 ^D	5.31
T ₈	Rec.NPK (160:80:80 kg /ha)	190.53 ^A	66.57 ^A	153.00 ^{AB}	39.36 ^{AB}	32.00 ^{AB}	12.13 ^B	28.28 ^{AB}	9.31
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	166.13 ^{AB}	67.44 ^A	162.99 ^A	42.33 ^A	34.52 ^A	13.96 ^A	32.28 ^A	11.45
General Mean		148.74	49.94	111.70	28.50	26.11	10.38	22.47	8.12
CV%		11.30	14.54	13.27	24.79	8.03	8.03	16.79	31.36
LSD at 5%		29.09	28.12	11.47	12.23	3.63	1.44	6.53	NS

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

4.1.5.5.1. Iron (Fe)

Tissue uptake of Iron was significant with the application of different treatments. While, The treatment T₉ with application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) recorded the highest Fe uptake in the main crop (6.64 and 4.33 kg/ha) and ratoon (2.18 and 1.41 kg/ha) during 2015 and 2016, respectively. While, the lowest value was recorded in T₇ in the main crop (2.87 and 1.64 kg/ha) and in ratoon (0.81 and 0.61 kg/ha) during 2015 and 2016, respectively.

4.1.5.5.2. Manganese (Mn)

Application of different levels of nitrogen through FYM with and without bio-fertilizer and inorganic fertilizer has significant differences in term of manganese uptake by the plant tissue during two years of the experiment. highest plant Mn uptake was observed in T₉ in the main crop (0.81 and 0.53 kg/ha) and ratoon (0.24 and 0.12 kg/ha) While, the lowest uptake was registered in T₇ in the main crop (0.43 and 0.19 kg/ha) and ratoon (0.10 and 0.06 kg/ha) during 2015 and 2016, respectively.

4.1.5.5.3. Zinc (Zn)

Graded levels of N through FYM with and without bio-fertilizer and inorganic fertilizer had significant influence on Zn uptake by the plant tissue of the main crop and ratoon during two years of the experiment. Whereas, the highest Zn uptake in the main crop (0.49 and 0.45 kg/ha) and (0.21 and 0.16 kg/ha) in ratoon was recorded in T₉ with application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) during 2015 and 2016, respectively. The lowest Zn uptake by plant tissue was in T₇ in the main crop (0.28 and 0.15 kg/ha) and ratoon (0.11 and 0.07 kg/ha) in 2015 and 2016, respectively

4.1.5.5.4. Copper (Cu)

The Cu uptake by the plant tissue has significant differences due to different treatments whereas, the treatment T₉ recorded the highest Cu uptake (0.15 and 0.14 kg/ha) in the main crop and (0.07 and 0.05 kg/ha) in ratoon during 2015 and 2016 respectively. While, the lowest value was observed in T₇ in the main crop (0.07 and 0.05 kg/ha) and ratoon (0.02 and 0.02 kg/ha) during two years of the experiment respectively.

Table 32. Micronutrient uptake (kg/ha) in basil (*Ocimum basilicum*) main crop as influenced by organic manure, bio-fertilizers and inorganic fertilizer

Treatments		2015				2016			
		Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	3.89 ^B	0.56 ^{CD}	0.36 ^{CD}	0.10 ^{BCD}	3.11 ^{ABCD}	0.32 ^{BCD}	0.26 ^{BCD}	0.08 ^{CD}
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	5.09 ^{AB}	0.72 ^{AB}	0.43 ^{AB}	0.12 ^B	3.63 ^{ABC}	0.38 ^{BC}	0.31 ^{BC}	0.09 ^{BC}
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	3.47 ^B	0.58 ^{BCD}	0.34 ^{CD}	0.08 ^{CD}	2.18 ^{ABCD}	0.27 ^{CDE}	0.19 ^D	0.06 ^{CD}
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	4.26 ^B	0.64 ^{BCD}	0.40 ^{BC}	0.10 ^{BCD}	2.40 ^{BCD}	0.30 ^{BCDE}	0.22 ^{CD}	0.07 ^{CD}
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	3.24 ^B	0.51 ^{DE}	0.32 ^{DE}	0.07 ^{CD}	1.84 ^{CD}	0.24 ^{DE}	0.17 ^D	0.06 ^D
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	3.89 ^B	0.61 ^{BCD}	0.38 ^{BCD}	0.08 ^{CD}	1.99 ^{BCD}	0.26 ^{DE}	0.20 ^D	0.06 ^{CD}
T ₇	Rec. FYM (10 t/ha) only	2.87 ^B	0.43 ^E	0.28 ^E	0.07 ^D	1.64 ^D	0.19 ^E	0.15 ^D	0.05 ^D
T ₈	Rec.NPK (160:80:80 kg /ha)	5.04 ^{AB}	0.70 ^{ABC}	0.44 ^{AB}	0.11 ^{BC}	3.80 ^{AB}	0.40 ^B	0.32 ^B	0.10 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	6.64 ^A	0.81 ^A	0.49 ^A	0.15 ^A	4.33 ^A	0.53 ^A	0.45 ^A	0.14 ^A
General Mean		4.26	0.62	0.38	0.1	2.77	0.32	0.25	0.08
CV%		21.11	9.59	7.7	14.56	25.49	14.76	16.93	15.75
LSD at 5%		1.55	0.1	0.05	0.24	1.22	0.081	0.073	0.02

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

Table 33. Micronutrient uptake (kg/ha) in basil (*Ocimum basilicum*) ratoon as influenced by organic manure, bio-fertilizers and inorganic fertilizer

Treatments		2015				2016			
		Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	1.46 ^{ABC}	0.15 ^{BCDE}	0.16 ^{BC}	0.03 ^{BCD}	0.74 ^B	0.08 ^{AB}	0.10 ^B	0.03 ^B
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	1.82 ^{AB}	0.18 ^{BC}	0.18 ^B	0.05 ^{AB}	0.89 ^B	0.10 ^{AB}	0.11 ^B	0.03 ^B
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	1.27 ^{BC}	0.13 ^{BCDE}	0.13 ^{CD}	0.03 ^{CD}	0.67 ^B	0.07 ^B	0.09 ^B	0.03 ^B
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	1.77 ^{AB}	0.16 ^{BCD}	0.14 ^{CD}	0.04 ^{BCD}	0.74 ^B	0.09 ^{AB}	0.10 ^B	0.03 ^B
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	1.02 ^{BC}	0.12 ^{DE}	0.13 ^{CD}	0.03 ^{CD}	0.67 ^B	0.06 ^B	0.08 ^B	0.02 ^{BC}
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	1.31 ^{BC}	0.13 ^{CDE}	0.14 ^{CD}	0.03 ^{BCD}	0.76 ^B	0.08 ^{AB}	0.09 ^B	0.03 ^{BC}
T ₇	Rec. FYM (10 t/ha) only	0.81 ^C	0.10 ^E	0.11 ^D	0.02 ^D	0.61 ^B	0.06 ^B	0.07 ^B	0.02 ^C
T ₈	Rec.NPK (160:80:80 kg /ha)	1.53 ^{ABC}	0.19 ^B	0.15 ^{BCD}	0.05 ^{ABC}	0.99 ^B	0.11 ^{AB}	0.11 ^B	0.04 ^B
T ₉	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	2.18 ^A	0.24 ^A	0.21 ^A	0.07 ^A	1.41 ^A	0.12 ^A	0.16 ^A	0.05 ^A
General Mean		1.46	0.16	0.15	0.04	0.83	0.09	0.1	0.03
CV%		22.42	13.66	10.24	20.36	16.42	20.47	20.06	11.63
LSD at 5%		0.56	0.037	0.027	0.14	0.23	0.03	0.035	0.063

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer

4.1.6. Nitrogen balance (kg ha^{-1})

Data from Tables 34 to 36 revealed an actual increase in soil nitrogen balance for all treatments and the results presented in figures 22. to 24. The treatment T_2 with application of FYM (10 t/ha) +100% Rec. N through FYM + BF recorded maximum gain of N in the soil (42.40 and 49.60 kg ha^{-1}) during 2015 and 2016, respectively. While recommended dosage of organic fertilizer (T_7) attained the least value (4.91 and 11.49 kg ha^{-1}) respectively.

The pooled data of the two years of trials showed a clear effect of biofertilizers as it increased the nitrogen gain in soil by (46 kg ha^{-1}) with application of FYM (10 t/ha) +100% Rec. N through FYM + BF in T_2 . While, the minimum gain (8.2 kg ha^{-1}) was recorded with application of recommended dose of FYM in T_7 .

To highlight the differences between treatments in respect to actual gain of N (kg ha^{-1}) The treatment T_8 with application of recommended dose of NPK (160:80:80 kg /ha) and T_7 applied with recommended dose of FYM (10 t/ha) was considered a baseline (100 %). Then compared with the other treatments; as shown in Table 36. and figure 24.

The treatment T_2 with application of FYM (10 t/ha) +100% Rec. N through FYM + BF gained (3.15) and (5.60) fold of N comparing with T_8 and T_7 respectively. It could be concluded from the Table 36. With respect to different levels of N through FYM, that when we increase the level of N through FYM, the actual gain of N increases.

4.1.7. Economic studies

The economics has been worked out by comparing costs and returns as influenced by different levels of organic manures along with and without bio-fertilizers and inorganic fertilization in basil. Total cost under each treatment was worked out on the basis of cost of agro inputs and man power needed for one hectare area. The procedure for calculating the cost for particular treatments is given in the APPENDIX III and V.

Table 34. Nitrogen balance on 2015

Treatment	initial fertility (kg ha ⁻¹)	N added (kg ha ⁻¹)				Nitrogen uptake (kg ha ⁻¹)	Expected balance (kg ha ⁻¹)	Actual Fertility after harvest (kg ha ⁻¹)	Apparent gain/losses (kg ha ⁻¹)	Actual gain/losses (kg ha ⁻¹)
	(A)	Mineral fertilizer	Rec. FYM	Rec. N through FYM	Total (B)	(C)	(D)=B-C	(E)	F=E-D	G=E-A
T ₁	185	0	64	160	409	117.84	291.16	220.15	-71.01	35.15
T ₂	185	0	64	160	409	150.62	258.38	227.40	-30.97	42.40
T ₃	185	0	64	120	369	107.51	261.49	211.68	-49.81	26.68
T ₄	185	0	64	120	369	134.02	234.98	222.57	-12.42	37.57
T ₅	185	0	64	80	329	89.10	239.90	203.21	-36.69	18.21
T ₆	185	0	64	80	329	105.95	223.05	211.78	-11.37	26.78
T ₇	185	0	64	0	249	78.04	170.96	189.91	18.95	4.91
T ₈	185	160	0	0	345	169.93	175.07	195.96	20.89	10.96
T ₉	185	160	64	0	409	208.20	200.80	199.58	-1.21	14.58

Table 35. Nitrogen balance on 2016

Treatment	initial fertility (kg ha ⁻¹)	N added (kg ha ⁻¹)				Nitrogen uptake (kg ha ⁻¹)	Expected balance ((kg ha ⁻¹))	Actual Fertility after harvest	Apparent gain/losses (kg ha ⁻¹)	Actual gain/losses Actual gain/losses (kg ha ⁻¹)
	(A)	Mineral fertilizer	Rec. FYM	Rec. N through FYM	Total (B)	(C)	(D)=B-C	(E)	F=E-D	G=E-A
T₁	220.15	0	64	160	444.14	82.17	361.97	262.10	-99.87	41.95
T₂	227.40	0	64	160	451.40	100.4	351.16	277.00	-74.16	49.60
T₃	211.68	0	64	120	395.68	74.85	320.83	246.00	-74.83	34.32
T₄	222.57	0	64	120	406.56	81.07	325.50	266.70	-58.80	44.13
T₅	203.21	0	64	80	347.21	70.61	276.60	228.00	-48.60	24.79
T₆	211.68	0	64	80	355.68	75.19	280.49	246.40	-34.19	34.62
T₇	189.91	0	64	0	253.90	63.09	190.82	201.40	10.58	11.49
T₈	195.96	160	0	0	355.95	115.99	239.96	214.20	-25.76	18.24
T₉	199.58	160	64	0	423.58	134.31	289.28	222.00	-67.28	22.42

Nitrogen sheet balance during 2015 and 2016

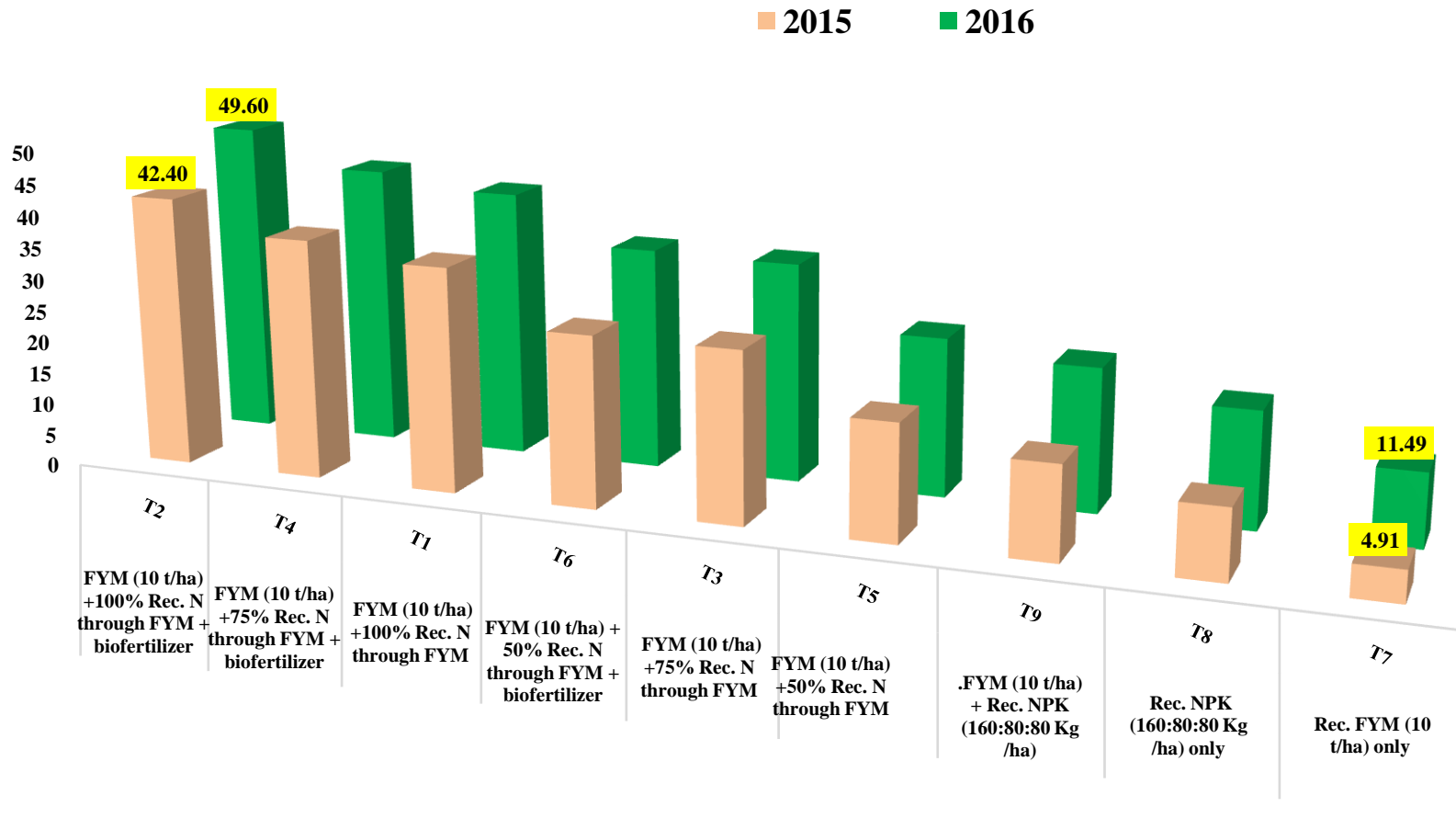


Fig. 23: Nitrogen gained during 2015-2016 (kg/ha)

Table 36. Nitrogen balance pooled data for trials of the two years

Treatments		2015	2016	pooled data	Compared with T8 %	Compared with T7 %
T₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	49.60	42.40	46	315.07	560.98
T₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	44.13	37.57	40.85	279.79	498.17
T₁	FYM (10 t/ha) +100% Rec. N through FYM	41.95	35.15	38.55	264.04	470.12
T₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	34.72	26.78	30.75	210.62	375.00
T₃	FYM (10 t/ha) +75% Rec. N through FYM	34.32	26.68	30.5	208.90	371.95
T₅	Rec. NPK (160:80:80 kg /ha)+ Rec. FYM (10 t/ha)	24.79	18.21	21.5	147.26	262.20
T₉	FYM (10 t/ha) +50% Rec. N through FYM	22.42	14.58	18.5	126.71	225.61
T₈	Rec.NPK (160:80:80 kg /ha)	18.24	10.96	14.6	*100.0	178.05
T₇	Rec. FYM (10 t/ha) only	11.49	4.91	8.2	56.16	**100.0

*T7 was considered a baseline (100 %). Then compared with the other treatments;

**T8 was considered a baseline (100 %), then compared with the other treatments.

Comparison of recommended FMY and mineral doses with other treatments

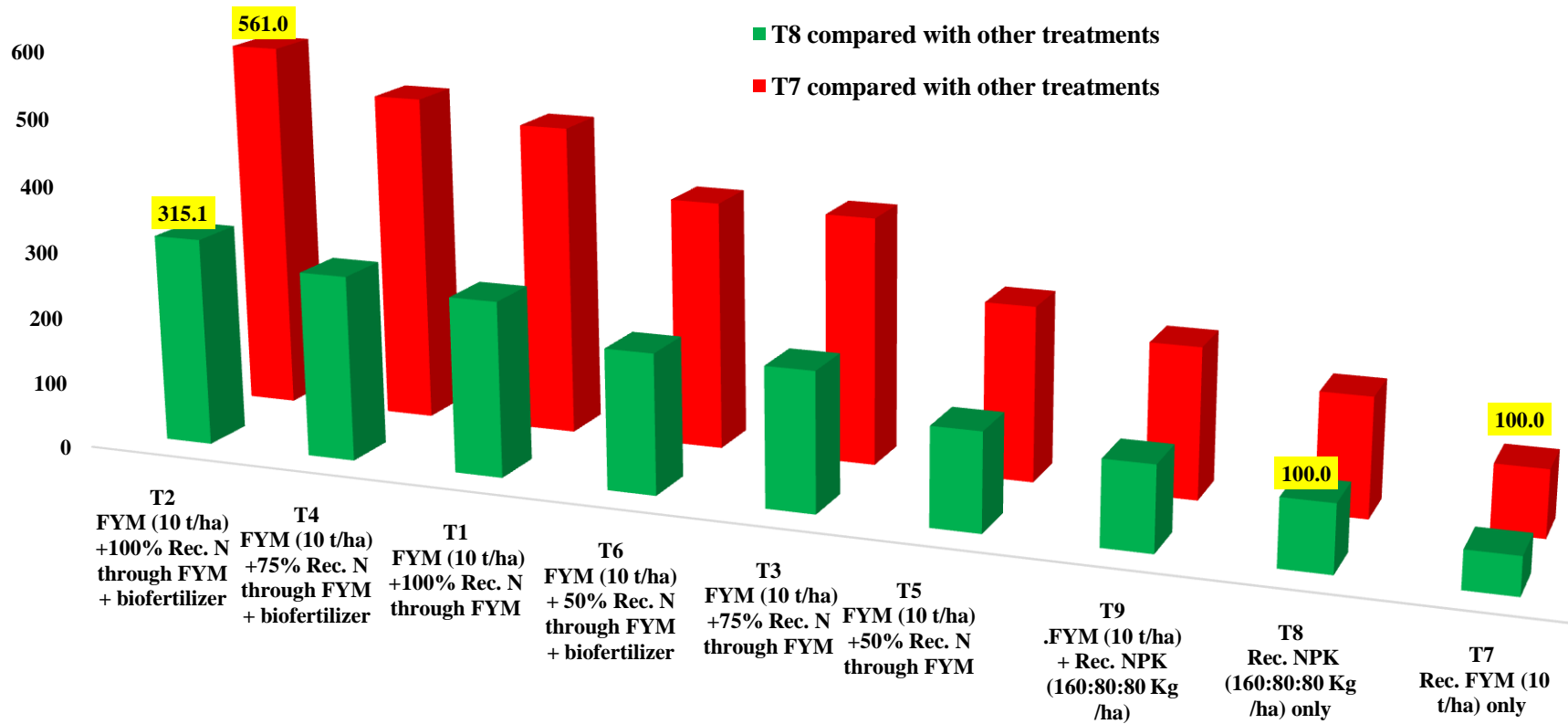


Fig. 24: Nitrogen balance comparison of T₇ and T₈ with other treatments (pooled data of gained N) %

Oil has important medicinal properties; it is of complex and variable composition. considering the overall oil yield (t/ha) application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) in T₉ recorded maximum net income (171,99 and 113,172 Rs./ha) during 2015 and 2016, respectively. While the minimum value has been in T₇ (40,175 and 6,41 Rs./ha) during 2015 and 2016 respectively as showed in Table 37.

The perusal of data reveals that that total costs was highest (55,515 and 55,026 Rs./ha) in T₂ plots applied with FYM (10 t/ha) +100% Rec. N through FYM + BF Whereas, minimum expenditure (35,790 and 35,301 Rs./ha) was with application of Rec. NPK (160:80:80 kg /ha) during 2015 and 2016, respectively.

The maximum gross income returns of (213,780 and 15,496 Rs./ha) obtained from plots applied with Rec.NPK (160:80:80 kg /ha) + FYM (10 t/ha) during 2015 and 2016, respectively.

For benefit cost ratio, application of 100% recommended dose of NPK fertilizer in T₈ fetched maximum B/ C ratio (5.49) in the first year. While the minimum value (2) has been recorded in T₇.Whereas, in the next year application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) in T₉ recorded maximum B/C ratio (3.71) while, the minimum value was in T₇ (1.02).

For the pooled data of the tow years of experiements, as shown in Tale 38. application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) in T₉ recorded maximum gross income (142581,3 Rs./ha) While the minimum value has been recorded in T₇ (20407,73 Rs./ha).

Table 37. Economic of organic, bio-fertilizer and inorganic practices in basil (*Ocimum basilicum*)

Treatments		Total Cost Rs./ha		Cumulative oil yield l/ha		Gross income (oil yield) Rs./ha		Net income Rs./ha		B/C ratio	
		2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	55,015	54,526	238,37	141,26	143022,0	84756	88,007	29,741	2.60	1.54
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	55,515	55,026	294	179,2	176400,0	107520	120,885	52,005	3.18	1.94
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	51,265	50,776	172,76	103,84	103656,0	62304	52,391	11,039	2.02	1.22
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	51,765	51,276	232,21	116,82	139326,0	70092	87,561	18,327	2.69	1.35
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	47,515	47,026	157,58	94,38	94548,0	56628	47,033	9,113	1.99	1.19
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	48,015	47,526	172,91	100,11	103746,0	60066	55,731	12,051	2.16	1.25
T ₇	Rec. FYM (10 t/ha) only	40,015	39,526	133,65	67,76	80190,0	40656	40,175	6,41	2.00	1.02
T ₈	Rec.NPK (160:80:80 Kg /ha)	35,790	35,301	327,51	220,47	196506,0	132282	160,716	96,492	5.49	3.70
T ₉	Rec. NPK (160:80:80 Kg /ha)+ Rec. FYM (10 t/ha)	41,790	41,301	356,3	258,27	213780,0	154962	171,990	113.172	5.12	3.71

1 liter oil = 600 Rs. Note: B: C ratio was calculated taking into account the total cost and gross returns obtained over two years of the experiment Data statically not analysed

Table 38. Economic of organic, bio-fertilizer and inorganic practices in basil (*Ocimum basilicum*), Mean values of gross income, net income , benefit cost ratio of two years of experiment

Treatments		Total Cost of cultivation Rs./ha	Cumulative oil yield l/ha	Gross income (oil yield) Rs./ha	Net income Rs./ha	B/C ratio
T ₁	FYM (10 t/ha) +100% Rec. N through FYM	54,770	189.815	113889	58873,73	2.07
T ₂	FYM (10 t/ha) +100% Rec. N through FYM + BF	55,270	236.6	141960	86444,73	2.56
T ₃	FYM (10 t/ha) +75% Rec. N through FYM	51,020	138.3	82980	31714,73	1.62
T ₄	FYM (10 t/ha) +75% Rec. N through FYM + BF	51,520	174.515	104709	52943,73	2.02
T ₅	FYM (10 t/ha) +50% Rec. N through FYM	47,270	125.98	75588	28072,73	1.59
T ₆	FYM (10 t/ha) +50% Rec. N through FYM+BF	47,770	136.51	81906	33890,73	1.71
T ₇	Rec. FYM (10 t/ha) only	39,770	100.705	60423	20407,73	1.51
T ₈	Rec.NPK (160:80:80 Kg /ha)	35,545	273.99	164394	128604,3	4.59
T ₉	Rec. NPK (160:80:80 Kg /ha)+ Rec. FYM (10 t/ha)	41,545	307.285	184371	142581,3	4.41

Legend: FYM- Farm Yard Manure

Rec. - Recommended

BF – Bio-fertilizer.

Values of gross income, net income , benefit cost ratio at 2015

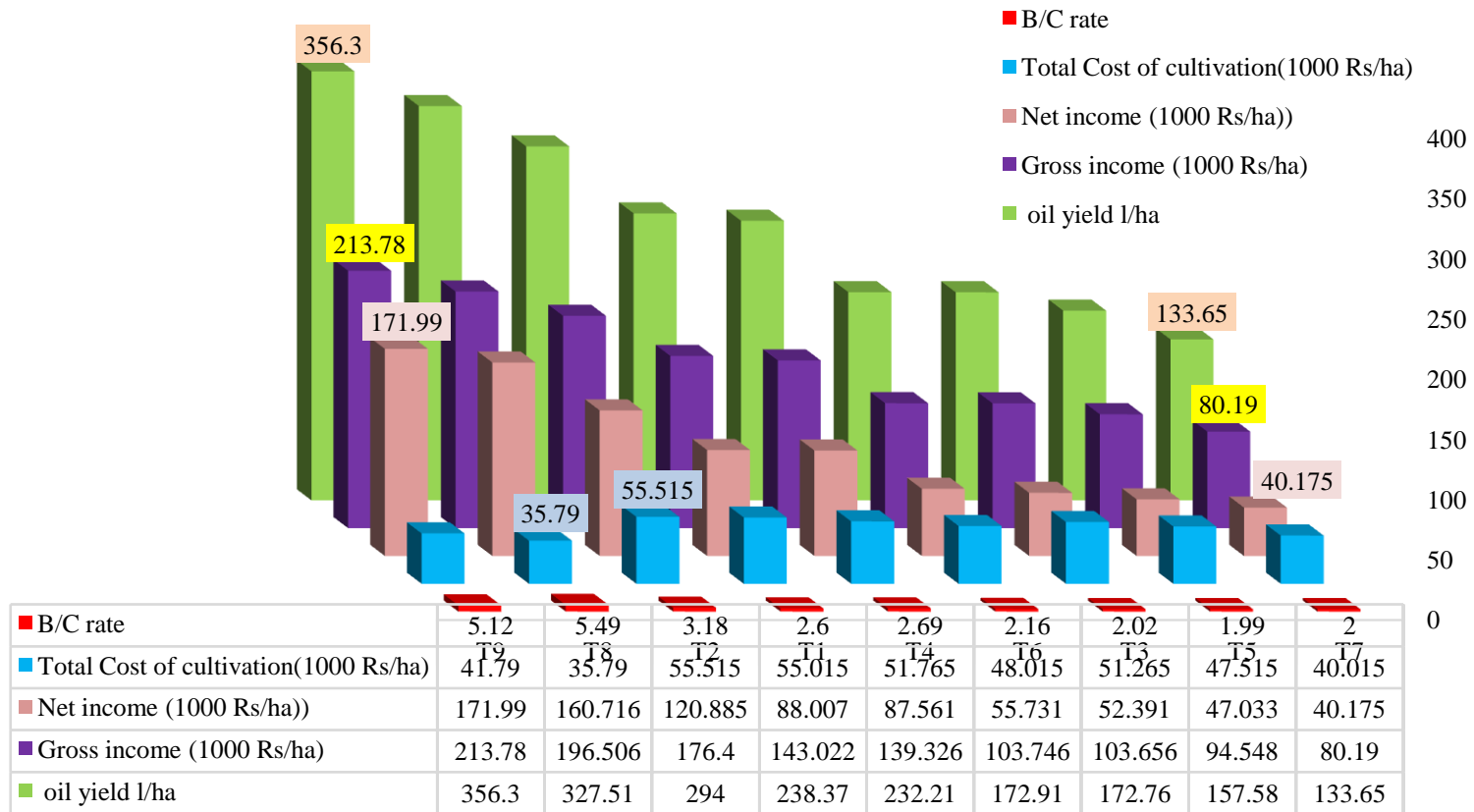
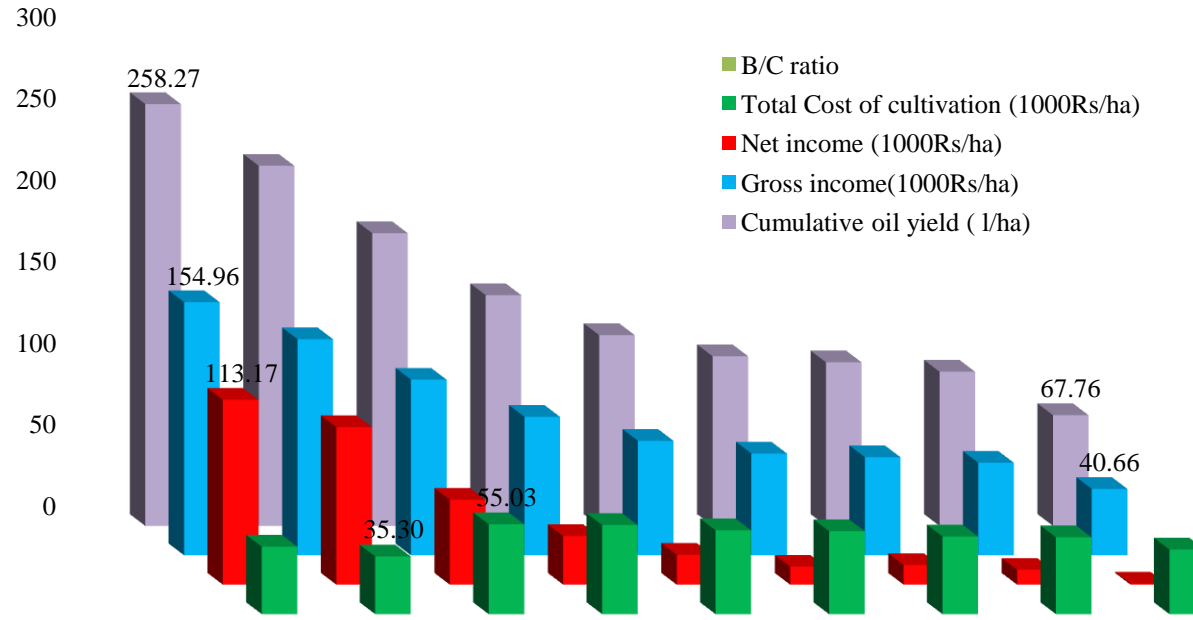


Fig. 25: Economics of organic, bio-fertilizer and inorganic practices in basil (*Ocimum basilicum*), -Values of gross income, net income, benefit cost ratio at 2015

Values of gross income, net income , benefit cost ratio at 2016



B/C ratio	3.71 T9	3.70 T8	0.00 T2	1.54 T1	1.35 T4	1.22 T3	1.25 T6	1.19 T5	1.02 T7
Total Cost of cultivation (1000Rs/ha)	41.30	35.30	55.03	54.53	51.28	50.78	47.53	47.03	39.53
Net income (1000Rs/ha)	113.17	96.49	52.01	29.74	18.33	11.04	12.05	9.11	0.64
Gross income(1000Rs/ha)	154.96	132.28	107.52	84.76	70.09	62.30	60.07	56.63	40.66
Cumulative oil yield (l/ha)	258.27	220.47	179.20	141.26	116.82	103.84	100.11	94.38	67.76

Fig. 26: Economics of organic, bio-fertilizer and inorganic practices in basil (*Ocimum basilicum*), Values of gross income, net income, benefit cost ratio at 2016

Mean values of gross income, net income , benefit cost ratio of two years of experiments

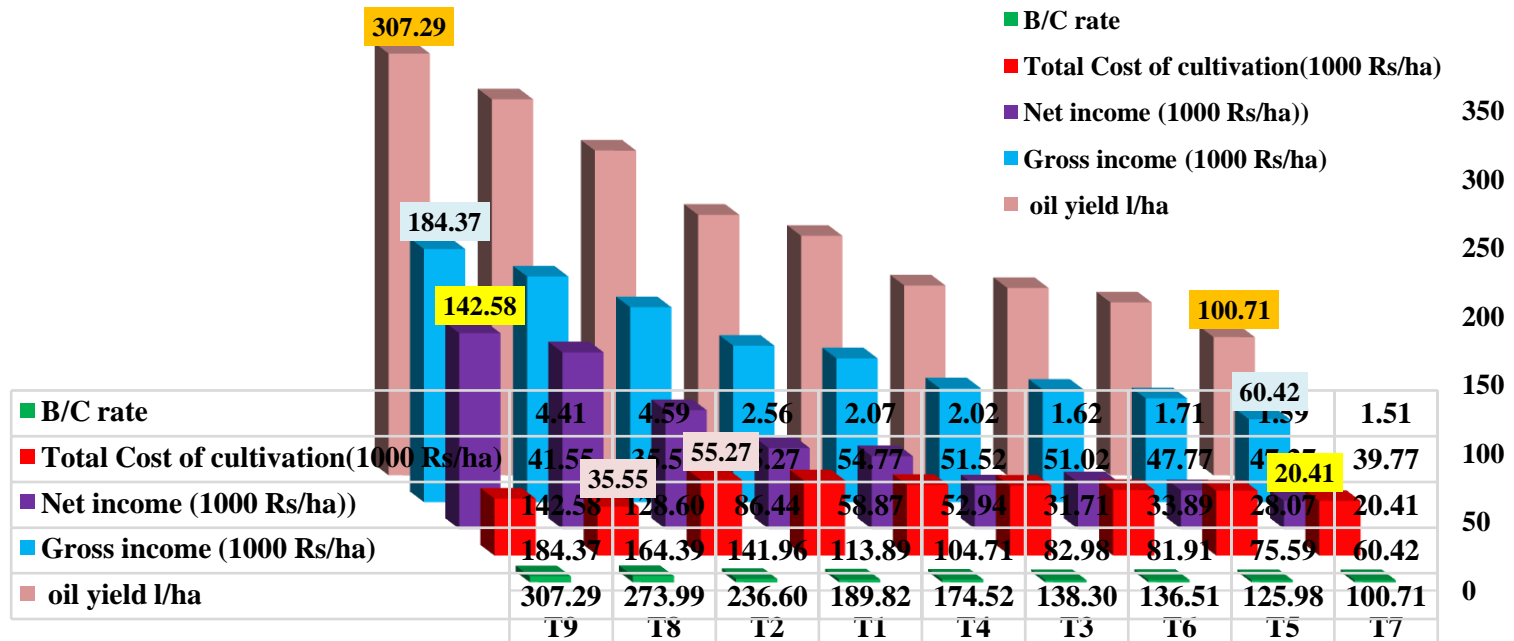


Fig. 27: Economics of organic, bio-fertilizer and inorganic practices in basil (*Ocimum basilicum*), Mean values of gross income, net income, benefit cost ratio of two years of experiment

V. DISCUSSION

Intensive cropping systems with fertilizer responsive crops that rely on high input of inorganic fertilizers often lead to no sustainability in production and also pose a serious threat to soil health. Application of organic sources of nutrients along with recommended dose of inorganic fertilizers is rapidly being practiced. However, considering economics and also nutrient status of the soil, entire dependence on organic sources of nutrients may not be adequate to attain the maximum productivity. Integrated supply of nutrient to plants through planned combinations of organic and inorganic sources is becoming an increasingly important aspect of environmentally sound agriculture. In cultivation of medicinal and aromatic plants, the real value is given to the quality while yield and quantity comes in the second step of importance. Sustainable agricultural approaches are the best methods in which these plants revealed better performance on the account of the harmony with nature. Therefore, current research focused to identify the optimum fertilization that lead to enhance the yield, give the best quality of basil oil and enrich the nutrient of the soil. The results of the investigation are critically discussed in this chapter

5.1 Experiment I : Effect of organic manure and biofertilizers on growth, herb and oil yield, nutrient uptake and oil quality of basil

5.1.1 Growth parameters

5.1.1.1 Plant height

Plant height differed significantly due to application of different levels of N through FYM along with and without bio-fertilizers and inorganic fertilizer (Tables 1a.to 1c.)

Application of organic manure along with inorganic fertilizer in T₉ (Rec. NPK (160:80:80 kg /ha) + FYM (10 t/ha) recorded maximum plant height in the main crop at 30, 60 (DAP) and at harvest during kharif 2015 (53.53, 74.40 and 76.43 cm) and (55.27, 83.13 and 86 cm) during kharif 2016 respectively. Similarly, at second harvest (ratoon) the plants that manured with (T₉) recorded highest values in plant height at 30 (DAP) and at harvest during kharif 2015 (55.9 and 61.33cm) and (54.20 and 59.07 cm) during kharif 2016, respectively. Application of bio- fertilizer enhanced the plant height in companion with FYM with noticing that (T₂) FYM (10 t/ha) +100% Rec. N through FYM + BF recorded the highest plant height comparing with other bio-fertilization treatments in the main crop at 30, 60 (DAP) and at harvest during kharif 2015 (45.47, 72 and 74 cm) and (50.13, 76.80 and 79.73 cm) during kharif 2016, respectively. Similarly, at second harvest (ratoon) the treatment (T₂) recorded highest values in plant height at 30 (DAP) and at harvest (50.13 and 55.47cm) and (52.53 and 54.73 cm) during kharif 2015, 2016 respectively.

The effect of different levels of N through FYM on plant height indicated positive response in relation to quantity applied. In general, the highest level in (T₁) FYM (10 t/ha) +100% Rec. N through FYM recorded the maximum plant height in the main crop during 2015 and, 2016, at 30, 60 (DAP) and at harvest, respectively (46.20, 69.60 and 71.48cm), (48.67, 74.47 and 77.43 cm) respectively. While, the lowest height was recorded in T₇ (43, 59.13 and 62.37 cm) and (41.80, 66.73 and 70.13 cm) at 30, 60 (DAP) and at harvest during 2015 and 2016, respectively.

Nutrients are readily available through inorganic fertilizers; Nitrogen helps the plant by promoting vegetative growth through photosynthates which metabolically converted into protein and thereby adding to production of more vegetative tissues. Phosphorus application helped in the better absorption and efficient utilization of phosphorus. As constituent of DNA and RNA phosphorus has been reported to play a significant role in the metabolic processes of plants. Potassium aids in the effective conversion of photosynthetic for the better growth and ultimately yield of the plant (Dasar, 2004). Moreover higher growth due to the application of organic manure along with inorganic fertilizer can attributed to the ability of organic manure of improving the physical conditions of the soil, resulting in rapid multiplication of beneficial soil microbes, besides supplying adequate major and minor nutrients which might have enhanced the absorption, translocation and assimilation of nutrients, favored an increase in plant growth (Gill *et al.*, 1999).

Application of bio-fertilizer along with organic manure promotes plant growth by various direct and indirect mechanisms viz, production of phytohormones, solubilization of minerals and suppression of disease (Mahfouz and Sharaf Eldin, 2007). It includes different micronutrients which have the ability to convert main nutrition elements from unavailable form to available form during biological processes (Rajendran and Devaraj, 2004) lead to develop better plant height (Bi *et al.*, 2003).

The results confirm the findings of Panchabhai *et al.* (2005) and Yadav *et al.* (2013) in ashwagandha, Bhaskar *et al.* (2005) in *Coleus forskohlii*, Anwar *et al.* (2005) in *Ocimum basilicum*, Kothari *et al.* (2005) in *Spilanthus acmella*, Rajendran and Gnanavel (2008) in *Aloe vera*, Velmurugan *et al.* (2008) in *Curcuma longa*, El-Ghadban *et al.* (2006) in marjoram, Eid and ElGhawwas (2003) in Mint

5.1.1.2 Number of branches:

Different levels of N through organic manures with and without bio-fertilizers and inorganic fertilizer significantly affected the number of branches per plant (Tables 2a.to 2c).

Application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) i.e., T₉ recorded the maximum number in the main crop at 30, 60 (DAP) and at harvest (14.47, 21.67 and 24.07 plant⁻¹), (13.83, 21.73 and 24.13 plant⁻¹) during kharif 2015 and, 2016, respectively. In the second harvest (ratoon) the number of branches increased comparing with the first crop at 30 (DAP) but the vegetative duration period was much shorter so the number of branches at harvest time was lower. However, the plants manured with NPK (160:80:80 kg /ha) + FYM (10 t/ha in (T₉) recorded the highest value at 30 (DAP) and at harvest during kharif 2015 (21.73 and 24.40 plant⁻¹) and kharif 2016 (21.27 and 23.80 plant⁻¹), respectively. Addition of biofertilizer along with FYM improved the number of branches, and the highest number was observed in (T₂) FYM (10 t/ha) +100% Rec. N through FYM + BF in the main crop at 30, 60 (DAP) and at harvest during kharif 2015 (14.47, 21.67 and 24 plant⁻¹) and (13.83, 21.73 and 24.13 plant⁻¹) during kharif 2016, respectively.

In general, the treatments that included application of higher dose of N through FYM were more branching comparing with lower levels. Incorporation of manures and fertilizers significantly increased the available nutrients of the soil. Organic manures act as a source of plant nutrient and humus, which improves the soil physical condition by increasing its capacity to absorb and store water, improving aeration and favoring microbial activity, thereby making conditions favorable for nutrient uptake (Joy *et al.*, 2005). The combined application of inorganic fertilizers and organic manures might have supplied adequate amounts of nutrients, which favored higher metabolic rate and auxin activities in the plant, resulting in better growth attributes. This is in accordance with the findings of Manohar *et al.* (2012), Wafaa *et al.* (2006), Somnath (2005), and Chauhan *et al.* (2005).

Bio-fertilizers might have served to provide a conducive atmosphere in soil for nitrogen accumulation, besides making increased availability of nutrients. That led to increase in the number of branches. Similar findings have been reported by Hemalatha *et al.* (2008) in kalmegh, Kalyanasundaram *et al.* (2008) in sweet flag and Anuja and Jayasri (2011) in sweet basil.

5.1.1.3 Number of leaves:

Significant differences were observed with respect to number of leaves per plant due to application of different levels of N through organic manure with and without bio-fertilizers and inorganic fertilizer in the main crop and ratoon during two years of the experiment (Tables 3a.to 3c).

The highest number of leaves in the main crop at 30, 60 (DAP) and at harvest was observed in (T₉) NPK (160:80:80 kg/ha) + FYM (10 t/ha) during kharif 2015 (206.20, 352.53 and 365.50 plant⁻¹) and (158.67, 331.33 and 417.67 plant⁻¹) during kharif 2016, respectively. In the second harvest (ratoon) the use of NPK (160:80:80 Kg /ha) + FYM (10 t/ha) i.e., (T₉) as soil incorporation radically increased the number of leaves 30 (DAP) and at harvest during kharif 2015(400.93 and 446.73 plant⁻¹) and (325 and 389.33 plant⁻¹) during kharif 2016, respectively. While, the lowest number was recorded in T7 (208.13 and 248.47 plant⁻¹) and (230 and 245.47plant⁻¹) at 30 (DAP) and harvest during kharif 2015 and, 2016, respectively.

Increase vegetative growth with application of organic manure along with chemical fertilizer due to bulky structure of organic manure that reduces the soil compaction and improves the aeration in addition to the supply of essential plant nutrients, thereby increases the soil biological activities (Hayworth *et al.*, 1996) while the chemical fertilizer promote the growth due to increase in availability of nutrients especially nitrogen (Chand *et al.*, 2011). organic manures not only supply major nutrients but also sufficient quantity of required micronutrients such as Zn, B, Fe, Cu, Mn etc. (Bahadur *et al.*, 2004). It has been reported that the microbial population increased at tremendous rate as the organic matter decomposed in the soil with the subsequent release of nitrogen for the growth (Yadav *et al.*, 2006). The results are in agreement with the findings of Kumarvael (2003) in *Artemissia annua* and Chand *et al.* (2001) in *Mentha arvensis*

5.1.1.4. Leaf area (cm²)

Different levels of N through organic manures with and without bio-fertilizers and inorganic fertilization significantly affected the average leaf area per plant Table 4. Application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ recorded maximum leaf area in the main crop (15.66, 17.04 and 16.35 cm²) and in ratoon (9.48, 10.11 and 9.79 cm²) during kharif 2015, 2016 and pooled data respectively. While, the minimum value was recorded in T₇ in the main crop (8.56 and 8.83 cm²), (5 and 5.97 cm²) in ratoon and (8.69 and 5.48) in pooled data during two years of the experiment respectively.

Increase the leaf area with application of FYM along with inorganic fertilizer could relate to more nutrition that assigned to development leaf, because of release nutrition material by microorganisms in the soil and followed by increased plant growth (Ashour, 1998). That will be as a result production of more assimilate and increased cell division and cells size (Sellosse *et al.*, 2004). The results are in agreement with the findings of Chaitra and Patil (2006) in china aster ; Ahmed *et al.*, (2011) in marjoram

5.1.1.6. Days taken for flowering (day)

The number of days taken for first flowering significantly influenced by different treatments in the main crop and ratoon in two years of experiment as shown in Table 5. and 6. Maximum number of days till first flowering was recorded with application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ in the main crop (38.33, 35 and 36.67 day) and ratoon (26.67, 24.46 and 25.56 day) during 2015, 2016 and, pooled data, respectively. Whereas, the minimum number was recorded in T₇ in the main crop (31, 22 and 26.50 day), and ratoon (16.67, 16.33 and 16.50 day) respectively. Similarly, for the number of days till 50% flowering, the treatments differed significantly and application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) in T₉ recorded the maximum number in the main crop (54.66, 48 and 51.33 day) and ratoon (39.80, 33.33 and 36.57 day) during kharif 2015, 2016 and pooled data respectively. Application of bio-fertilizer enhanced the duration of vegetative growth, and maximum days till 50% flowering was recorded in T₂ FYM (10 t/ha) +100% Rec. N through FYM + BF during kharif 2015 and 2016 in the main crop (47.33, 40.67 day), in ratoon (31.95, 24.67 day), and in pooled data (44 and 28.31 day) respectively.

Presence and balancing of nutrients such as nitrogen and micro nutrients in organic manure along with chemical fertilizer in T₉ impose a direct effect on the structure of chlorophyll and protein synthesis that led to the development and extended the vegetative growth (Adediran *et al.*, 2004). This response is related to plant metabolism. Because supplying the needs of plant in terms of elements such as nitrogen and photosynthetic production that causes enhancing of vegetative growth duration (Begay, 2005), It is also a fact that the organic manures release nutrients slowly compared to synthetic fertilizers which known with presence of readily available form of nitrogen that resulted in increase the vegetative growth period of plants mainly by elongation of cells and partly by cell division (Maynard and David, 1987). While, bio-fertilizer provided a more balance nutrition for plants as optimum availability of nitrogen and better mobilization, solubilization of phosphate also increased activity of gibberellic acid which improved the vegetative growth and physiological process, indigenous plant phytohormone balance, this may reflect on increasing the number of days till flowering. Preethi *et al.*, (1999) and Dobbelaere *et al.* (1999).

5.1.2. Yield parameters

5.1.2.1. Fresh weight of leaves (g/plant)

There was a significant difference between treatments in respect to fresh weight of leaves per plant in the main crop and ratoon during the two years of the experiments. Data from Table 7. Indicated that application of NPK (160:80:80 Kg /ha) + FYM (10 t/ha) i.e., T₉ recorded the highest fresh weight of leaves per plant in the main crop and ratoon during kharif 2015 (173.67 and 234.33 g/plant), (227.33 and 209.66 g/plant) during kharif 2016 and (200.5 and 221.99 g/plant) in the pooled data respectively. Minimum value was recorded in minimum level of N through organic manure in T₇ in the main crop (90, 107.67 and 98.83 g/plant) and in the second harvest (120, 90 and 105 g/plant) during kharif 2015, 2016 and pooled data respectively. Bio-fertilizer had a positive impact on the fresh weight of leaves in the second harvest, and maximum value (191.67, 132.33 and 162 g/plant) could be observed with application of FYM (10 t/ha) +100% Rec. N through FYM + BF (T₂) during kharif 2015, 2016 and pooled data respectively.

The fresh weight of leaves is completely dependent on the growth attributes through the life cycle of the crop. Nutrients released from both organic and inorganic fertilizers would have resulted in the increased nutrient availability, ascribed to improvement of soil physico-chemical attributes of plant growth and adequate supply of both macro and micro nutrients, accelerated mobility of photosynthates from the source to the sink as influenced by the growth hormone release or synthesized due to the application of organic manures (Mohanty *et al.*, 2006). However, the production of more leaves with combined application of NPK fertilizers and FYM might be due to reason that higher concentration of nitrogen has tendency to increase cell number with an overall increased in leaf production (Bijimol and Singh, 2001), promote the development of leaves and hasten the maturity of plants with higher rate of cell multiplication and differentiation which resulted in better vegetative growth (Belorkar *et al.*, 1992). Application of biofertilizer along with FYM might have helped the plant metabolic activity through the supply of important micronutrient such as zinc, iron, copper, manganese, etc. These are involved in biochemical synthesis of many phytohormones. Better vigorous growth and leaf weight may also be result of increased meristematic activities and increase in number and size of cells due to effect of growth promoting substances produced by these bio-fertilizers provided a more nutrition for the plants as a balance result of mechanism of interaction between nitrogen fixing and phosphate solubilizing bacteria Belimov *et al* (1995). These results are in line with (Mukesh *et al.*, 2006 in marigold; Vikas *et al.*, 2008 and Thakur *et al.*, 2008 in *Viola pilosa*; Mohanchandra, 2003 in *Solanum nigrum*; Badran and Safwat, 2004 in fennel and Swaminathan *et al.*, 2008 in *davana*)

5.1.2.2. Dry weight of leaves (g/plant)

There was a significant difference in dry weight of leaves per plant at the main crop and ratoon during the two years of the experiments (Table 13.) , application of NPK (160:80:80 Kg /ha) + FYM (10 t/ha) i.e., T₉ recorded the highest dry weight of leaves per plant in the main crop and ratoon during kharif 2015 (34.67 and 40.80 g/plant) , (45.60 and 39.46 g/plant) during kharif 2016 and (42.14 and 40.13g/plant) in the pooled data respectively. Minimum value was recorded recommended dose of organic manure in T₇ of the main crop (18.30, 23.53 and 20.19 g/plant) and ratoon (22.13, 17.73 and 19.93 g/plant) during kharif 2015, 2016 and pooled data respectively. Effect of bio-fertilizer application could be observed in the treatment (T₂) FYM (10 t/ha) +100% Rec. N through FYM + BF that recorded the highest dry weight in the main crop and ratoon during kharif 2015 (26.11 and 36.87 g/plant), (39.47 and 24.80 g/plant) during kharif 2016 and (32.79 and 30.83 g/plant) in the pooled data respectively.

Organic manure cause better physical, chemical and biological function, which provides carbon as an energy source to soil microbes resulting in enhanced yield parameters, increasing soil fertility that enable it to produce stable production of herbage (Mando *et al.*, 2005) Dry leaf yield can be correlated to other growth parameter in the same treatment, combined application of NPK fertilizers and FYM, resulted in maximum plant height, number of branches and number of leaves that lead in conclusion to give the best dry leaf yield due to proper supplied of nutrients and soil conditions conducive for plant growth (Kandeel, 2002).

Along with organic manure application of bio-fertilizer increased the leaf yield, these results could be attributed to the effect of the N₂-fixing bacteria that producing adequate amounts of IAA, gibberellins, cytokinins and B group vitamins that promote rooting capacity, and enhanced the growth with an eventual increase on the uptake of nutrients from the soil (Rodriguez and Fraga 1999; Revilas *et al.*, 2000). Phosphate solubilizing bacteria release organic and inorganic acids which reduce soil pH leading to change of phosphorus and other nutrients to available forms ready for uptake by plants (Singh and Kapoor, 1999). Therefore, the percentages of N and P elements in the leaves were increased and

this increment led to promote the growth and leaf yield of basil plants. Similar results have been reported by Kandeel *et al.* (2001), Hassan (2009) on roselle; Gupta *et al.* (2011) in black Henbane; Griffe *et al.* (2003) in peppermint, Amin Gafouri *et al.* (2010) in sesame, Rezvani moghadam *et al.* (2009) in sweet fennel, Yazdani (2010) in *Silybum marianum*, El-Ghawwas *et al.* (2002) in fennel, El-Sayed *et al.* (2002) in spearmint and marjoram and Khater (2001) in caraway plants.

5.1.2.3. Fresh and dry weight of stem (g/plant)

There was a significant difference in fresh weight of stem per plant at the main crop and ratoon during the two years of the experiments (Tables 8. and 14.), application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ recorded the highest value in the main crop (698, 582.27 and 640.13 g/plant) and ratoon (186.67, 139.33 and 163 g/plant) during kharif 2015, kharif 2016 and in the pooled data respectively. Minimum value was recorded with application the recommended dose of FYM in (T₇) of the main crop and ratoon during kharif 2015 (509.33, 116.67 g/plant), (227.07, 72 g/plant) kharif 2016 and (599.40, 147.67 g/plant) in the pooled data respectively. Similarly, for the dry weight of stem the treatments differed significantly and the maximum dry weight of stem could be observed in T₉ (135.07, 35.07 g/plant), (107.94, 27.08 g/plant) in the main crop and ratoon during kharif 2015, 2016 respectively. While the minimum value was recorded in T₇ of the main crop (93.19 and 41.34 g/plant) and of the second harvest (19.67 and 13.67 g/plant) during kharif 2015, 2016 respectively. Maximum dry weight of the stem in pooled data of the main crop and ratoon could be observed in (T₉) NPK (160:80:80 kg /ha) + FYM (10 t/ha (121.51, 31.07 g/plant) followed by T₈ (109.72, 27.69 g/plant) while, the minimum value was in T₇ (67.26, 16.67 g/plant) respectively.

All the biotic and abiotic soil components should be in balance to accomplish optimum plant growth and yield parameters, improves soil physical properties by increasing the distribution and stability of soil aggregates and decreasing soil bulk density (Mcrae and Mehuys, 1988). That could be achieved by applying organic manure; the majority of the carbon is evolved as carbon dioxide or incorporated into biomass. However, a small portion of the carbon is biochemically altered and remains in the soil as organic matter. That imparts many desirable biological, chemical, and physical properties to soil (Stevenson, 1994). Compared to the organic fertilizers, inorganic fertilizers directly affect crop yields, since the nutrients in inorganic fertilizers can be directly taken up by plants. Moreover, the presence of organic and inorganic substances in the soil is associated with a general increase in nutrient contents and with their subsequent effects on properties such as microbial activity, the humus fraction, soil structure and saturation of the ion-exchange system (Kirchner *et al.*, 1993) that will enhance nutritional status due to increase inorganic nutrient absorption with application of organic manure and that could as a result enhance the weight of stem. (Sundharaiya *et al.*, 2000)

5.1.2.4. Fresh and dry weight of inflorescence:

Fresh weight of inflorescence differed significantly due to application of various levels of N through FYM with and without bio-fertilizers and inorganic fertilizer in the main crop and ratoon during two years of the experiment (Tables 9. and 15.) Wherein, (T₉) with application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) recorded maximum fresh weight in the main crop (168, 138.33 and 153.17 g) and in ratoon (133.33, 95.33 and 114.33 g) during 2015, 2016 and in the pooled data, respectively. While, the minimum value was recorded in lowest level of N through FYM in T₇ in the main crop and ratoon during 2015(109.67 and 78 g) , (102.67 and 61.33g) during 2016 and in pooled data (106.17, 69.67 g) respectively.

Dry weight of inflorescence showed significant differences due to the application of organic manures, bio-fertilizer and inorganic fertilizer in the main crop and ratoon during the two years of experiment. In the main crop maximum dry weight of inflorescence was registered in T₉ (47.93, 46.50 and 47.21 g) during 2015, 2016 and in the pooled data, respectively. In the second harvest (ratoon) same application in the treatment T₉ recorded the highest value (32, 23.80 and 27.90 g) In the pooled data, application of recommended dose of chemical fertilizers along with FYM (10 t/ha) *i.e.*, T₉ recorded significantly highest value in respect to dry weight of inflorescence per plant (47.21 and 27.90 g/plant) in the main crop and ratoon respectively. While, the lowest value was observed in T₇ (28.75 and 15.37 g/plant) respectively.

Application of both organic and inorganic nutrients might have resulted in rapid synthesis, translocation and accumulation of photosynthates from source to sink which might have ultimately

contributed in improving the vegetative growth, dry matter accumulation and their partitioning towards the developing flowers that lead to increased number and the yield of flowers, Similar results were reported by Brajeshwar *et al.* (2007) in Senna, Sharma and Uppal (2004) in Kala Zeera, Kathiresan and Venkatesha (2002) in gladiolus, Rajadurai and Beaulah (2000) in African marigold, Yadav *et al.* (2005) and Patil (2014) in ashwagandha.

5.1.2.5. Fresh herbage yield (t/ha):

Data indicated significant differences among the treatments with respect to fresh herbage yield in the main crop and ratoon during first and second years of cropping. As showed in Table 12. Application of NPK (160:80:80 kg /ha) + FYM 10 t/ha (T₉) recorded the highest fresh yield in the main crop and ratoon (41.59 and 20.97 t/h) During Kharif 2015 and 2016 respectively. Whereas, the lowest fresh yield was recorded in T₇ (28.36 and 12.59 t/ha respectively). Whereas, the fresh yield was lower during Kharif 2016 comparing with the first year, and the same application of T₉ recorded the highest fresh yield in the main crop and ratoon (38.31 and 17.77 t/ha) while, the minimum value was observed in T₇ (17.49 and 8.93 t/ha) respectively. Similarly, in the pooled data application of NPK (160:80:80 kg /ha) along with FYM 10 t/ha recorded the highest yield between the treatment in the main crop and ratoon (39.95 and 19.37 t/ha), the positive effect of biofertilizer application could be observed in T₂ FYM (10 t/ha) +100% Rec. N through FYM + BF that recorded the highest fresh weight (32.87 and 15.45 t/ha). For cumulative herbage yield application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ recorded significantly the highest cumulative herbage yield (62.56, 56.08 and 59.3 t/ha) while, the minimum value (40.95, 26.42 and 33.7 t/ha) was recorded in T₇ during 2015 and 2016 and the pooled data respectively.

Recommended dose of chemical fertilizer is expected to release greater quantity of nutrients particularly N, P, K at a faster rate and higher level and there by greater uptake by the plants which resulted in higher growth and yield parameters. On the other hand application of FYM along with inorganic fertilizer release of nutrients after mineralization. Such controlled but regulated supply of nutrients increased uptake N, P, K which in turn, brought about higher growth and yield Merestala (1996). Increase in the yield parameters with combined use of organic and inorganic application reported in earlier reports of Joy *et al.* (2005) in black musli, Kothari *et al.* (2005) in *Spilanthus acmella*, Rajendran and Gnanavel (2008) in Aloe vera and Ravikumar *et al.* (2012) in coleus.

Application of bio-fertilizer has positive trend in term of herbage yield, this improvement of vegetation yield may be due to the element of phosphorus which is important component which stimulates the photosynthesis and enters into the composition of rich energy compounds and strengthens roots of the plant leading to growth improvement (Abu Dahi, and Alyunis, 1988). These results were supported with other investigation of El-Komy (2005), Yazdani *et al.*, (2009) and Alireza (2012).

5.1.2.6. Dry herbage yield (t/ha):

There were significant differences in dry herbage yield per hectare at the main crop and ratoon during two years of the experiment (Table 18.). Significantly the treatment (T₉) NPK (160:80:80 kg /ha) + FYM (10 t/ha) registered the maximum value in the main crop (8.71, 8.16 and 8.43 t/ha) and in ratoon (4.31, 3.21 and 3.76 t/ha) during kharif 2015, 2016 and pooled data respectively. While minimum value was recorded in T₇ in the main crop and ratoon during kharif 2015 (5.54 and 2.34 t/ha), (4.05 and 1.82 t/ha) during kharif 2016 and in the pooled data (4.80 and 2.08 t/ha) respectively. Among the biofertilizer treatments application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ recorded maximum dry herbage yield in the main (7.71, 6.24 and 6.97 t/ha) and in ratoon (3.66, 2.45 and 3.05 t/ha) during kharif 2015, 2016 and pooled data respectively. For cumulative dry herbage yield application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ recorded significantly the highest value (13.02, 11.37 and 12.19 t/ha) while, the minimum one (7.88, 5.87 and 6.87 t/ha) was recorded in T₇ during 2015, 2016 and in the pooled data respectively.

It can be stated that chemical and physical properties of humic acid in an organic fertilizer had its positive effect on dry yield, by increasing the capacity of nutrients, regulating growth hormones and activity of microorganisms that enhanced accumulation of nitrogen in plant (Arancon *et al.*, 2005). Also, by creating a more favorable environment for root growth and nutrient availability, which lead to increased plant growth and dry matter (Scheffer and Koehler, 1993). Synergistic effect of bio-fertilizer leads to more absorption of water and soil minerals and increases growth and yield of host plant (Ratti *et*

al., 2001). might be due to the fact that phosphate solubilizing bacteria were able to absorb nutrients from solution at faster rates than non -trateded plants resulting in accumulation of more N, P and K in the leaves (Rai, 2006) which lead to increase the yield. These results are on line with other findings with Khaliq and Janardhanan (1997) in mint, Kapoor *et al.* (2004) in fennel and Joshee *et al.* (2007) in *Scutellaria integrifolia*.

5.1.2.7. Oil yield per hectare (l/ha)

Oil yield per hectare differed significantly due to application of various levels of N through FYM with and without bio-fertilizers and inorganic fertilizer in the main crop and ratoon during two years of the experiment (Table 20.). Application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) i.e., T₉ recorded highest oil yield among the treatments in the main crop (211.94, 187.46 and 199.7 l/ha) and in ratoon (144.36, 70.81 and 107.58 l/ha) during 2015, 2016 and pooled data respectively. Whereas, lowest oil yield per hectare was recorded with application of recommended dose of FYM in T₇ in the main crop (95.13 and 52.40 l/ha) in ratoon (38.52 and 15.36 l/ha) during 2015 and 2016 respectively, and in the pooled data (73.8 and 26.94 l/ha). Application of bio-fertilizer along with FYM increased the oil yield per hectare, and the treatment T₂ FYM (10 t/ha) + 100% Rec. N through FYM + BF registered significantly the highest value between the other applied levels in the main crop (182.04, 123.13 and 152.6 l/ha) and ratoon (111.96, 56.07 and 84.02 l/ha) during kharif 2015, 2016 and pooled data respectively. For cumulative oil yield application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) i.e., T₉ recorded significantly the highest value (356.3, 258.27 and 307.28 l/ha) while, the minimum value (133.65, 67.76 and 100.70 l/ha) was recorded in T₇ during 2015, 2016 and pooled data respectively

Essential oil is synthesized from products of photosynthesis through enzymatic actions. Higher oil recovery had resulted in the increase in number of leaves as well as number of inflorescence. A positive correlation between increased leaf yield and oil content was reported by Nehra *et al.* (1981) and Arularasu and Sambandamurthi (1999) in Tulsi. The soil with its content in macro and micro elements, enhanced by the use of organic fertilizers, plays an essential role in the plant growth and development and also it can be noted that the vegetative mass is rich and the amount of essential oil is high when using organic manures (Khalid *et al.*, 2006). Moreover, combined applications of organic and inorganic improve soil properties and make suitable plant growth conditions that lead to increase oil yield (Chand, 1999; Patra *et al.*, 2000). That integration of organic manure with inorganic fertilizer may increase the water holding capacity of soil which helps in dissolution of nutrients resulting in a higher nutrient uptake and better yields. (Jennifer, 2015).

Nitrogen fixing bacteria and phosphate solubilizing bacteria application through improvement of phosphorus and nitrogen uptake and eventually increase of biomass amount, has a positive effect on essential oil content. These findings are in accordance with the observations of Shaalan (2005) in *Borago officinalis*, Harshavardhan *et al.* (2007) in *Mellisa officinalis*, Dadkh (2012) on fennel, EL-ghandour *et al.* (2009) in marjoram, Gandhikumar (1996) in davana and Jahan *et al.* (2013) in basil.

5.1.3 Quality parameters

Chemical compositions of the essential oil for sweet basil differed under different types of fertilizers in the maincrop and ratoon during two years of the experiment. As shown from Table 21a to 21d. Forteen constituents were identified in *O.basilicum* by GLC. The high economic value of basil oil is due to the presence of phenyl propanoids, like eugenol, Methyl chavicol and their derivatives or terpenoids like monoterpen linalool, and limonene (Kividompolo and Hyotylainen, 2007). Therefore, there has been growing interest in developing simple methodologies to increase polyphenols concentration and essential oil content in basil to further enhance their overall nutritional value (Toor, 2006). Factors which may potentially affect essential oil composition may differ, in the same genotype, depending on the light regime (Skrubis and Markakis, 1976) or type of fertilizer this (Morales *et al.*, 1993).

The dominant constituent in basil oil with organic and inorganic fertilizers was methyl chavicol and linalool, this agrees with data produced by (Marotti, 1996).

Comparing the integration peaks, there was differences in methyl chavicol percentage among the treatments. Application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) i.e., T₉ recorded the highest percentage in the main crop of 2015 (52.3%) while, in the second season application of FYM (10 t/ha)

+100% Rec. N through FYM + BF i.e., T₂ recorded maximum Methyl chavicol percentage (63.78%). Whereas, the lowest percentage was recorded in T₇ (40.05 and 46.2%) during 2015 and, 2016, respectively. In the second harvest (ratoon) application of FYM (10 t/ha) +100% Rec. N through FYM + BF i.e., T₂ recorded the highest percentage (59.39 and 59.67%) whereas, the lowest percentage (40.22 and 41.49%) was observed in T₇ during 2015 and, 2016, respectively.

Application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) i.e., T₉ recorded the highest percentage of Linalool in the main crop (25.29 and 22.88%) and ratoon (26.59 and 25.19%). Whereas, the lowest percentage was recorded in T₇ of the main crop (19.20 and 15.20%) and ratoon (15.28 and 16.25%) during 2015 and, 2016, respectively.

Eugenol content were also detected, although at lower concentration, and was highest with application of NPK (160:80:80 kg /ha) i.e., T₈ in the main crop (2.48 and 1.34 %) and ratoon (1 and 3.20%) during 2015 and 2016 respectively. While, the lowest percentage was recorded in T₁ in the main crop (0.01 and 0.02%) and ratoon (0.02 and 0.01%) respectively.

Among the monoterpene hydrocarbons in basil oil, α -pinene is the most important, application of FYM (10 t/ha) +100% Rec. N through FYM + BF i.e., T₂ recorded maximum α -Pinene percentage in the main crop (1.74 and 0.23%) and ratoon (0.24 and 0.99%) during 2015 and, 2016, respectively. While, a low percentage was recorded in T₈ (0.10 and 0.09%) of the main crop and in ratoon (0.13 and 0.18%) during 2015 and, 2016, respectively.

Biostimulants application such as nitrogen biofertilizer and phosphatic biofertilizer through the improvement of biological activities of soil and nutrient elements absorption, caused more growth and biomass production which leads to improvement of the essential oil quality (Shaalan, 2005). These findings are in accordance with the observations of Rashmi *et al.* (2008) in *Ocimum gratissimum*, Kumar *et al.* (2009) in *Artemisia pallens*, Moradi *et al.* (2011) in *Foeniculum vulgare*, Darzi (2013) in *Pimpinella anisum* and EL-hindi and EL-boraie (2005) in marjoram and Makkizadeh *et al.* (2011) in sweet basil.

Application of high level of N through organic manure showed the highest level for phenolics content. They may be attributed to the higher pathogenic pressures in organic farming which in turn may have a biotic stress, and caused an increase in the level of phenolics grown organically (Sousa *et al.*, 2005). Adding biofertilizers resulted in an increase in phenolics content because of multi-biofertilizer are usually play as a growth promoting rhizobacteria (Javanmardi *et al.*, 2002). Thus microorganisms can fix N₂ and supply it to the plant they synthesis siderophores which play a key role for solubilization of minerals such as phosphorus and iron which become readily and available for plants.

Temperature is an important factor that regulates plant metabolism, with rates of enzyme activity increasing up to about 40°C, after which most plant enzymes become inactivated or even damaged irreversibly (Kaufman *et al.*, 1998). At high temperatures, the largest class of plant secondary metabolites, the terpenoids, play a role in stabilising membranes (Wink, 1999), which may explain why the total terpenoid content in leaves was enhanced in the second year of cropping.

5.1.4. Soil Parameters

5.1.4.1. Physical parameters

The influence of different levels of N through FYM with and without bio-fertilizer and inorganic fertilizer on soil physical properties was presented in Table 22.

5.1.4.1.1. Bulk density (Mg m⁻³)

The bulk density of the soil after cropping was found to be significant due to application of different level of N through FYM with and without bio-fertilizer and inorganic fertilization, and the lowest value (1.18 and 1.17 Mg m⁻³) was recorded in (T₂) with application of FYM (10 t/ha) +100% Rec. N

through FYM + BF. While, the highest bulk density was recorded with application of RD of NPK in T₈ (1.23 and 1.24 Mg m⁻³) during 2015, and 2016, respectively.

Soil bulk density is a significant soil property that sum up general soil structural characteristics. It is an important indication of soil compaction (Abu-Hamdeh, 2003). Preserving an adequate amount of organic matter through FYM and bio-fertilizer in the soil stabilizes soil structure. Occurrence of angular pores created by the combination of soil and amendment particles, lead to decrease the bulk densities of these soils (Thomas *et al.*, 1996). The highest bulk density in inorganic fertilizer treated plots may be due to low organic matter content in the soil and formation of compact layer. (Dejene and Lemlem, 2012; Shirani *et al.* 2002 and Islam *et al.*, 2006).

5.1.4.1.2. Porosity (%)

There were differences in the porosity of the soil after cropping as affected by different level of N through FYM with and without bio-fertilizer and inorganic fertilization during two years of the experiment. Among the different treatments, application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ recorded the maximum porosity (44.5 and 44.87 %) in 2015, and 2016, respectively. While, the minimum value (41.40 and 41.29%) was recorded in T₈ with 100% RFD of NPK (160:80:80 kg /ha) in 2015, and 2016, respectively.

Porosity determines the rate and movement of air and water into the soil. Organic matter plays a dominant role in fine particle aggregation by increasing organic carbon that will reduce the solid phase and increase the air phase. This reduction of solid phase may increase inter- and intra- aggregate spaces which leads to the increment in porosity of soils. Characterization of soil porosity in relation to organic matter incorporation had been reported by Watson *et al.* (1986) and Bouma (1991). Most studies consider the correlation between organic C and porosity as direct one (Mota *et al.*, 2014, Stock *et al.*, 2008 and Gregory *et al.*, 2009).

5.1.4.1.3. Particle density (g/cm³)

There was no significant difference among the treatments in respect to particle density. Application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ recorded the minimum particle density (2.65 and 2.61 g/cm³). While, the maximum value (2.83 and 2.83 g/cm³) was recorded with application of recommended dose of NPK *i.e.*, T₈ in 2015, and 2016, respectively.

Particle density varies with the type of soil minerals present as well as the amount of organic matter. However, organic matter, which is a soil solid, weighs much less per unit volume than soil mineral, readily influences particle density. (Jeyamangalam *et al.*, 2012) The use of a bio-fertilizer that increases the stable fractions of organic matter provides evidence of an increase in the soil OM stability. In turn, the contribution of the organic matter fractions those are more resistant to decomposition (Zhao *et al.*, 2005) because it retains water and helps soil particles to bind and resist against soil compaction, stabilizes soil structure (Thomas *et al.*, 1996).

5.1.4.2. Chemical parameters

Data in Table 23 indicated the influence of different levels of N through FYM with and without bio-fertilizer and inorganic fertilizer on soil chemical parameters.

5.1.4.2.1. Soil pH

Application of different levels of N through FYM along with and without bio-fertilizer and inorganic fertilizer recorded different values of soil pH. The lowest value was with application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ (7.76 and 7.71). At the same time, the application of recommended dose of chemical fertilizer recorded the highest soil pH (8.01 and 8.00) after the experiment during 2015, and 2016, respectively.

The soil pH decreases while applying organic manure, due to mineralization, degradation of hydrolyzed polysaccharids and synthesis of organic acids by microorganism through the breakdown of the substrate. While, While, inorganic fertilizers such as urea has a temporary high pH effect and

medium capacity to acidify the soil. This view supported by the findings of Azeez and Van Averbek (2012). Applying bio-fertilizer resulted in reduction of soil pH due to various acids (amino acids such as glycine and cysteine as well as humic acid or acid forming compounds and active microorganisms released from the addition of biofertilizer. These results are in agreement with those obtained by Shaban *et al.* (2012) and Poraas *et al.* (2009).

5.1.4.2.2. Electrical conductivity

Data indicated significant differences among the treatments with respect to electrical conductivity in the soil after cropping, and it was maximum (0.37 and 0.39 dSm⁻¹) in T₈ (160:80:80 kg /ha), while minimum value was recorded in T₂ (0.34 and 0.27 dSm⁻¹) in 2015, and 2016, respectively. Increment in the level of N through FYM increased the electrical conductivity.

Electrical conductivity can serve as a measure of soluble nutrients for both cations and anions. Soil EC indicates the mineralization of organic matter in soil serves as a measure of soluble nutrients. Thus, the improvement in EC might be due to volume reduction which might have increased the concentration of nutrients and insoluble salts (Smith and Doran, 1996). While, lowering the soluble salts concentration with bio-fertilizer application decreased the soil EC. Applied urea in the soil was further transformed to nitrate by nitrification and that was responsible for higher soil EC, It indicates that the chemical fertilizers are responsible for the enhanced salinity of the soil. These findings are in close agreement with (Katkar *et al.*, 2006; Arbad *et al.*, 2008 and Hussain *et al.*, 2002) .

5.1.4.2.3. Organic carbon (%)

Organic carbon per cent in the soil differed significantly due to application of various levels of N through FYM with and without bio-fertilizers and inorganic fertilization. Highest organic carbon in the post harvest soil samples was recorded with application of FYM (10 t/ha) +100% Rec. N + BF *i.e.*, T₂ (0.63 and 0.66 %) While, the lowest organic carbon per cent in the soil after cropping (0.52 and 0.53%) was recorded with application of (160:80:80 kg /ha) in T₈ during 2015, and 2016, respectively.

Organic carbon per cent is fine indicators of soil quality which influence soil function in specific ways (e.g., immobilization–mineralization) and are much more sensitive to change in soil management practices (Saviozzi *et al.* 2001). The results showed the positive influence of higher level of N through FYM and bio-fertilizer in increasing the organic carbon content that could be because of the effect of FYM and bio-fertilizer in stimulation of soil microbial activity, therefore increasing the C output. Similar results were also found by Halvorson *et al.*, (2002); Su *et al.*, (2006) and Lou *et al.*, (2011).

5.1.4.2.4. Available Macronutrient in the soil:

Data on Table 24. Showed significant differences in available nitrogen, phosphorus and potassium in the soil (kg/ha) as influenced by different levels of N through FYM with and without bio-fertilizer and inorganic fertilizer.

5.1.4.2.4.1. Available Nitrogen (kg/ha)

The available nitrogen in soil after cropping differed significantly. It was higher in plots supplied with higher level of nitrogen through FYM along with bio-fertilizer in T₂ (227.40 and 277 kg/ha) while, it was least (189.91 and 201.23 kg/ha) in T₇ applied with recommended dose of FYM during 2015 and 2016, respectively.

The plant rhizosphere is a versatile and dynamic ecological environment of intense microbes–plant interactions for harnessing essential macro and micronutrients from a limited nutrient pool (Jeffries, 2003). FYM along with microbial fertilizer play a vital role in increasing the N availability in the soil by direct contribution as well as indirectly by influencing chemical transformation reaction and microbial activity, it secrete some molecules acting as inducers/signals to help the process of N- fixation as reported by Parmar and Dadarwal (1999) and Murugan *et al.* (2011) influencing the recirculation of nutrients, enhancing microbial activities that caused the transportation of soluble nitrogen into microbial protein thereby preventing nitrogen loss by leaching as recorded by Tiwari *et al.* (1989) Johnkutty and Menon(1981), Jenkinson *et al.* (1985) and Iwueke (1991).

5.1.4.2.4.2. Available Phosphorus (kg/ha)

Available phosphorus in the soil differed significantly among the treatments Application of recommended dose of fertilizers (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ recorded the highest soil available phosphorus (42.31 and 58.15 kg/ha) while, the lowest soil available phosphorus (27.33 and 34.17 kg/ha) was observed in T₇ after cropping during 2015, and 2016, respectively.

Organic supplements have been reported to increase P availability in soils (Guppy *et al.*, 2005; Gichangi and Mnkeni, 2009) and enhance the bioavailability of P fertilizers (Hua and Zhou., 2008).

5.1.4.2.4.3. Available Potassium (kg/ha)

Available potassium content was increased significantly in the soil after cropping in all treatments. Highest potassium content (296.8 and 340.60 kg/ha) in the soil after cropping was recorded in T₂ with application of FYM (10 t/ha) + 100% Rec. N through FYM + BF during 2015 and 2016, respectively. While, it was found to be lowest (212.8 and 234.90 kg /ha) in T₇ with application of recommended dose of FYM.

The solubilizing action of certain organic acids produced during decomposition of FYM had greater capacity to hold K in available forms lead to increase in exchangeable K as a result of improved physico-chemical conditions reaching to good balance between nutrients in the soil solution and improvement of nutrient exchange between soil and plant (Bhandari *et al.* 1992). Bio-fertilizer application lead to increment in “K” percentage due to the effect of different strain groups and nutrients mobilizing microorganism which helps in availability of metals and their forms in the composted material and increased the levels of extracted minerals (Sharma, 2002).

5.1.4.2.5. Exchangeable Secondary nutrient in the soil

Data on Table.25. showed the effect of different treatments on exchangeable secondary nutrient in the soil.

5.1.4.2.5.1. Exchangeable calcium

Higher exchangeable calcium content in the soil after cropping was noticed in T₉ (1278.78 and 1368.33 ppm) with application of FYM (10 t/ha) +100% Rec. N through FYM + BF in 2015 and 2016, respectively (Table 25). Soil application of recommended dose of organic manure in T₇ registered least exchangeable calcium content of soil after cropping (617.78 and 985.75 ppm) in 2015 and 2016, respectively.

5.1.4.2.5.2. Exchangeable magnesium:

Application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ enhanced the exchangeable magnesium content of the soil after cropping (200 and 225 ppm) in 2015 and 2016, respectively. Compared to rest of the treatments as shown in Table 26. Recommended dose of FYM treated plot (T₇) recorded the least exchangeable magnesium content in the soil after cropping (153.33 and 176.67 ppm) in 2015 and 2016, respectively.

Organic manure markedly increased the contents of SOC and reduced soil acidification, The solubility of Ca and Mg may be increased due to the production of carbonic acid from CO₂ released by decay of organic matter and bio-fertilizer (Rao, 2005)

5.1.4.2.6. Available micronutrient in the soil

Data on Table.26. showed the effect of different treatments on available micronutrients in the soil

5.1.4.2.6.1. Available Iron

Application of FYM (10 t/ha) +100% Rec. N through FYM along with bio-fertilizer *i.e.*, T₂ recorded the highest iron content in the soil after cropping (4.92 and 6.50 ppm) in 2015, and 2016, respectively. While, the plots treated with the recommended dose of FYM (10 t/ha) *i.e.*, T₇ registered the lowest iron content in the soil (3.08 and 3.75 ppm) during both the years.

In addition to being a source of Fe, organic manure is able to form Fe complexes that improve iron availability. Microorganisms release siderophores and plant exudates (e.g., phyto siderophores, organic acids, and flavonoids) which can bind and solubilize the Fe present in the soil. The biological decomposition of organic matter in the soil leads to form organic acids and reducing the pH of the soil. The soil pH reduction has a positive effect on ability to absorb nutrients, especially iron solubility (Lindsay, 1982).

5.1.4.2.6.2. Available Manganese

The data indicated a significant differences in the available manganese content in the soil after cropping. The highest available Mn was recorded with application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ (3.40 and 5.30 ppm) in 2015, and 2016, respectively. While, the treatment T₇ with application of recommended dose of FYM resulted in lower available manganese content in the soil (1.37 and 2.49 ppm) in 2015 and 2016, respectively.

Application of organic manure along with bio-fertilizer increases the availability of micronutrient to the plant, reducing the solubility and leaching (Unagwu, 2013).

5.1.4.2.6.3. Available Zinc

The available zinc content of soil after cropping was relatively higher in the plots treated with FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ (2.71 and 3.06 ppm) in 2015 and 2016, respectively. While, T₇ with application recommended dose of FYM accounted for lowest available zinc content in the soil after cropping (1.51 and 1.85 ppm) in 2015, and 2016, respectively.

The increase in available zinc due to FYM addition along with bio-fertilizer could be attributed to higher rate of mineralization of applied organic matter thereby increase the solubility of zinc (Sharma, 2013).

5.1.4.2.6.4. Available Copper

There was significant differences among the treatments in respect with available copper content in the soil after cropping. The treatment T₂ with application of FYM (10 t/ha) +100% Rec. N through FYM + BF recorded the highest soil available copper (2.78 and 4.16 ppm) in 2015 and 2016, respectively. While, the lowest value was noticed with application of recommended dose of FYM *i.e.*, T₇ (1.34 and 2.58 ppm) in 2015 and 2016, respectively.

The microorganisms in bio-fertilizers and FYM restore the soil's natural nutrient cycle and build the soil organic matter. Copper becomes attached to the soil organic matter and that increase its concentration in the soil (Shashi, 2011).

5.1.4.3. Biological parameters

Soil microbial population are the driving force behind regulating soil processes such as organic matter decomposition and nutrient cycling, it is imperative to have a better understanding of the factors that regulate its size, activity, and structure (Masto *et al.*, 2006). The microbial population dynamics is governed by interactions between plant type, climate, and management practice. Data in Table 27. indicated significant differences among the treatments with respect to soil biological properties

5.1.3.3.1 Population of heterotrophic free-living N₂ fixers (CFU ×10³/ g of oven dry soil)

Data indicated significant differences among the treatments with respect to Population of heterotrophic free-living N₂ fixers (CFU ×10³/ g of oven dry soil). While, maximum population of the colonies in the soil after cropping (40.66 and 63.33 CFU ×10³/ g) was recorded in T₂ with application of

FYM (10 t/ha) +100% Rec. N through FYM + BF during 2015 and 2016, respectively. Whereas, the treatment T₇ recorded the lowest counts (26.13 and 34 CFU ×10³/ g) during 2015 and 2016, respectively.

The addition of organic manure greatly influences the microbial populations which expected to cause changes in the organic matter content of soil that directly influenced microbial dynamics of soil (Deforest *et al.*, 2012). Application of bio-fertilizer stimulates the native soil micro organisms and reactivates the biogeochemical cycles leading to increase in the organic material that significantly increases the bacterial populations. The results are on line with Watts *et al.*, (2010), Krishnakumar *et al.* (2005) and Lalfakzuala *et al.*, (2008).

5.1.3.3.2 Population of phosphate solubilising bacteria (CFU ×10³/ g of oven dry soil)

The data on the population of phosphate solubilizing bacteria (CFU ×10³/ g of oven dry soil after cropping indicated that there was no significant differences between the treatments. In 2015 the application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ recorded the maximum value (5.6 CFU ×10³/ g) while, the lowest value (3 CFU ×10³/ g) was recorded in T₈. However, there were significant differences among the treatments in respect to population of phosphate solubilising bacteria in the soil after cropping was observed during 2016. In similar trend, application of FYM (10 t/ha) +100% Rec. N through FYM + BF recorded the highest population (6.6 CFU ×10³/ g) while, application of recommended dose of chemical fertilizer recorded the lowest population (3.9 CFU ×10³/ g).

Growth of P solubilizing microorganisms is generally accompanied by decrease in pH of the soil (Mishra, 1985). Reduction in pH is due to application of FYM along with bio-fertilizer is a result of the production of organic acids which include citric, gluconic, fumaric, malic, oxalic, lactic, 2- ketogluconic, malonic acids etc. (Vassilev, 1996).

Although chemical fertilization has resulted in increases in crop yield, this application was not sufficient in triggering a significant improvement in the soil microbial properties. Similar results were obtained by Wang *et al.*, (2011).

The addition of fertilizers enriched the soil microbial biomass and soil enzymes by enhancing the soil physicochemical properties of SOM and humus, especially through the addition of FYM. Root exudates augmented the soil microbes in general by the crop growth and that could explain the increase of soil population at harvest time comparing with the initial soil.

5.1.3.3.3. Population of fungal (CFU ×10³/ g of oven dry soil)

Fungal population in the soil after cropping in two years of the experiment was affected significantly by the treatments involving different levels of organic manure with and without bio-fertilizers and inorganic . Application of FYM (10 t/ha) +100% Rec. N through FYM + BF in T₂ recorded the maximum fungal population (6.4 and 5.33 CFU ×10³/ g) in the soil after cropping in 2015 and 2016 respectively. While, application of recommended dose of chemical fertilizer in T₈ recorded the lowest fungal population (3.6 and 2.5 CFU ×10³/ g) in the soil after cropping in 2015 and 2016 respectively.

Microbial population size and community structure are sensitive to changes in chemical properties of the surrounding soil (Pansombat *et al.*, 1997). Fungi constitute an essential component of biological characteristics in soil ecosystems. Organic carbon level in the soil and precipitation play pivotal role in fungal growth and sporulation. Greater microbial populations in FYM treated plots along with bio-fertilizer as compared to chemically amended plots due to enhancing the organic carbon in the soil, Similar kind of results was reported by Venkateswarlu and Srinivasarao, (2000). Application of farm yard manure can be viewed as an excellent way to recycle nutrients, provided a steady source of organic C to support the microbial community resulting in higher fungal populations comparing to NPK- treated plots.

Lower fungal population in the pre-harvest is attributed to lack of vegetation and organic amendment input. Even though the treatments were done in the same plots during the study period, the timing of fertilizer input was not same in both the years. This could be another factor for the uneven distribution of soil nutrients and hence, inconsistent variation in fungal population and diversity. And low temperature that prevailed in the first season could have influenced the proliferation of fungi, which

require low temperature for their growth; Song *et al.* (2007) indicated that difference in the establishment of field leads to alteration of microbial communities.

5.1.3.3.4. Population of Actinomycetes (CFU $\times 10^3$ / g of oven dry soil)

The data on actinomycetes population of the soil after cropping (CFU $\times 10^3$ / g of oven dry soil) indicated significant differences between the treatments. The highest population of actinomycetes (29.93 and 44.56 CFU $\times 10^3$ / g of oven dry soil) was recorded in T₉ with application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) during 2015 and 2016, respectively, while application of recommended dose of FYM (10 t/ha) in T₇ resulted in minimum population (20 and 30.5 CFU $\times 10^3$ / g of oven dry soil) during 2015 and 2016, respectively.

Actinomycetes are one of the predominant members of soil microbial communities and they have beneficial roles in soil nutrients cycling and agricultural productivity (Elliot and Lynch, 1995). Organic matter, salinity, relative moisture, temperature, pH and vegetation are important factors which control abundance of actinomycetes in soil (Mcarthy and Williams, 1992).

The density of actinomycetes is opposite to the hydrogen ion concentration, that could justify increasing its population with application of NPK along with FYM (Alexander, 1977) While, increasing the colony's in the second season comparing to first one due to a relatively low level of moisture, this property of actinomycetes might be due to their sporulation capability under stress conditions (El-Tarabily and Sivasithamparam, 2006)

5.1.5. Nutrient uptake by the plant

Nutrient removal by plants is related to their nutrient requirements which is an indicative of nutrient dose to be applied for getting maximum yield. The data on nutrient uptake was presented in Table (28. to 33.)

5.1.5.1. Nitrogen uptake (kg/ha)

The nitrogen uptake by the plant tissue showed significant differences due to various treatments in the first year of the experiment. Wherein, the treatment T₉ that is application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) resulted in the highest nitrogen uptake by the main crop (155.67 and 113.19 kg/ha) and ratoon (56.43 and 26.65 kg/ha) during 2015 and 2016, respectively. In contrast, the lowest nitrogen uptake by main crop (55.92 and 53.81 kg/ha) and ratoon (15.95 and 13.16 kg/ha) was recorded in T₇ applied with recommended dose of FYM only (10 t/ha) during 2015 and 2016, respectively. Among organic manure treatments, application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ recorded the highest nitrogen uptake by the main crop (112.69 and 84.80 kg/ha) and ratoon (40.24 and 19.44 kg/ha) during 2015 and 2016, respectively.

The use of mineral fertilizers is the fastest way to supply nutrients for plant (Mando *et al.*, 2005). Increase in the nitrogen uptake by the plant through application of chemical fertilizer has been reported by Golez *et al.* (2006) and Silva *et al.* (2006). Higher dose of organic manure lead to higher nitrogen uptake, and that was attributed to a slow and prolonged availability of nutrients, and its gradual mineralization process. Improvement in nitrogen uptake by the plant with application of organic manures has been reported by Sudha and Chandani (2002) and Preetha *et al.* (2005).

Nitrogen fixing bacteria producing adequate amounts of IAA, gibberellins, cytokinins and B group vitamins that promote rooting capacity, with an eventual increase on the uptake of nutrients from the soil (Rodriguez and Fraga 1999). Bio-fertilizer application lead to increase in nitrogen uptake as a result of release of phyto-hormones by microorganism which might have helped in better nutrient assimilation by plant. It is capable of mobilizing native elements from non-available form to available form through various biological processes responsible for increasing in the concentration and uptake of nutrient by the plant (Goel *et al.*, 1999)

Similar results was also reported by Attia and Saad (2001) in periwinkle, El-Kashlan (2001) in roselle plants.

5.1.5.2. Phosphor uptake (kg/ha)

There was significant differences in phosphorus uptake by the plant tissue in the main crop and ratoon during two years of the experiment as shown in Table 28. Whereas, the highest phosphorous uptake was recorded in T₉ with application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) in the main crop (43.80 and 32.43 kg/ha) and ratoon (16.14 and 14.01 kg/ha) during 2015 and 2016, respectively. While, the minimum value was recorded in T₇ of the main crop (20.54 and 14.22kg/ha) and ratoon (6.97 and 5.28 kg/ha) during 2015 and 2016, respectively. Application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ recorded the highest phosphorous uptake among different organic treatments by the main crop (36.76 and 27.17 kg/ha) and ratoon (14.53 and 12.54 kg/ha) during 2015 and 2016, respectively.

FYM reduces soil pH leading to change soil phosphorus and other nutrients to available forms ready for uptake by plants (Singh *et al.*, 2014). Nikolay *et al.* (1996) reported, that organic phosphorus is mineralized and immobilized by microbes' activities, as well as FYM has chelating effect on nutrients thereby continued nutrient availability through the growing period, subsequently plants will have higher nutrient uptake. The availability of phosphorus also improved by applying of biological fertilizers, P-solubilization ability of rhizosphere microorganisms is considered to be one of the most important traits associated with plant phosphate nutrition improving its availability to the plant (Chen *et al.*, 2006; Kloepper *et al.*, 1989; Nautiyal, 2000).

5.1.5. 3. Potassium uptake(kg/ha)

Significant differences could be observed among the treatments in respect to potassium uptake by the plant tissue in Table 29. Whereas, the potassium uptake was highest with application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) in T₉ for the main crop (163.33 and 116.16 kg/ha) and ratoon (55.56 and 39.27 kg/ha) in 2015 and 2016 respectively. The lowest K uptake was recorded with T₇ in the main crop (79.55 and 51.92 kg/ha) and ratoon (24.67 and 19.10 kg/ha) in 2015 and 2016, respectively. Application of FYM (10 t/ha) +100% Rec. N through FYM + BF *i.e.*, T₂ recorded the highest potassium uptake among different organic treatments by the main crop (124.97 and 85.23 kg/ha) and ratoon (44.05 and 29.44 kg/ha) during 2015 and 2016, respectively.

Potassium is often described as a quality element for crop production as it indirectly improves utilization of N and protein synthesis. Being bulky organic manure, reduces the soil compaction and improves the aeration in addition to increase of essential plant nutrient. While, higher doses of organic manures supply major nutrients so that higher concentration of K noticed in the plant tissue with combined application of inorganic and organic fertilizer might be due to available form of potassium through chemical fertilizer beside the production of phytohormones by microbial population through FYM which stimulate the root growth and improve the uptake of nutrient (Hayworth *et al.*, 1996). biofertilizers helped to release unavailable free potassium to available form in the soil solution and increased the potassium content in the soil, hence the uptake by plant was increased (Ajimaddin *et al.*, 2005).

Similar results have been reported by Swaefy *et al.* (2007) in peppermin, Heikal (2005) in Thymus and Abd El-Latif (2006) in *Salvia officinalis*.

5.1.5.4.Secondary nutrient uptake by the plant (Ca and Mg)

The data on secondary nutrient uptake by the plant tissue as influenced by different levels of N through FYM with and without bio-fertilizer and inorganic fertilizer are presented in Table 30.

5.1.5.4.1. Calcium (Ca)

Calcium uptake by the tissue of the main crop and ratoon of basil has significant differences due to varied treatments in the main and ratoon during during two years of the experiment. Wherein, the treatment T₈ with application of NPK (160:80:80 kg /ha) registered the highest calcium uptake in the main crop (190.53) during 2015. Whereas application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉ recorded highest Ca uptake (162.99 kg/ha) during 2016. While, in ratoon the treatment T₉ recorded highest Ca uptake (67.44 and 42.33 kg/ha) during 2015 and 2016, respectively. Whereas, the treatment

T₇ recorded the lowest value in the main crop (106.07 and 67.97 kg/ha) and ratoon (42.74 and 17.33 kg/ha) during 2015 and 2016, respectively.

Calcium plays a very important role in plant growth and nutrition, as well as in cell wall deposition. The marked increase in concentration of secondary nutrients (Ca) in the plant system as a result of integrated application of FYM and inorganic fertilizer might have been the consequence of improved nutritional environment in the rhizosphere, better root growth and proliferation, and it has been recorded that crops took up more nutrients when mineral fertilizer was added in what is known as 'luxury consumption' probably because nutrients from this source are readily available (Anuradha *et al.* 1995).

5.1.5.4.2. Magnesium (Mg)

The data on Mg uptake by the plant tissue of the main crop and ratoon indicated that there were significant differences between the treatments. While, the highest Mg uptake of the main crop (34.52 and 32.28 kg/ha) and ratoon (13.96 and 11.45 kg/ha) was recorded in T₉ with application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) in 2015 and 2016, respectively, while, the lowest content was recorded in T₇ in the main crop (19.49 and 15.26 kg/ha) and ratoon (7.13 and 5.31 kg/ha) in 2015 and 2016, respectively.

Many enzymes in plant cells require magnesium in order to perform properly. However, the most important role of magnesium is as the central atom in the chlorophyll molecule.

Organic manures and NPK fertilizers helped in better availability and absorption of nutrients by the plants. The greater uptake of nutrients can also be related to higher yield production due to greater accumulation of metabolites Kalyanasundaram *et al.* (2008).

5.1.5.5. Micronutrient uptake by the plant (Fe, Zn, Cu and Mn kg/ha):

Data indicated differences among the treatments with respect to micronutrient uptake in the main crop and ratoon during two years of the experiment as shown in Table 30 and 31.

5.1.5.5.1. Iron uptake (Fe)

Uptake of iron by the plant was found to be significant with the application of organic manures, bio-fertilizers and chemical fertilizers. The treatment T₉ with application of recommended NPK (160:80:80 kg/ha) + FYM (10 t/ha) recorded the highest Fe uptake in the main crop (6.64 and 4.33 kg/ha) and ratoon (2.18 and 1.41 kg/ha) during 2015 and 2016, respectively. The lowest iron uptake was recorded in T₇ in the main crop (2.87 and 1.64 kg/ha) and in ratoon (0.81 and 0.61 kg/ha) during 2015 and 2016, respectively.

Iron is a constituent of several enzymes and some pigments, and assists in nitrate and sulfate reduction and energy production within the plant. Although iron is not used in the synthesis of chlorophyll, it is essential for its formation.

Iron (Fe) level increased by organic manuring as a result of improving physical and chemical properties of the soil, increasing the microorganisms that allow more efficient nutrient use and increased the available nutrients to plant; these results are similar to those found by Nasef *et al.* (2004) and Ashmawy *et al.* (2008).

5.1.5.5.2 Manganese uptake (Mn)

Application of different levels of nitrogen through FYM with and without bio-fertilizer and inorganic fertilizer had significant differences in terms of manganese uptake by the plant during two years of the experiment. The highest plant Mn uptake of the main crop and ratoon was observed in T₉ with application of recommended NPK (160:80:80 kg/ha) + FYM (10 t/ha) in the main crop (0.81 and 0.53 kg/ha) and ratoon (0.24 and 0.12 kg/ha) during both the years (2015 & 2016). While, the lowest Mn uptake in the main crop (0.43 and 0.19 kg/ha) and ratoon (0.10 and 0.06 kg/ha) was registered with T₇ during 2015 and 2016, respectively.

Manganese is used in plants as a major contributor to various biological systems including photosynthesis, respiration, and nitrogen assimilation. It is required by plants in the second greatest quantity compared to iron.

Decline in soil pH due to bio-fertilizers and organic manures application had positive impacts on manganese availability as well as uptake by plant (Benbi and Brar, 2009).

5.1.5.5.3. Zinc uptake (Zn)

Zinc is a key constituent of many enzymes and proteins. It plays an important role in a wide range of processes, such as growth hormone production and internodes elongation.

Significant differences were observed in Zn uptake by the main crop and ratoon during two years of the experiment. The highest Zn uptake in the main crop (0.49 and 0.45 kg/ha) and in ratoon (0.21 and 0.16 kg/ha) was recorded in T₉ with application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) during 2015 and 2016, respectively. The lowest Zn uptake by the main crop (0.28 and 0.15 kg/ha) and ratoon (0.11 and 0.07 kg/ha) was recorded with recommended dose of FYM (10 t/ha) during 2015 and 2016, respectively.

Application of organic amendments, such as FYM along with inorganic fertilizer supplies the micronutrients in available form, thereby enriching the soil and plants by these elements (Singh, 1992).

5.1.5.5.4. Copper uptake (Cu)

Application of different levels of nitrogen through FYM with and without bio-fertilizer and inorganic fertilizer registered different copper uptake by the plant. The treatment T₉ with application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) recorded the highest Cu uptake (0.15 and 0.14 kg/ha) in the main crop and (0.07 and 0.05 kg/ha) in ratoon during 2015 and 2016, respectively. The lowest value was observed with T₇ in the main crop (0.07 and 0.05 kg/ha) and in ratoon (0.02 and 0.02 kg/ha) during the two years of the experiment..

Copper belongs to the least mobile heavy metal, plants have several copper- containing enzymes that play an important role in photosynthesis and respiration. Complexation reactions involving soil organic matter play a key role in the speciation of Cu in soil controlling its physico-chemical behavior, biological availability, accumulation and mobility (Plaza *et al.*, 2005) this result are in line with Obrador (2013), who found a strong correlations between organic matter in the soil and Cu uptakes by the plants.

5.1.6. Nitrogen sheet balance (Kg ha⁻¹)

Nitrogen is one of the basic nutrients used by plants to build many organic compounds, such as aminoacids, peptides, proteins, enzymes, or nucleic acids (Singh, 1996). However intensive cropping systems with fertilizer responsive crops that rely on high input of inorganic fertilizers often lead to "non-sustainability" in production and also pose a serious threat to soil health. Application of organic sources of nutrients with no or very little use of fossil fuel-based inorganic fertilizers is rapidly gaining favor (Anwar *et al.*, 2005).

There is a common sense among authors concerning the role of organic fertilizer like FYM in sustainable agriculture and improving soil quality, but the cost benefit rate (B:N) of organic fertilizer sources may forms the only obstacle for adopting of the application of fully organic nutrient resources. Therefore, the actual research is looking for a rational nutrient application approach like bio-fertilizer, or chemical fertilizer application along with organic manure, so that lead to increase production , improve soil properties and assure high B:C rate at the same times.

The data in respect of actual gain or loss from Tables 34. to 36. revealed that, the treatment T₂ with application of FYM (10 t/ha) +100% Rec. N through FYM + BF recorded mximum maximum gain of N in the soil (42.40 and 49.60 Kg ha⁻¹) during 2015 and 2016 respectively.While recommended dosage of organic fertilizer (T₇) attained the least value (4.91 and 11.49 Kg ha⁻¹) respectively.

The pooled data of the two years of trials showed a clear effect of bio-fertilizers as it increased the nitrogen gain in soil by (46 Kg ha⁻¹) with application of FYM (10 t/ha) +100% Rec. N through FYM + BF in T₂. While, the minimum gain (8.2 Kg ha⁻¹) was recorded with application of recommended dose of FYM in T₇. This result could be attributed to the fact that, bio-fertilizers generate plant nutrients like nitrogen through their activities in the soil or rhizosphere and makes them available to the plants on the soil (Rajendran *et al.*, 1998), help better sink source relations to allocate more nutrients, mobilize the availability of nutrients by their biological activity in particular and help in building up the micro flora and in turn the soil health in general, and may explain the increasing level of actual gain in the N soil content Dubey *et al.*, (2012). Because of that utilization of biofertilizers as a plant growth promoting rhizobacteria (PGPR) has become a feasible production practice, as they enhance plant growth, nitrogen fixation and soil health (Kloepper. 1992).

5.1.7 Economics of organic manure along with or without bio-fertilizer, organic fertilizer on basil (*Ocimum basilicum*) cultivation

As showed from the Table 37. The cost of cultivation was highest (55,515 and 55,026 Rs./ha) in the plots applied with FYM (10 t/ha) +100% Rec. N through FYM + BF. Whereas, minimum expenditure (35,790 and 35,301 Rs./ha) was with application of Rec. NPK (160:80:80 kg /ha) during 2015 and 2016, respectively. Chemical fertilizer has lower prices that could be the major obstacle that prevent farmers from adoption organic cultivation, during second year of the experiment the herbage yield was less, so it reflected on number of man days that could explain the decrease of expenditure.

The maximum gross returns of (213,78 and 15,49 Rs./ha) and maximum net income (171,99 and 113,172 Rs./ha) obtained from plots applied with Rec. NPK (160:80:80 Kg /ha) + FYM (10 t/ha) during 2015 and 2016 respectively.

Net returns from the data reveals that an application of NPK (160:80:80 kg /ha) in T₈ recorded maximum benefit-cost ratio (5.49) during 2015 While, the maximum benefit ratio in 2016 (3.71) was observed with application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) *i.e.*, T₉. The minimum value has been recorded with application recommended dose of FYM *i.e.*, T₇ (2 and 1.02) during 2015 and 2016, respectively.

Application of limited quantity of nutrients (NPK) only through chemical fertilizer *i.e.*, T₈ creates multiple-nutrients deficiencies in the soil which is considered as one of reason for limiting the crop production (Tiwari *et al.*, 2002) although it has lesser prices compared with organic manure which explain its maximum benefit ratio.

Application of nutrients through organic manure along with inorganic fertilizer *i.e.*, T₉ improved production of oil yield as well as soil fertility (Alizadeh *et al.*, 2010) which lead to increased returns from money spent. Adoption of a balanced fertilizer is the way of enhancing productivity and economic profitability of basil. These findings were supported by Sudhakara *et al.* (2010) and Vennila (2014) in coleus Patil (2014) in ashwaganda.

VI. SUMMARY

As the knowledge and awareness about global environmental issue, integrated supply of nutrient to plants through planned combinations of organic and inorganic sources is becoming an increasingly important aspect of environmentally sound agriculture. In cultivation of medicinal and aromatic plants, the real value is given to the quality while yield quantity comes in the second step of importance. Sustainable agricultural approaches are the best methods in which these plants can perform better on account of the harmony with nature.

The present investigation entitled "Effect of organic manure and biofertilizers on growth, herb, nutrient uptake, oil yield and quality of French Basil (*Ocimum basilicum* L.)" was carried out during two consecutive years (2015-2016) at Indian Institute of Horticultural Research (IIHR), Hessaraghatta Lake Post, Bengaluru. The results obtained during the course of study are briefly summarized and concluded as under:

6.1 Growth parameters

Growth parameters were recorded at 30 and 60 days after planting and at harvest. While, second set of observation for the ratoon was recorded at 30 days after planting and at harvest, and the observation were recorded for (Plant height, number of branches, number of leaves, , leaf area, time taken for first flowering and time taken for 50 % flowering).

Plant height at harvest, pointed out that the applications of 100 % NPK (160:80:80 kg /ha) in combination with FYM (10 t/ha) lead to maximum plant height (76.43, 86 and 81.22 cm) and (61.33, 59.07 and 60.2 cm) in the main crop and ratoon during 2015, 2016 and pooled data, respectively.

The highest number of branches at harvest in the main crop (31.50, 29 and 30.25 plant⁻¹) was obtained with application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) during 2015, 2016 and in the pooled data, respectively. Similarly, in the second harvest (ratoon) same treatment with application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) lead to maximum production of number of branches (24.40, 23.80 and 24.10 plant⁻¹) during 2015, 2016 and in the pooled data, respectively.

Maximum number of leaves per plant at harvest was in the main crop (365.50, 417.67 and 391.6 plant⁻¹) and in ratoon (446.73, 389.33 and 418.03 plant⁻¹) during 2015, 2016 and pooled data, respectively with application of Rec. NPK (160:80:80 kg /ha) + FYM (10 t/ha)

Leaf area of basil was influenced by different treatments. However, the application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) recorded maximum leaf area in the main crop (15.66, 17.04 and 16.35cm²) and in ratoon (9.48, 10.11 and 9.79cm²) during kharif 2015, 2016 and pooled data, respectively.

Number of days taken for first flowering was influenced significantly by different treatments in the main crop and ratoon during two years of experiment, as the maximum number of days taken for first flowering was recorded with application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) in the main crop (38.33, 35 and 36.67 day) and ratoon (26.67, 24.46 and 25.56 day) during 2015, 2016 and in the pooled data respectively. Similarly, the treatment T₉ recorded maximum number of days taken for 50% of flowering in the main crop (54.66, 48 and 51.33 day) and ratoon (39.80, 33.33 and 36.57 day) during kharif 2015, 2016 and, pooled data, respectively.

6.2 Yield parameters

The fresh herbage yield in basil differed significantly due to application of different levels of N through FYM with and without bio-fertilizers and inorganic fertilizer in the main crop and ratoon during two years of study. Application of Rec. NPK (160:80:80 kg /ha) + FYM (10 t/ha) produced maximum herbage yield in the main crop (41.59, 38.31 and 39.96 t/ha) and ratoon (20.97, 17.77 and 19.37 t/ha)

during 2015, 2016 and pooled data, respectively. Maximum cumulative herbage yield was with application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) (62.56 and 56.08 t/ha) while, the minimum value (40.95 and 26.42 t/ha) was recorded in T₇ during 2015 and 2016 respectively.

The treatment with application of Rec. NPK (160:80:80 kg /ha) + FYM (10 t/ha) registered significantly the maximum dry herbage yield (t/ha) in the main crop (8.71, 8.16 and 8.43 t/ha) and ratoon (4.31, 3.21 and 3.76 t/ha) during kharif 2015, 2016 and pooled data respectively. Cumulative dry herbage yield was also maximum (13.02 and 11.37 t/ha) with application of Rec. NPK (160:80:80 kg /ha) + FYM (10 t/ha) while, dry herbage yield was least (7.88 and 5.87 t/ha) with application recommended dose of FYM during 2015 and 2016, respectively

Application of Rec. NPK (160:80:80 kg /ha) + FYM (10 t/ha) produced highest oil yield in the main crop (211.94, 187.46 and 199.7 l/ha) and in ratoon (144.36, 70.81 and 107.58 l/ha) during 2015, 2016 and pooled data, respectively. Whereas, lowest oil yield per hectare was recorded with recommended dose of FYM in the main crop (95.13 and 52.40 l/ha) in ratoon (38.52 and 15.36 l/ha) during 2015, and 2016, respectively.

6.3 Quality parameters

Methyl chavicol percentage in the oil affected due to application of different treatments, and the treatment with application of Rec. NPK (160:80:80 kg /ha) + FYM (10 t/ha) recorded the highest percentage in the main crop of 2015 (52.3%) while, in the subsequent season application of FYM (10 t/ha) + 100% Rec. N through FYM + BF recorded maximum Methyl chavicol percentage (63.78%) whereas, the lowest percentage (40.05 and 46.2%) was recorded with application of FYM (10 t/ha) during 2015 and 2016 respectively. In the second harvest (ratoon) application of FYM (10 t/ha) + 100% Rec. N through FYM + BF recorded the highest percentage (59.39 and 59.67%) whereas, the lowest percentage (40.22 and 41.49%) was observed with application of recommended dose of FYM (10 t/ha) during 2015 and 2016 respectively.

Application of Rec. NPK (160:80:80 kg /ha) + FYM (10 t/ha) recorded the highest percentage of Linalool in the main crop (25.29 and 22.88%) and ratoon (26.59 and 25.19%). Whereas, the lowest percentage was recorded with application of recommended dose of FYM (10 t/ha) of the main crop (19.20 and 15.20%) and ratoon (15.28 and 16.25%) during 2015 and 2016, respectively.

6.4 Soil parameters

6.4.1 Physical properties

The highest bulk density was recorded with 100% Rec. NPK (160:80:80 kg /ha) (1.23 and 1.24 Mg m⁻³) in 2015 and 2016, respectively. Whereas, the lowest bulk density of the soil was recorded with application of FYM (10 t/ha) + 100% Rec. N through FYM + BF (1.18 and 1.17 Mg m⁻³) in 2015 and 2016, respectively.

Application of NPK (160:80:80 kg /ha) + FYM (10 t/ha) recorded the maximum porosity (44.5 and 44.87 %) in 2015 and 2016, respectively. While, the minimum value (41.40 and 41.29%) was recorded with 100% Rec. of NPK (160:80:80 kg /ha) in 2015 and 2016, respectively.

Application of FYM (10 t/ha) + 100% Rec. N through FYM + BF recorded the minimum particle density (2.65 and 2.61 g/cm³). While, the maximum value (2.83 and 2.83 g/cm³) was recorded with application of recommended dose of NPK in 2015 and 2016, respectively.

6.4.2 Chemical properties

Highest soil pH after cropping (8.01 and 8) was recorded with application of 100% Rec. of NPK (160:80:80 kg /ha) in 2015 and 2016, respectively.

Maximum electrical conductivity of soil after cropping (0.37 and 0.39 dS m⁻¹) was observed with application of 100% Rec. of NPK (160:80:80 kg /ha) during 2015 and 2016, respectively.

Application of FYM (10 t/ha) +100% Rec. N through FYM + BF recorded the maximum organic carbon (0.63 and 0.66 %) in the in the post-harvest soil samples collected during 2015 and 2016, respectively.

Available macronutrients

Highest available nitrogen in the soil after cropping (227 and 236.33 kg/ha) was recorded with application of FYM (10 t/ha) +100% Rec. N through FYM + BF during 2015 and 2016, respectively.

Application of (160:80:80 kg /ha) + FYM (10 t/ha) recorded the highest available phosphorus (42.31 and 58.15 kg/ha) during 2015 and 2016, respectively.

Application of FYM (10 t/ha) +100% Rec. N through FYM + BF recorded the highest available potassium in the soil after cropping (296.80 and 340.60 kg/ha) during 2015 and 2016, respectively.

Exchangable Secondary nutrient in the soil

The plot treated with (160:80:80 kg /ha) + FYM (10 t/ha) recorded significantly higher exchangeable calcium content in the soil (1278.78 and 1368.33 ppm) during 2015 and 2016, respectively.

Application of FYM (10 t/ha) +100% Rec. N through FYM + BF enhanced the exchangeable magnesium content (200 and 225 ppm) in post-harvest soil samples during 2015 and 2016, respectively compared to rest of the treatments.

Available micronutrients in the soil

Application of FYM (10 t/ha) +100% Rec. N through FYM along with bio-fertilizer recorded the highest iron content in the soil after cropping (4.92 and 6.50 ppm) in 2015 and 2016, respectively.

The highest available zinc in the soil after cropping was in the plots supplied with FYM (10 t/ha) +100% Rec. N through FYM + BF (2.26 and 2.30 ppm) in 2015 and 2016, respectively.

Application of FYM (10 t/ha) +100% Rec. N through FYM + BF recorded the highest available copper (1.49 and 2.80 ppm) in 2015 and 2016, respectively.

Application of FYM (10 t/ha) +100% Rec. N through FYM + BF resulted in the highest available manganese in the soil (2.44 and 3.69 ppm) in 2015 and 2016, respectively.

6.4.3 Soil biological proprieties

Population of heterotrophic free-living N₂ fixers (CFU ×10³/ g oven dry soil) was maximum in the soil after cropping (40.66 and 63.33 CFU ×10³/ g) with application of FYM (10 t/ha) +100% Rec. N through FYM + BF during 2015 and 2016, respectively.

There was no significant change in the PSB during the first year (2015). Hence, application of FYM (10 t/ha) +100% Rec. N through FYM + BF recorded the maximum effect (5.6 CFU ×10³/ g) on the population of phosphate solubilizing bacteria (CFU ×10³/ g) of oven dry soil after cropping during subsequent year (2016).

Application of FYM (10 t/ha) +100% Rec. N through FYM + BF recorded the maximum fungal population (6.4 and 5.33 CFU ×10³/ g) in the soil after cropping in 2015 and 2016, respectively.

The highest population of Actinomycetes (29.93 and 44.56 CFU $\times 10^3$ /g) was recorded with application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) during 2015 and 2016, respectively.

6.5 Nutrient uptake by the plant

6.5.1. Macronutrient uptake by the plant

Application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) recorded the highest nitrogen uptake in main crop (155.67 and 113.19 kg/ha) and ratoon (56.43 and 26.65 kg/ha), highest phosphorous uptake in the main crop (43.80 and 32.43 kg/ha) and ratoon (16.14 and 14.01 kg/ha) and highest potassium uptake in the main crop (163.33 and 116.16 kg/ha) and ratoon (55.56 and 39.27 kg/ha) during 2015 and 2016, respectively.

6.5.2 Secondary nutrient uptake in the plant (Ca and Mg)

Application of NPK (160:80:80 kg/ha) registered the highest calcium uptake in the main crop and ratoon (190.53 and 67.44 kg/ha) during 2015 whereas, application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) recorded highest calcium uptake in the main crop and ratoon. (162.99 and 42.33 kg/ha) in subsequent year.

The highest Mg uptake of the main crop (34.52 and 32.28 kg/ha) and ratoon (13.96 and 11.45 kg/ha) was recorded in T_9 with application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) in 2015 and 2016, respectively.

6.5.3 Micronutrient uptake by the plant (Fe, Mn, Zn and Cu kg/ha)

Application of NPK (160:80:80 kg/ha) + FYM (10 t/ha) recorded the highest Fe uptake in the main crop (6.64 and 4.33 kg/ha) and ratoon (2.18 and 1.41 kg/ha), highest plant Mn uptake (0.81 and 0.53 kg/ha) and ratoon (0.24 and 0.12 kg/ha), highest Zn uptake in the main crop (0.49 and 0.45 kg/ha) and (0.21 and 0.16 kg/ha) in ratoon and highest Cu uptake (0.15 and 0.14 kg/ha) in the main crop and (0.07 and 0.05 kg/ha) in ratoon during 2015 and 2016, respectively.

6.6 Nitrogen sheet balance (Kg ha⁻¹)

Application of FYM (10 t/ha) + 100% Rec. N through FYM + BF in 2015 recorded the highest gain (42.4 Kg ha⁻¹) in the soil of 2015. While recommended dosage of FYM attained the least value of gained nitrogen in soil (11.5 Kg ha⁻¹). Whereas, the maximum gain of N in the soil during 2016 (20.58 Kg ha⁻¹) was recorded with application of NPK (160:80:80 kg/ha) + FYM (10 t/ha). The pooled data of the two years of trials showed a clear effect of biofertilizers as it increased the nitrogen gain in soil by (27.3 Kg ha⁻¹) with application of FYM (10 t/ha) + 100% Rec. N through FYM + BF.

6.7 Economics of cultivation

Economics of cultivation were calculated by taking into account all the costs involved in cultivation, gross income, net income and B:C ratio

For the pooled data of two years of experiment. Application of NPK (160:80:80 Kg/ha) + FYM (10 t/ha) recorded maximum net income (142,581.3 Rs./ha), maximum gross income (184,371 Rs./ha). While, the maximum B/C ratio (4.59) was with application of Rec. NPK (160:80:80 Kg/ha)

Conclusion

Sweet basil (*Ocimum basilicum*) is a popular culinary herb grown for fresh or dry leaf and essential oil. Recently, basil was shown to rank highest among species and herb crops for phenolic compounds, which are associated with decreasing risks of cancer and aging diseases.

This experiment has the potential to contribute information towards adoption best treatment that could increase the fresh and dry herb yield, oil yield and its best quality, insure sustainability in agricultural systems as it relates to nutrient uptake in the soil and finally provide higher returns from money spent.

It is concluded from the results of this study that application of organic manures along with inorganic nutrients is best for cultivation of basil, Since there was significant difference observed between the treatments in improving plant growth and yield of basil, Application of NPK (160:80:80 kg /ha) + FYM 10 t/ha recorded the highest fresh herbage yield, dry herbage yield and oil yield in the main crop and ratoon during 2015 and, 2016, respectively.

Application of FYM (10 t/ha) +100% Rec. N through FYM + BF recorded the highest Methyl chavicol percentage in the main crop (63.78%) during 2016 and in ratoon (59.39 and 59.67%) during Kharif 2015, 2016, respectively.

For nutritional status of the soil, the study showed that it was improved by biofertilization practice application of such organic sources and biofertilizers that could minimize the nutrients losses from soil . The soil N nutrient balance in the present study revealed that much of the nitrogen was removed from the soil with the application of inorganic N fertilizer resulting in a negative soil N balance. The highest positive N balance was recorded for the combined application of biofertilizers with FYM in the treatment T₂ which recorded the highest gain (42.4 Kg ha⁻¹).

For economic benefit, cultivation of basil with application of NPK (160:80:80 Kg /ha) + FYM (10 t/ha) was highly remunerative, that the pooled data of the tow years of experiements recorded maximum net income (142581.3 Rs./ha).

Based on the results of this research, future line of work:

- Agricultural extensions and decisions makers should take some measurements to encourage farmers to use Arka Microbial Consortium (AMC) biofertilizers by pointing out its effects on soil health that lead to achieve sustainable agriculture.
- FYM in combination with inorganic fertilizer form a rational alternative to mineral or FYM fertilizer alone, for improving basil crop growth parameters, herbage yield and oil yield taking into account the its benefit/cost ratio which could justify the use of FYM.
- Using of organic fertilizer in combination with microbial inoculation need to be encouraged as suitable cropping pattern that increase the oil quality as highly remunerative practice for basil cultivation.
- More long terms researches are needed to concrete the effects of FYM on soil fertility and "health" on one hand, and to lucid nitrates and nitrites content in herbage and oil production, as they are affected by nitrogen mineral fertilizer doses and substantially reduce the production quality on the another hand.

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APPENDIX-Ia

Monthly mean meteorological data during 2015

Month	Max. Temp. (°C)	Min. Temp. (°C)	Mean Temp. (°C)	Max. RH (%)	Min. RH (%)	Rainfall (mm)
Jan, 15	30.5	21.2	25.8	70.9	55.9	0
Feb, 15	27.0	20.5	23.7	66.8	47.2	0
Mar, 15	29.6	21.1	25.4	70.0	44.8	0
Apr, 15	28.9	20.9	24.9	69.7	45.1	65.8
May, 15	28.7	21.0	24.8	70.0	43.8	186.2
Jun, 15	30.5	21.4	26.0	78.2	53.4	89
Jul, 15	30.4	21	25.7	77.7	50.6	62.2
Aug, 15	30	20.1	25.1	79.2	49.5	140.4
Sep, 15	30.1	19.8	25.0	80	50.8	251.2
Oct, 15	30.7	20.6	25.7	76.1	52.3	145.5
Nov, 15	27.8	17.4	22.6	84.2	52.2	173
Dec, 15	28.8	17.5	23.2	78.3	51.5	0.5

APPENDIX-Ib

Monthly mean meteorological data during 2016

Month	Max. Temp. (°C)	Min. Temp. (°C)	Mean Temp. (°C)	Max. RH (%)	Min. RH (%)	Rainfall (mm)
Jan, 16	27.2	15.5	21.4	81.8	46.3	0
Feb, 16	33	19.5	26.3	74.6	51.5	0
Mar, 16	36.5	22.9	29.7	66.3	41.8	0
Apr, 16	37.8	23.6	30.7	69.9	43.2	0
May, 16	34.5	21.3	27.9	75.2	38.6	93.9
Jun, 16	29.2	19.4	24.3	82.8	44	130.4
Jul, 16	29.2	20.6	24.9	79	48.7	174.2
Aug16	27	20.6	23.8	80.6	58.1	16.5
Sep, 16	25.2	21.7	23.5	80.5	54.5	58.0
Oct, 16	26	19	22.5	58	38	15.2
Nov, 16	27	18	22.5	64	28	9.00
Dec, 16	28	17	22.5	73	37	62.0

APPENDIX II

Characteristics of experiment soil

1	Physical characters											
	Bulk density (Mg m⁻³)						Porosity (%)					
	1.3						42					
	Chemical characters											
2	pH	EC (dSm⁻¹)	OC (%)	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
				kg/ha			ppm					
	7.75	0.36	0.5	185	28	200	1050	100	3	1.5	1.22	1.3

APPENDIX-IIIa

Cost of cultivation of one hectare of *Ocimum basilicum* in 2015

Sl. No.		Unit price (Rs)	Quantity	
1	Land preparation		days	4000
2	Seeds			1500
3	Plant protection (chemical)			1500
4	Irrigation			1000
5	Labour(mandays)			
	1.Transplanting	300	7 days	2100
	2. Weeding	300	10 days	3000
	3. Plant protection	300	4 days	1200
	4.Cost of raising nursery and maintenance	300	10 days	3000
6	Harvesting	300	30 days	9000
7	Distillation (LumpbSum)			6000
8	Supervision and miscellaneous charges	1.000		1000
	Sum	31.300		31,300
	Contingencies: 5%		1565	1,565
	Sub total			32,865
	Interest of capital working; 3.5%		1150,28	1150,8
	Total			34,015

APPENDIX-IIIb

Cost of cultivation of one hectare of *Ocimum basilicum* in 2016

Sl. No.		Unit price (Rs)	Quantity	
1	Land preparation		days	4000
2	Seeds			1500
3	Plant protection(chemical)			1500
4	Irrigation			1000
5	Labour(mandays)			
	1.Transplanting	350	7 days	2450
	2. Weeding	350	10 days	3500
	3. Plant protection	350	4 days	1400
	4.Cost of raising nursery and maintenance	350	10 days	3500
6	Harvesting	350	20 days	7000
7	Distillation (LumpbSum)			5000
8	Supervision and miscellaneous charges	1.000		1000
	Sum	30.850		30,850
	Contingencies: 5%		1543	1,543
	Sub total			32,393
	Interest of capital working; 3.5%		1133,74	1133,74
	Total			33,526

APPENDIX-V

Quantity and cost of applied fertilizer in each treatments

Treatments		Quantity of input t /ha			Cost of input in Rs/ha			
		FYM	NPK	BIO	FYM	NPK	BIO	Total cost
T1	FYM (10 t/ha) +100% Rec. N through FYM	35	0	-	21000	0	0	10500
T2	FYM (10 t/ha) +100% Rec. N through FYM + BF	35	0	5	21000	0	500	11000
T3	FYM (10 t/ha) +75% Rec. N through FYM	28.75	0	-	17250	0	0	8.625
T4	FYM (10 t/ha) +75% Rec. N through FYM + BF	28.75	0	5	17250	0	500	91250
T5	FYM (10 t/ha) +50% Rec. N through FYM	22.5	0	-	13500	0	0	6750
T6	FYM (10 t/ha) +50% Rec. N through FYM+BF	22.5	0	5	13500	0	500	7250
T7	Rec. FYM (10 t/ha) only	10	0	-	6000	0	0	3000
T8	Rec.NPK (160:80:80 Kg /ha)	0	rec	-	0	1774.4	0	5360
T9	Rec. NPK (160:80:80 Kg /ha)+ Rec. FYM (10 t/ha)	10	rec	-	6000	1774.4	0	8360
Fertilizer requirement								
Chemical fertilizer		price		Recommended dose kg /ha		Recommended dose/plot		
a.urea		5.4 Rs/kg		160		700g		
b. SSP		5.3 Rs/kg		80		1 kg		
c. MOP		6.08 Rs/kg		80		270g		