# STUDIES ON THE EFFECT OF ORGANIC MANURES, FERTILIZERS AND HARVESTING SCHEDULES ON GROWTH AND YIELD OF LEMONGRASS (*Cymbopogon flexuosus* Nees ex. Steud Wats)

*Thesis*

**by**

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**(H-2019-90-M)**

**submitted to**

**Dr. YASHWANT SINGH PARMAR UNIVERSITY OF HORTICULTURE AND FORESTRY SOLAN (NAUNI) HP-173 230 INDIA**

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**MASTER OF SCIENCE**

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**DEPARTMENT OF VEGETABLE SCIENCE**

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# CERTIFICATE - I

This to certify that the thesis titled, "**Studies on the effect of organic manures, fertilizers and harvesting schedules on growth and yield of lemongrass (*Cymbopogon flexuosus* Nees ex. Steud Wats*)"*** is submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science Spices, Plantation, Medicinal and Aromatic Plants** in the discipline of **Horticultural Science** to Dr. Yashwant Singh Parmar University of Horticulture & Forestry, (Nauni) Solan (HP) – 173 230 India is a bonafied research work carried out by **Mr. Subham Attri** son of Shri Mahipal Sharma under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigations have been fully acknowledged.

**Place: Nauni, Solan**
**Dated:**

**Prof. Meenu Sood**
**Chairperson**
**Advisory Committee**

## CERTIFICATE - II

This is to certify that the thesis titled, **"Studies on the effect of organic manures, fertilizers and harvesting schedules on growth and yield of lemongrass (*Cymbopogon flexuosus* Nees ex. Steud Wats)"** submitted by **Mr. Subham Attri (H-2019-90-M),** son of Shri Mahipal Sharma to Dr Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP) – 173 230 India in the partial fulfilment of the requirements for the degree of **Master of Science Spices, Plantation, Medicinal & Aromatic Plants** in the discipline of **Horticultural Sciences** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an Internal Examiner.

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**Place: Nauni, Solan**

**Dated: __ / __ / 2020** **(Subham Attri)**

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# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| % | : | Per cent |
| Rs | : | Rupees |
| t | : | tonnes |
| g | : | gram |
| HP | : | Himachal Pradesh |
| DAP | : | Days after planting |
| ml | : | milliliter |
| $^{o}$C | : | Degree centigrade |
| pp. | : | Pages |
| kg | : | kilogram |
| RBD | : | Randomized block design |
| SE | : | Standard error |
| *i.e* | : | that is |
| *viz* | : | videlicet (namely) |
| ANOVA | : | Analysis of variance |
| l | : | liter |
| ha | : | hectare |
| sp. | : | Species |
| *et al.* | : | and others |
| m | : | meter |
| cm | : | centimeter |
| $cm^2$ | : | centimeter square |
| RDF | : | recommended dose of fertilizer |

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# *Chapter-1*

# INTRODUCTION

Medicinal and aromatic plants play a significant role in the health care system around the world. In developing countries, large number of people are dependent on traditional medicine system. In addition, many aromatic plants are also used domestically and commercially. Out of 4,22,000 species of plants about 12.5% are known to have medicinal properties. Medicinal and aromatic plants need to be cultivated so as to ensure a constant supply as well as for conservation. The increasing demand of medicinal and aromatic crops make them lucrative substitute crop to the traditional one for the small holders (Rao *et al.,* 2004). Many countries like India, Sri Lanka, Thailand and China validate the use of medicines in their healthcare system. The Indian System of Medicines 'Ayurveda', 'Sidha' and 'Unani' fully and 'Homeopathy' to some extent depend on the medicines derived from the plant materials (Prajapati *et al.,*2003).

Aromatic plants are a special kind of plants possessing odorous volatile substances which are mainly used for their aroma and flavour. Sometimes, they are used for medicinal purposes. They are in increasing demand for their essential oils, aroma, chemical drugs and pharmaceuticals in the world. Aromatic compounds are present in plants i.e., in root, wood, bark, leaves, flower, fruit, seed. There are about 1500 species of aromatic plants which are used as raw material in perfumery industry but only about 500 species are known in detail at present. The scientific cultivation of aromatic plants is labour intensive task, so it provides great opportunities of employment in rural areas. In today's world, there is a wide role of aromatic plants.

Lemongrass (*Cymbopogon flexuosus* (Nees ex. Steud) Wats) is an aromatic plant grown worldwide in the tropical and subtropical regions and it belongs to family Poaceae. It has a distinctive strong lemon like odour, hence, called lemongrass. It is because of high citral content in the essential oil present in the leaves. The genus *Cymbopogon* includes 140 species (Verma and Sobti, 1984). Generally, three species are identified (Gupta, 1969), mostly two species are grown in India, first is *Cymbopogon flexuosus* (known as East Indian Lemongrass/ Cochin grass / Malabar grass) grown in Kerala, the second one is *Cymbopogon citratus* (known as West Indian Lemongrass/ American Lemongrass) which is grown in India

as well as in foreign countries. Third species is *Cymbopogon pendulus* (known as Jammu Lemongrass) identified by the Regional Research Laboratory, Jammu which is suitable for cultivation in Jammu and Kashmir and other north Indian regions with high oil recovery. C. *flexuosus* is an aromatic grass, about 3m tall. The leaves are linear, lanceolate, 125 cm long and 1.7 cm broad. The panicles are very large, dropping, lax, greyish or greyish-green, rarely purple-tinged with the raceme pairs in dense masses. The plant is spreading 100-135 cm tall, slightly hairy, the lower glumes of the sessile spike lets are 3-4, rarely 4-5 mm long, 1mm wide, with 1-3 definite or obscure intracranial nerves, slowly concave with one or two depressions. (Farooqi and Sreeramu, 2001).

*C. flexuosus* is indigenous to India and used in Indian traditional healthcare system for more than 2000 years. It is distributed in Australia, Europe, South America, Africa and Indian subcontinent. It is commercially cultivated in Assam, Maharashtra and Uttar Pradesh. East Indian lemongrass is further of two types the red grass and the white grass. The red grass is true *C. flexuosus* and also known as Choomannapoolu. The colour of stem is reddish and oil contains 75 per cent or more aldehydes, mainly carry citral. Whereas, white grass is known as Wellapoolu. The colour of the stem is white and oil obtained from the plant has very low aldehyde content and is poor in solubility. (Husain *et al*.,1988)

The major chemical constituents of lemongrass oil obtained from leaves are geraniol (30.5%), citronellol (24.1%), neral (10.3%) and geranial (13.6%). Citral (31.52%), Z-citral (28.82%), linalool (4.82%), geranyl acetate (3.57%) and trans-geraniol (3.66%). It serves as natural precursor for semi synthetic vitamin-A synthesis (Srivastava *et al.,* 2013). Lemongrass is used to treat many problems like digestive tract spasms, stomachache, high blood pressure convulsions, pain, vomiting, cough, rheumatism, fever, common cold etc. It also works as mild astringent to kill the germs. Lemongrass oil is also said to relieve headaches, stomachaches, abdominal discomfort, and muscular pain when applied directly to the skin. It also has antioxidant properties and inhibits the growth of various germs and yeast. It also stimulates the uterus and menstrual flow.

Besides its benefits, lemongrass has been linked to various hazardous effects, including lung problems after inhaling lemongrass oil and deadly poisoning after a kid consumed a lemongrass oil-based insect repellant. It is also harmful to pregnant women because it appears to initiate a menstrual flow, increasing the chances of miscarriage.

The yield and quality of lemongrass is mostly influenced by the climatic and agronomic management factors.The management of plant nutrition is a significant aspect that influences plant output.Plants may receive nutrition in both organic and inorganic forms.In general, plant nutrition may be provided in an inorganic manner for intensive crop production, but this degrades the soil's health and fertility, lowering yield and quality.

The use of various organic fertilizers is growing because they are non-polluting, increase soil health and quality, and reduce weeds.Organic manures, such as farm yard manure (FYM) and vermicompost, can be applied to boost crop yield in a variety of ways. Some liquid organic manures such as jivamrit have the capability to boost growth and provide immunity in the plant system. Organic manures are rich in macro as well as micro nutrients, vitamins, amino acids growth promoting factors like IAA, GA and valuabe microorganisms (Palekar, 2006 and Natarajan, 2007).

It is an established fact that fertilization either in organic or inorganic form is the most important factor for exploiting inherent potential of the crop to the maximum possible extent. Oil yield varies according to the fertilizer application in the field. Results can be better when the NPK is given with organic manures (Ghosh and Chatterjee, 1976).

The lack of standard agro-techniques is the major hindrance in the cultivation of lemongrass. Therefore, it is essential to screen the manures and fertilizers for their efficacy and to find out specific combination under particular agroclimatic conditions for high yield and quality of essential oil. The present investigations evolve the efficacy of organic and inorganic fertilizers and harvesting schedules in enhancing the overall yield of end products. Hence, the following objectives were proposed for these studies:

i) Morphological studies of *Cymbopogon flexuosus*
ii) To study the effect of different organic manures, fertilizers and harvesting schedules on growth and yield of *Cymbopogon flexuosus*
iii) Estimation of cost of cultivation, gross return, net return and B:C ratio

# *Chapter-2*

# REVIEW OF LITERATURE

The literature pertaining to the present investigations entitled **"Studies on the effect of organic manures, fertilizers and harvesting schedules on growth and yield of lemongrass (*Cymbopogon flexuosus* (Nees ex. Steud) Wats*)"***is reviewed in this chapter. The available literature on this plant and other related species has been reviewed under the following headings:

2.1 Taxonomical classification
2.2 Species and varieties
2.3 Origin and distribution
2.4 Morphological characteristics
2.5 Chemical composition
2.6 Medicinal importance and other uses
2.7 Cultivation practices

## 2.1 TAXONOMICAL CLASSIFICATION

| | | |
|---|---|---|
| Kingdom | : | Plantae |
| Sub Kingdom | : | Viridiplantae |
| Super division | : | Embryophyta |
| Division | : | Tracheophyta |
| Class | : | Magnoliopsida |
| Super order | : | Lilianae |
| Order | : | Poales |
| Family | : | Poaceae |
| Genus | : | *Cymbopogon* |
| Species | : | *flexuosus* (Nees ex. Steud) Wats |

*Cymbopogon flexuosus* (Nees ex. Steud) Wats is a perennial aromatic plant. It is commonly known as lemongrass because it has a typical strong lemon like odour from the oil present in the leaves. Essential oil of lemongrass contains high citral content. (Guenther 1950; Weiss, 1997; Ranade, 2004).

The herb originated in Asia and Australia. Lemongrass was one of the herbs to travel along the spice route from Asia to Europe. Lemongrass oil of commercial importance is popularly known as Cochin oil. In the world trade, since 90% of it is shipped from Cochin port. The annual world production of lemongrass oil is around 1000 t from an area of 16000 ha. In India, it is cultivated in an area of 4000 ha and the annual production is around 250 t. The crop is cultivated in poor, marginal and waste lands and also along the bunds as live mulch. The well ramified root system of the plant help in soil and water conservation (Joy *et al.,* 2006).

Lemongrass (*Cymbopogon flexuosus*) has a sweet, herbaceous and lemony fragrance and mainly used in the preparation of soups, curries and teas. In Philippines, lemongrass was distilled for export purpose as early as 17$^{th}$ century. In 1951, essential oil of closely related species citronella was presented at world's fair at London crystal palace. In India, lemongrass oil is a favourite oil for many years and it is commonly known as "choomanapolu" which indicates to the plant red grass stem (Juntachote *et al.,* 2006). Indigenous Australians used citrus fruit to make a drink and use for washing of skin cuts and eyes (Shankar *et al.,* 2005).

## 2.2 SPECIES AND VARIETIES

Lemongrass belongs to family Gramineae (Poaceae) and the genus Cymbopogon. Generally three species are identified (Gupta, 1969; Chandra and Narayanan, 1971) *viz. Cymbopogon flexuosus* (East Indian Lemongrass), *Cymbopogon citratus* (West Indian Lemongrass) and *Cymbopogon pendulus* (Jammu lemongrass).

### 2.2.1 *Cymbopogon flexuosus* (Nees ex Steud) Wats. (2n=20, 40)

It is known as East Indian, Cochin or Malabar grass. *C. flexuosus* is a tufted robust perennial grass of about 2 m height. The leaves are linear and lanceolate. It flowers freely. The inflorescence is very large and highly branched terminal drooping panicle bearing paired spikes on tertiary branches. The spikes bear spikelets in pairs of which one is sessile and the other pedicellate. The sessile spikelet is an awned bisexual floret whereas, the pedicellate is an awn less staminate floret. Under this species, two varieties or types are identified based on the colour of stem.

*C. flexuosus var. flexuosus* – It is red grass. The stem and leaf sheath are reddish or purple in colour. It is recognized as the true lemongrass and is commercially cultivated. The essential oil contains more than 75-80% citral, exhibits good solubility in alcohol and hence

is superior in quality (Guenther, 1950). The geranial rich variants of *C. flexuosus* with high oil content could be useful as additional sources of geraniol and not as an alternative to geraniol from *C. martinii* (Kulkarni *et al.*, 1996).

*C. flexuosus var. albescence* – This white grass is characterized by the white colour of the stem. The plant is normally seen wild. The essential oil contains less than 65-70% citral, exhibits poor alcohol solubility and is hence considered inferior in quality.

Sugandhi (OD-19): Released from the Aromatic and Medicinal Plants Research Station (AMPRS), Odakkali, Kerala, India. A red stemmed variety adapted to a wide range of soil and climatic conditions and most popular in India. The plant grows to a height of 1-1.75 m with profuse tillering, yielding 35-40 t/ha/year herb containing 0.3% oil (125 kg/ha) with 80-85% citral under rain-fed condition (Joy *et al*., 2001).

Pragati (LS-48): Evolved through clonal selection from OD-19 at Central Institute of Medicinal and Aromatic Plants (CIMAP), Lucknow, India. It is tall growing with dark purple leaf sheath, adapted to North Indian Plains and Tarai belt of subtropical and tropical climate. Average oil content is 0.63% with 86% citral (Sharma *et al*., 1987).

### 2.2.2 *Cymbopogon citratus* (DC) Stapf. (2n=40, 60)

It is known as West Indian or American lemongrass. It is a stemless perennial grass with numerous stiff tillers arising from short rhizomatous rootstock, making large tussocks. It seldom flowers under cultivation. Leaf blade is narrow, linear, glaucous, drooping with scabrous margin, ligule truncate, inflorescence rarely produced, a large loose panicle; spathe bracts long and narrow, sessile spikelets, awn less , linear, lanceolate. The essential oil contains 74-76% citral and exhibits poor solubility.

### 2.2.3 *Cymbopogon pendulus* (Nees ex Steud) Wats.

It is Jammu lemongrass and is white stemmed and dwarf in nature. The plant is frost resistant and suited to Sub-Himalayan areas of North India. The essential oil contains around 75-80% citral and exhibits medium solubility in alcohol (Joy *et al.*, 2001).

## 2.3 ORIGIN AND DISTRIBUTION

Lemongrass is grown in many parts of tropical and subtropical South East Asia and Africa. It was grown in India a century back and now commercially cultivated in different parts of India. Lemongrass is native to India, Pakistan and Sri Lanka (Manzoor *et al.*, 2013).

In Pakistan it is grown in the Northern areas, Gilgit and Juglote cropping in seasons. In India, it is grown in Western Ghats, Karnataka, Tamil Nadu and states other than foot slopes of Sikkim and Arunachal Pradesh (Tzortzakis and Economakis, 2007).

Lemongrass is distributed in Africa, Indian subcontinent, South America, Australia, Europe and North America. In India, they grow wild in all regions extending from sea level to an altitude of 4200 m. Several species are endemic to India. East Indian Lemongrass grows wild in India and is cultivated well in Kerala, Assam, Maharashtra and Uttar Pradesh. It is also distributed in Guatemala and China. West Indian lemongrass is believed to have originated either in Malaysia or in Sri Lanka. It is widely distributed throughout the tropics and is grown in West Indies, Guatemala, Brazil, Congo, Tanzania, India, Thailand, Bangladesh, Madagascar and China. Jammu lemongrass is mostly confined to North Indian states such as Jammu and Kashmir, Sikkim, Assam, Bengal and Madhya Pradesh (Handa and Kaul, 2001). Traditionally lemongrass is grown in high rainfall area as a rainfed crop in Kerala state. But under semi-arid tropical conditions, it is grown as irrigated crop (Singh, 1999).

## 2.4 MORPHOLOGICAL CHARACTERISTICS

*Cymbopogon flexuosus* is a tufted robust perennial aromatic plant grows upto a height of 2 m also known as Cochin or Malabar grass. Leaves are linear and lanceolate, tapering at the end, small hairs are present on the surface. It flowers freely and large inflorescence and highly branched terminal drooping panicle bearing paired spikes on tertiary branches. The spikes bear spikelets in pairs of which one is sessile and the other is pedicellate. The sessile spikelet is an awned bisexual floret whereas, the pedicellate is an awn less staminate floret (Joy, 2006).

Marigowda *et al.* (2016) studied the morphological features of East Indian lemongrass (*Cymbopogon flexuosus*). They observed that *Cymbopogon flexuosus* is an aromatic plant which grows up to a height of 3 m having short and thick rhizome having an incline inflorescence. The leaves are linear acuminate, tapering at the ends, weakened upwards to long filiform tip, glaucous green, impregnate with purple or reddish tinge, minutely scabrid on both surfaces. The leaf is having fine hairs at the upper surface, and shortly hairy on the lower surface. The inflorescence is large, loose with many long flexuosus branches. The axis

of the inflorescence is 12 nodded, joints are smooth and polished, slightly expanded at the tip, flattened, smooth and glabrous.

## 2.5 CHEMICAL CONSTITUENTS OF OIL

Lemongrass oil are specified by monoterpene constituents like citral, limonene, citronellal, elemol, geraniol, linalool, citronellol, 1,8-cineole, methylheptenone, b-carophyllene, geranylformate and geranyl acetic acid derivation. Chemical characterization of essential oil is done with the use of GC-MS (Ahmad *et al.,* 2008). It has antioxidant and anti-inflammatory properties which are identified as mono and polymeric flavonoids such as apigenin glycosides, luteolin and proantho cyanidins (Francisco *et al.,* 2013). Mono and polymer flavonoids such as luteolin and apigenin glycosides and proanthocyanidins have been acknowleged which have contributed mainly to the antioxidant and anti-inflammatory properties. Due to the presence of higher content of aldehydes lemongrass possesses lemon like odour. It has two geomatric isomers, neral (citral-b), geranial (citral-a) (Hanna *et al.,* 2012).

*Cymbopogon flexuosus* oil contains aldehydes (75-85%) consisting mainly citral. Other constituents in the oil are linalool (1.34%), geraniol (5.00%), citronellol, nerol (2.20%), 1,8 cineole, citronellal (0.37%), linalyl acetate, geranyl acetate (1.95%), α-pinene (0.24%), limonene (2.42%), caryophyllene, β- pinene, β- thujene, myrcene (0.46%), β- ocimene (0.06%), terpenolene (0.05%), methyl heptanone (1.50%) and α-terpineol (0.24%) (Weiss, 1997; Ranade, 2004).

Citral has a citrus flavour and as a component of fragrance formulations, use of citral is limited due to its strong propensity to get polymerise, oxidise and discolour. But despite of all these drawbacks, it is used in many formulations due to its capability to undergo extensive number of reactions (Mestri, 2006). The most important acyclic terpene alcohols such as geraniol, linalool and citronellol are used as flavour and fragrance substances. In flavour compositions, geraniol is used in small quantities to highlight citrus notes. Nerol is used for bouquetting citrus flavours. Citronellol is added for bouquetting purposes to citrus compositions. Pinene is an important starting material in the fragrance and flavour industry.

Bhatnagar (2020) identified twenty five volatile compounds in the essential oil of *Cymbopogon flexuosus* by GC-MS analysis. In essential oil of the lemongrass, main constituents are monoterpenes with major proportion of citral and geraniol and minor

proportion of citronellal, β-caryophyllene, camphene, limonene, neryl acetate, borneol and caryophyllene oxide. Essential oil of lemongrass distilled by hydro distillation showed that volatile constituents are 93.58% of total composition. The large proportion found in the essential oil were citral [a isomeric mixture of geranial (40.29%) and neral (34.29%)], followed by geraniol (1.47%), linalool (1.65%), limonene (0.92%), β-caryophyllene (1.14%), neryl acetate (0.82%), camphene (2.01%), borneol (1.01%) and caryophyllene oxide (1.10%) as a major constituents. The minor constituents were citronellal (0.44%), α-terpineol (0.35%), β-myrcene (0.42%), citronellol (0.22%) and γ-cadinene (0.62%).

Rao *et al.* (2005) conducted the experiment at CIMAP Bangalore showed that young leaves of lemongrass contained more oil but less citral in the oil than old leaves and during winter months formation of citral appeared to be slow.

## 2.6 MEDICINAL IMPORTANCE AND OTHER USES

Lemongrass is cultivated for its oil which is used in culinary flavouring, it is used in major categories of alcoholic and non-alcoholic beverages, frozen dairy desserts, candy, baked goods, meat puddings, meat products fats and oils. It is used to flavour wine, fish and sauces. It is also used as fragrance in perfumes and cosmetics such as creams and soaps. Lemongrass is used to make herbal teas, in confectionaries and also in many non-alcoholic beverages and baked foods. It has many chemical compounds which enable to control pathogens and increase plant resistance to many diseases (Wifek *et al.*, 2016). Leaves of lemongrass are used to make many types of teas and it also work as analgesic, antipyretic, spasmolytic, tranquilizer, anti-inflammatory and diuretic. Due to antimicrobial activities of lemongrass oil it is used against various pathogenic fungi (Vardar *et al.*, 2003).

It is used as a food flavouring, and can be used dried, powdered or in fresh. It is commonly used in tea, soups and curries, and also served with poultry, fish, beef and seafood. Infusion of lemongrass leaves and other parts is effective in fighting against several stomach infections, ulcers, stimulate digestion and excretion, and also helpful for treating nausea, stomach aches and constipation (Carbajal and Casaco, 1989; Leite,1986). Therefore, in many countries lemongrass is used as a medicinal herb (Avoseh,2015). At some places of world, a hot water extract of the whole plant is administered orally to stimulate blood flow in the pelvic area of uterus. A hot water extract of the dried leaves is taken orally as a diuretic and renal antispasmodic. Tea prepared from the leaves of lemongrass is known to have

antispasmodic, anti inflammatory and analgesic effects (Tapsell *et al.*, 2006). The biological activity of lemon grass is due to the presence of essential oil and phenolic compounds including phenolic acids, flavonoids, and tannins (Olorunnisola, 2014; Roriz, 2014; Tavares, 2015).

Lemongrass iced tea is prepared by marinade some stalks in a few quartz of boiling water. It is mainly used in Asian cookery. A syrup made by steeping lemongrass in a mixture of hot water and sugar can be used to improve fruit salads and when it is mixed with seltzer (Carbonated water) it results home made soda. A paste prepared from the mixture of lemongrass, garlic, ginger and oil can be cooked with coconut oil to make delicious sauce for noodles, vegetables and seafood dishes. Its oleoresin is also used in flavouring foods, drinks and bakery products (Gawali and Meshram, 2019).

Citral is major component of essential oil in lemongrass and is commonly used in detergents, soaps, household cleaner, mosquito cream, agarbatti, tea blending. Oil also serves as base material for isolates such as geraniol, citronellol these can be converted into most widely used aromatics. The oil has many therapuetic and medicinal properties (Ranade, 2004). Because of the presence of citral into lemongrass oil it is also used in antibiotics, soaps and aftershaves with fresh lime fragrance. It is a popular ingradient in aromatherapy (Anon, 2006). Lemongrass oleoresin is mainly used in flavouring foods, drinks and bakery preperations.

Leaves of lemongrass can be used as source of cellulose in the manufacture of paper and cardbaord. Reduction in root knot nematode disease was observed in soil amended with leaves of *C. flexuosus.*

## 2.7 CULTIVATION PRACTICES

### 2.7.1 Climate

*C. flexuosus* flourish in sunny, warm, humid conditions of the tropics. It produce highest oil yield per t of herbage where the rainfall averages 2500-3000mm annually. In areas where rainfall is poor, it can be grown with supplemental irrigation. Day temperature of 25-30°C is considered optimum for maximum oil production, with no extremely low night temperature. Short periods above 30°C have little general effect on plants, but severely reduce oil content. The plant is hardy and resistant to draught. Maximum plant height was

recorded during rainy season and least during second harvest non- rainy season. The yield of oil fluctuates greatly with the season, the condition of the plant material, its moisture content and the age of planting (Singh, 1999). The monsoon span is characterized by higher oil content, while the winter and autumn by comparatively lower oil content. However, the above major environmental components individually seem to have no direct relationship with the oil content. The influence exerted by the climatic factors is cumulative in exertion (Handique *et al*., 1984).

### 2.7.2 Soil

Lemongrass flourishes in a wide variety of soil ranging from rich loam to poor laterite. In sandy loam and red soils, it requires good manuring. Calcareous and water-logged soils are unsuitable for its cultivation (Farooqi and Sreeramu, 2001). Both species can be grown on a range of soils and it appears that good drainage is the most important factor. Plants growing in sandy soils have higher leaf oil yield and citral content. Although *C. flexuosus* flourishes in well drained sandy loams but in India, it is grown in almost all types of land available from very light sandy soil to upland laterites. Soils of pH 5.5 to 7.5 are utilized. *C. citratus* is more commonly grown on soils with higher acidity than *C. flexuosus*. In India, the highest herb and oil yields per hectare of *C. flexuosus* are obtained in soils of pH 7.5. Lemongrass will grow and produce average herbage and oil yields on highly saline soils. It grows well on poor soils along hill slopes (Ranade, 2004). Behura *et al.*,(1991) studied the performance of five aromatic Cymbopogon species – palmrosa, citronella, *C. pendulas* and *C. flexuosus* in chromite overburden soil of Kaliapani, Orissa.

### 2.7.3 Propagation techniques

Lemongrass is generally propagated through seeds. Seed is mixed with sand in the ratio of 1:3 and sown in the field at the rate of 20 to 25 kg/ha. Alternatively, seedlings can be raised in a nursery in one-tenth of the area of the main field and transplanted after 45 days. This method which requires 3-4 kg seeds/ha is ideal for uniform stand and better growth of the plants. Small plantation of lemongrass can be established by planting of slips.

*C. flexuosus* is propagated through seeds while *C. citratus* is propagated through division of clumps (Anon, 1981). Hussain *et al.* (1988) reported that propagation through vegetative means from selected clones was considered better as seed propagation tended to cause considerable genetic heterogeneity resulting in deterioration of yield and oil quality and

clonal proliferation played a very important role in the propagation of lemongrass. In a number of field experiments, the growing population of geranium, menthol-peppermint and palmrosa, citronella and lemongrass were sprayed with varying amount of salicylic acid once or twice. It was observed that salicylic acid application did not affect the herbage and essential oil yields as well as the quality of essential oil in all these essential oil crops examined (Ram *et al.*, 1997). It was found that herb yield was positively correlated with tallness, larger number of tillers/plant and long and broad leaves (Nair and Singh, 1984).

A study was conducted for two years to test the performance of clonal and seedling progenies of lemongrass type, OD-440. From a two year study of the comparative performance of the seedlings progenies and clonal progenies raised using the slips of parents; it was conclusively proved that this type was a stabilized one. Hence, the fluff of the type could also be used for cultivation just like slips without affecting the quality of the type (Shylaraj, 1988)

### 2.7.4 Nursery raising

The recommended seed rate is 3-4 kg/ha. The seeds are uniformly broadcasted on the beds and are covered with a thin layer of soil. The seed bed is irrigated frequently. Lemongrass seeds have a dormancy of a few weeks and they lose viability in a few months. The seeds collected during the months of January-February are usually sown in the nursery during April-May. Seeds germinate in 5-7 days. Seed viability is lost in a few months. Germination is very poor if sown after October.

### 2.7.5 Transplanting

The seedlings raised in the nursery beds are transplanted in the field at 6-7 leaf stage. 50-70 days old seedlings are planted during the monsoon season. A spacing of 30 cm x 30 cm with a plant density of 111000/ha is recommended. A wider spacing of 60 cm x 45 cm for seedlings and 90 cm x 60 cm for slips has been recommended for fertile, irrigated land under North Indian conditions (Farooqi *et al.*, 1999). Lemongrass was tested with three spacings and different fertility levels under poplar for its performance in Kumauni foot hills for two years. The spacing of 45 cm x 45 cm and fertility level of NPK (250:100:180) were proved to be superior in respect of number of tillers , plant height, herbage yield and oil yield when compared to other treatments in the first and second year, respectively (Joy *et al.*, 2006).

### 2.7.6 Effect of organic manures and fertilizers

Lemongrass requires 275 kg N, 50 kg $P_2O_5$and 175 kg $K_2O$/ha/annum. Under rainfed conditions of Kerala, application of 100 kg N in 3 to 4 split doses was found to be optimum though a response up to 200 kg was recorded. The application of 50 kg/ha each of $P_2O_5$ and $K_2O$ as a basal dose gave encouraging results in West Bengal. It is recommended to apply 60:45:35 kg /ha N, $P_2O_5$ and $K_2O$ basally and 60 kg N in 3 to 4 splits /annum as top dressing during the growing season as an optimum dose. Spent lemongrass compost at 10 t /ha and wood ash at 2 t /ha, which are obtained as by-products of grass distillation, are applied at the time of bed formation (Hussain *et al.*, 1988). It also responds well to the application of copper, iron, calcium and sulphur. It was reported from CIMAP, Lucknow that a lower dose of boron (2.5 ppm) in combination with chloride salts (chloride salinity) can be beneficial for the crop (Farooqi and Sreeramu, 2001).

In chromate overburdened soil, application of lime at 6 t/ha and fertilizer at 100 kg N, 50 kg $P_2O_5$ and 50 kg $K_2O$/ha produced higher plant height, tiller number and herb yield of *C. pendulus* (Behura *et al.*, 1998).

Rao and Chand (1998) conducted four field experiments under the semiarid tropical climate of Andhra Pradesh to study the response of different varieties of lemongrass to NPK fertilizers applications under different spacings. They revealed that lemongrass responded to application of 100 kg N/ha under irrigated conditions and 75 to 80 kg N/ha under rainfed condition. Essential oil concentrations and quality were not affected by N application.

Sharma *et al*. (1980) conducted an experiment to study the effect of green manuring, phosphorus, potassium and zinc on growth and yield of lemongrass and found that highest yield was obtained with the treatment of 40 kg/ha nitrogen along with 10 t/ha FYM as compared to all other treatments.

Pareek *et al*. (1984) analysed the effect of farmyard manure and micronutrients on yield and quality of palmarosa grass and reported that with the treatment of 40 kg/ha nitrogen and 10 t/ha FYM higher plant height (147.50 cm), number of tillers (169.7), dry herbage yield (94.5 q/ha), length of inflorescence (29.6 cm) and oil yield (107.7 kg/ha) was obtained as compared to control.

Rao *et al.* (1991) studied the effect of different amount of nitrogen, phosphorus and potassium on herbage and essential oil yield of *Cymbopogon martinii.* Among all the applied doses of N (0, 150, 300 kg/ha), P (0, 22, 44 kg/ha), K (0, 42, 84 kg/ha) maximum herbage and oil yield was attained with the application of N:P:K (150:22:42 kg/ha), higher dose of fertilizers show some decrease in the yield.

Thimmarayappa *et al*. (2000) investigated the effect of organic manures and inorganic fertilizers on growth, yield attributes and yield of cardamom. The experiment was conducted with six treatments *viz* 100% organic manure, (75%) organic manure + (25%) inorganic fertilizer, (50%) OM + (50%) IF, (25%) OM + (75%) IF, (100%) IF and control and they revealed that treatment of (100%) inorganic fertilizer gives maximum number of bearing sucker (9.96), plant height (212), panicle production per clump (23.15) and green capsule yield (707 kg/ha). Further as this treatment increases the yield which gives higher benefit cost ratio of 4.19.

Rao (2001) studied the effect of different levels of organic manures and fertilizers on above ground biomass and oil yield of palmarosa and investigated that application of 15 t/ha/year of FYM gives higher biomass yield (10.7%) and higher oil yield (10.3%) in comparison to control and also higher biomass yield (57.6%), higher essential oil yield (60.3%) was obtained by the application of 80 kg/ha/year of nitrogen in the crop as compared to control.

Ram *et al.* (2003) carried out an experiment to investigate the influence of organic fertilizer nitrogen use efficiency and herb and essential oil yield in geranium. They concluded that among all the nitrogen levels (0, 80, 160 and 240 kg/ha) application of 160 kg/ha nitrogen recorded the highest plant growth and essential oil yield.

Nataraja *et al.* (2003) studied the influence of nitrogen, phosphorus and potassium on growth and yield of black cumin. The experiment comprised of twenty seven treatments with different levels of nitrogen (0, 50, 100 kg/ha), phosphorus (0, 20, 40 kg/ha) and potassium (0, 30, 60 kg/ha). They concluded that maximum plant spread (427.75 $cm^2$) and number of seeds (57.52) per pod was obtained with the treatment of 100 kg/ha of nitrogen and also application of NPK (50:40:30 kg/ha) gave higher test weight (2.38 g) and seed yield (17.45 q/ha).

Venkatesh *et al.* (2003) carried out an experiment with twelve treatments to analyze the influence of rock phosphate, single super phosphate and their combination with FYM on

turmeric. They reported that maximum dry rhizome yield (46 q/ha) was obtained by applying combination of rock phosphate + single super phosphate (1:1) + FYM (10 t/ha) but maximum curcumin content (6.02) was attained with the treatment of RP + SSP (1:3) + FYM (10 t/ha).

Yadav *et al.* (2003) conducted an experiment to study the effect of integrated use of Farmyard manure on growth and yield of isabgol and concluded that highest plant growth (tiller/plant 6.84, number of spikes plant 40.74, grains/spike 667.16), grain yield 16.59 q/ha and straw yield 35.93 q/ha was obtained by the use of nitrogen, through urea (25%) and FYM (75%) in isabgol.

Anwar *et al.* (2005) analysed the effect of organic manures and inorganic fertilizers on growth, herb and oil yield of basil. They revealed that among all the treatments application of combination of 5 t/ha vermicompost + NPK 50:25:25 kg/ha gave the maximum plant growth, herb yield and oil yield.

Vasanthkumar (2006) revealed that Jeevamrutha is a fermented liquid product full of microbes which upon application to the soil increases the soil biomass and also improves the soil health.

Thakur (2006) carried out an experiment to investigate the effect of integrated nutrient management through vermicompost and inorganic fertilizers on growth and yield of geranium and found that treatment of 5 t/ha vermicompost along with 50% recommended dose of NPK gave higher plant growth and herbage yield as compared to the other treatments.

Dhage *et al.* (2008) observed that in ashwagandha maximum root yield (91.3 g), seed yield (1.33 g) and biomass yield (92.70 g) was obtained by the application of higher levels of fertilizers with 5 t/ha FYM.

Manjunatha *et al.,* (2009) studied the effect of FYM treated with jeevamrit on soil properties and yield of sunflower. The yield attributes *viz.*, test weight (49.26 g), seed yield (1774 kg/ha) and stalk yield (4.21 t/ha) were significantly increased by the application of FYM and jeevamrit in combination as compared to control.

Umesha *et al.* (2011) conducted a three year field experiment to study the effect of organic manures and biofertilizers on growth and yield of stevia. The experiment was conducted with total eighteen treatments and the results showed that plant growth parameters

like plant height, number of branches and plant spread were affected by different organic manures and showed variation from harvest to harvest. Treatment of FYM (25 t/ha) + vermicompost (2 t/ha) + neem cake (1 t/ha) + biofertilizers (10 kg/ha) gave the maximum dry leaf yield (6.16 t/ha) during first year and 4.34 t/ha during second year.

Punam *et al.* (2012) investigated the effect of organics on plant growth and oil yield of lemongrass plant and recorded the maximum herbage yield in first and second year as 7853 kg $ha^{-1}$ and 7278 kg $ha^{-1}$ respectively. Highest oil percentage was 0.46% with the application of organic manure (FYM @ 20 t/ha + Vermicompost @ 15 t/ha) and agnihotra ash as compared to other treatments.

Farnaz *et al.* (2014) carried out an experiment to investigate the effect of compost on yield and essential oil of dill. They applied four different doses of compost (0, 5, 10 and 15 t/ha) and reported that highest seed yield and essential oil yield was obtained by the application of 10 t/ha of compost and with the application of 15 t/ha of compost maximum biological yield was obtained.

Godara *et al.* (2014) conducted a field experiment to investigate the influence of organic and inorganic sources of fertilizers on growth, yield and economics of fennel. The experiment comprised of eight treatments of organic manures, inorganic fertilizers and their combinations. They revealed that the treatment of 100% RDN (90:45:0) applied through fertilizers recorded maximum vegetative growth and yield (2325 kg/ha), net return (Rs. 62,091) per ha and benefit ratio (3.01) over other treatments.

Godara *et al.* (2014) also studied the effect of organic and inorganic sources of fertilizers on growth, yield of coriander (*Coriandrum sativum* L.). The results showed that application of (100%) RDF (60:45:0) through inorganic fertilizers significantly enhanced the plant height (96.52 cm), number of primary branches (6.92), number of secondary branches (15.32), number of umbels per plant (44.24), test weight (8.49), yield (1024 kg/ha), net returns (Rs. 59556 per ha) and benefit cost ratio (3.66) as compared to other treatments.

Sasikala *et al.* (2016) investigated the response of different doses of vermicompost on growth and yield of lemongrass. The plants were treated with five different doses of vermicompost *viz* 2, 4, 6, 8, 10 g/plants and they observed that the maximum height (86),

number of tillers (107) and herbage yield (317 g/plants) was obtained with 10 g/plant of vermicompost as compared to control and other treatments.

Kalasare *et al.* (2016) carried out an experiment to study the response of integrated nutrient management on growth and yield of fennel consisting of 12 treatments and the results revealed that treatment $T_4$ (100% RDN + Azospirillum + vermicompost at 2 t/ha + PSB) have significantly higher values of plant height (148 cm), number of branches per plant (9.6) seed yield (2719 kg/ha) over other treatments.

Kumbar *et al.*, (2016) study the combined effect of FYM and liquid manures (jeevamrit and panchagavya) on growth and yield of French bean. There were 12 treatment combinations comprised of two levels of each jeevamrit (0 and 1000 l/ha) and panchagavya (0 and 3%) with three levels of FYM. They observed that with the application of 1000 l/ha of jeevamrit and foliar application of panchagavya (3%) significantly increased the plant height (26.7 and 26.6 cm), number of branches (6.93 and 6.89), number of pods per plant (15.89 and 15.40) and pod weight/plant (81.58 and 79.42 g) as compared to control.

Shivran *et al.* (2016) studied the effect of different organic manures and fertilizers on growth and productivity of fenugreek. The experiment comprised of different treatments *viz.* control, inorganic fertilizers and organic manures (farm yard manure, poultry manure, vermicompost and neem cake) alone or in combinations to provide 40 kg/ha of nitrogen. They found that highest vegetative growth (plant height, branches/plant, pods/plant, seeds/pod), seed yield (1781 kg/ha), biological yield (5173 kg/ha) was observed with the application of 50% RDN through vermicompost and 50% RDN through inorganic fertilizers.

Srinivas *et al.* (2017) analyzed the effect of different compositions of fly ash and vermicompost on the herbage and oil yield of *Cymbopogon flexuosus* and treatments included eleven different combinations of fly ash + vermicompost, RDF and control. The results showed that the maximum herbage yield was obtained with treatment of 6 t/ha fly ash + 4 t/ha vermicompost and no concrete values are recorded for oil content.

Kumar *et al.* (2017) carried out a field experiment with eighteen treatments to study the impact of different manures on ashwagandha production under rainfed conditions. They observed that among all the treatments application of 10 t/ha FYM + 2.5 t/ha Vermicompost

+ 2 kg/ha PSB + 2 kg/ha Azotobacter along with organic mulch recorded the highest plant height (39.41 cm), fresh leaf weight (47.93 g), dry leaf weight (7.72 g), number of branches (11.21), root length (18.13 cm), fresh root yield (29.53 q/ha) and dry root yield (9.45 q/ha) and benefit cost ratio (2.45) was also highest.

Bajya *et al.* (2017) investigated the effect of integrated nutrient management on growth, yield and quality of fennel and revealed that highest plant height (147.67 cm), fresh weight (121.20 g), dry weight (43.93 g), branches/plant (8.83), seed yield per plant (14.03 g) was obtained by the application of 50% RDN through vermicompost + 50% RDN through fertilizer.

Siddappa *et al*. (2017) conducted a field experiment to study the effect of farm yard manure and jeevamrutha on yield and yield attributes of fieldbean and they concluded that the treatment combination of FYM level at 200% N equivalent + jeevamrutha @ 1500 l/ha was the best treatment. This treatment resulted in maximum number of pods per plant (30.6), no. of seeds per pod (3.6), pod weight per plant (22.5), grain yield (1378 kg/ha) and haulm yield (1681 kg/ha).

Kurubetta *et al*. (2017) stated that combined application of 100% RDF + jeevamrutha @ 500 l/ha at planting, vegetative and bulb initiation stage resulted in higher bulb yield (225 q/ha) in onion.

Nandapure *et al.* (2017) investigated the effect of different manures and fertilizers on uptake of micronutrients in java citronella and reported that the combined application of 10 t/ha FYM + 140:40:80 kg/ha NPK have significant improvement on uptake of micronutrients like Fe, Mn, Zn and Cu in the crop as compared to other treatments.

Devi *et al.* (2017) observed that combined application of organic manures, fertilizers and PGPR have significantly increased the biological properties of soil. They concluded that nutrient uptake and biological properties of soil were improved with the application of 80% NPKM + 30% N through FYM and vermicompost.

Saini *et al.* (2018) estimated the effect of different level of nitrogen on herbage and oil yield of lemongrass. They applied three levels of nitrogen (50, 100, 150 kg/ha) and concluded that the highest herbage and oil yield was attained when crop was treated with 150 kg/ha nitrogen and lowest yield was obtained with the application of 50 kg/ha.

Premathilake *et al.* (2018) studied the effect of different fertilizers on crop growth, oil yield and chemical composition of lemongrass with three different fertilizer mixtures $T_1$ (compost only), $T_2$(inorganic fertilizer) (278 kg/ha urea, 296 kg/ha triple super phosphate and 175 kg/ha muriate of potash and $T_3$ (inorganic fertilizer + compost)with $T_0$ control (without fertilizer). They determined that the highest herb yield (15.94 t/ha), dry matter yield (4.82 t/ha) and oil yield (fresh weight) (59.16 kg/ha) were recorded in the $T_3$treatment with 106.5g compost, 2.96gurea, 3.15g tsp and 1.86g mop per plant.

Dhanyashri *et al.* (2018) analysed the effect of different levels of spacing and organic fertilizers on productivity of safed musli and they reported that when the spacing was 30 cm and 15 q/ha vermicompost was applied, maximum number of roots (19.8), length of roots (11.9 cm) and average diameter of roots (0.9 cm) was obtained. Further with this treatment maximum average fresh weight of roots per plant (75.5 g), average yield of roots (15.62 q/ha) was also recorded.

El-Mahrouk *et al.* (2018) carried out a field experiment to study the effect of NPK and some growth stimulators (extracts of compost tea, Spirulina platensis algae and lithovit) on vegetative growth and oil yield of lemongrass. They revealed that the highest herb (272.70 g/plant) and oil yield (1.43 ml/plant) was obtained by the application of 400 kg ammonium sulphate (20.5% N), 300 kg calcium superphosphate (15.5% $P_2O_5$) and 100 kg potassium sulphate (48% $K_2O$) per feddan combined with compost tea.

El-Sayed *et al.* (2018) conducted an experiment to study the effect of NPK, biofertilizers (Nitrobien and Phosphorien) at 1, 2 and 4 g/plant, compost and poultry manure at 5, 10 and 15 t/feddan oil production of lemongrass. They concluded that poultry manure produced the highest essential oil as compared to the other treatments. The average essential oil percentage at first harvesting is 0.14% - 0.30% and at second harvest 0.133% - 0.283%.

Anusha *et al.* (2018) reported that maximum plant height (22.2 cm), number of pods per plant (31.5), leaf area (2.05 $cm^2$) and pod yield (2333 kg/ha) was obtained with the application of RDN through farm yard manure (60%) + neem cake (40%) + seed treatment with ghanajeevamrutha + foliar spray of panchgavya @ 3%.

Kusuma *et al.* (2019) conducted a field experiment to study the effect of integrated nutrient management on growth and yield of fennel. The results obtained showed that highest

plant height (209.97 cm), number of primary and secondary branches (16.43 and 7.50 respectively), number of umbels per plant (29.24) was attained by the combined application of FYM (15 t/ha) + NPK (90:60:30 kg/ha) + RDPK + *Azospirillum* at 5 kg/ha + PSB at 3 kg/ha.

Sen *et al.* (2019) carried out an experiment to investigate the effect of different organic manures and fertilizers on growth and yield attributes of black cumin. The results revealed that among all the twelve treatments application of RDF (100%) + FYM (15 t/ha) + 4 kg/ha *Azophos* have increased the plant height (57.20 cm), number of capsules per plant (23), yield/ha (961.89 kg/ha) and net returns.

Nandapure *et al.* (2020) studied the effect of different organic manures and fertilizers on growth and yield of Java citronella and reported that the highest plant height (140.20 cm) and number of tillers (58.43) and maximum herbage yield (26.44 t/ha) was attained with the combined application of the 10 t/ha FYM + 140:40:80 kg/ha NPK.

Mahantesh *et al.* (2020) analysed the response of integrated nutrient management on growth and yield of patchouli and concluded that with the treatment of 150:50:50 kg/ha NPK + 12 t/ha FYM maximum herbage yield (18.01 t/ha), plant height (64.61 cm) and number of branches (27) was recorded as compared to other treatments.

Gangadhar *et al.* (2020) studied the influence of organic manures, jeevamrutha on growth and yield of chilli. They observed that maximum plant height (91.05 cm), leaf area index (1.57), total dry matter accumulation (33.76 and 0.39 %) was obtained with the application of jeevamrutha as compared to other organic manures.

Kadam and Kamble (2020) investigated the effect of organic manures on growth, yield and quality of turmeric. The experiment comprised of nine treatments of different manures and maximum fresh yield (312.12 q/ha) and dry yield (62.42 q/ha) was obtained with the application of 25 MT FYM + 200:100:100 kg/ha of N:P:K. Further with this treatment, highest benefit cost ratio (1.59) was attained as compared to all other treatments.

Mastan *et al.* (2020) studied the effect of different organic manures and biofertilizers on growth and yield of senna and revealed that treatment of RDN (100%) through urea recorded the highest plant height (87.26 cm), number of branches (17.40) and dry matter production (0.867 kg/m$^2$) but the application of (100%) RDN through vermicompost +

biofertilizers gives the maximum number of leaves, leaf area ($cm^2$), stem girth and total chlorophyll content.

Devkota *et al.* (2021) conducted a field experiment to study the effect of different organic manures and fertilizers on growth and yield of cauliflower. The experiment comprised 10 treatments *viz.* Control, NPK, FYM, half NPK + half FYM, 125% RDF, Recommended dose of Organic manure (OM), Double dose of OM, Half dose of OM, OM half+ half NPK, OM Half + half FYM. They observed that the highest number of leaves per plant (16.67), plant spread (75.33 cm), curd yield/plant (1019 g), biomass yield per plant (2046 g) was obtained in $T_{10}$ (half organic manures + half FYM) and highest plant height (51 cm) was obtained in $T_4$ (half NPK + half FYM).

Pamula and Kerketta (2021) investigated the effect of different organic manures and fertilizers on growth and yield of turnip and the results showed that the maximum plant height (46.74 cm), number of leaves per plant (22.30), leaf length (30.23 cm), shoot weight per plant (23.87 g), root length (5.61 cm), root weight (117.48 g), root yield per plot (14.92 kg/plot) and root yield per hectare (355.17 q/ha) was recorded in $T_{10}$ (25% RDN (20:12.5:12.5) + 75% PM (7.5 t/ha) as compared to other treatments.

### 2.7.7 Irrigation

In case of drought, the crop should be irrigated every alternate day for about a month after planting. It is recommended that 4 to 6 irrigations are given during the period from February to June under North Indian conditions, for optimum yield. Quality of the essential oil is not affected by soil moisture regimes (Singh *et al.*, 1997). A study at CIMAP field station Bangalore showed that growth, herbage, oil yield and nitrogen uptake increased due to increased levels of water regimes except nitrogen utilization efficiency during rainy season (Singh, 1997). Another study at CIMAP field station Bangalore showed that plant growth characters, herbage and oil yield were influenced by the irrigation level (Singh, 1999). Herb yield and oil yield suffered the most and leaf width and citral content of oil the least under stress (Pandey *et al*, 1998).

At CIMAP Lucknow, fourteen genotypes belonging to five species of *Cymbopogon C. flexuosus, C. pendulas, C. martinii. var. motia, C. winterianus* and *C. caesius* were subjected to irrigated and non- irrigated moisture regimes, to screen out potential genotypes having tolerance to water stress and understand the behaviour of stress tolerance. The

interspecific comparison to stress tolerance revealed reduction of performance for early vigour, tillering vigours, growth vigours and production vigour in all the species except *C. martini* for oil yield. The response of different varieties/genotypes to unirrigated regime in terms of percentage loss in vigour was -21.1 to -42.7% for early vigour and -10.5 to -51.2 % for tillering vigour (Misra and Sharma, 1999).

### 2.7.8 Weed control

The first 25-30 days after planting (or harvest) is the crop-weed competition period. For a good establishment of the crop, the field should be kept weed free for the initial period of 3-4 months after planting. Once the crop is well established, it can compete with weeds.

Generally, 2-3 weeding are necessary in a year. Among herbicides, diuron at 1.5 kg ai/ha and oxyfluorfen at 1.5 kg ai/ha are effective for weed control (Hussain *et al.*, 1988). Duhan and Gulati (1973) and Khosla (1979) observed a significant control of dicot weeds with the application of 2-4- D (sodium salt). They also suggested spraying paraquat at 2-2.5 l/ha in 500 l of water immediately after cutting the grass as an excellent method of weed control.

Under rainfed conditions, the field gives a dried appearance during the summer months of Dec – May. The dry grass and stubbles of the crop is set on fire in May, prior to the onset of monsoon. This practice kills the termites attacking crop stubbles and also helps to rejuvenate the old clumps.

### 2.7.9 Intercropping

The plant does not tolerate shade and oil yield is drastically reduced when the crop is grown under diffused light (Pareek and Gupta, 1985). Studies at AMPRS, Odakkali indicated poor tillering, lean growth and reduced oil yield when the crop is grown as intercrop in coconut gardens; the oil content was also found to be reduced by 20%. In contrast, intercropping in cinnamon plantation which is regularly pruned for extraction of bark and leaf oil was found to be profitable. In new plantations of cashew, mango and coconut, lemongrass is cultivated during the initial 4 to 5 years of plantation establishment. An interesting method of integrating *C. flexuosus* into plantations of other crops was proposed for Bangladesh, but not widely implemented (Khan, 1979). Pratibha and Korwar (2003) suggested lemongrass for crop diversification in semi-arid regions.

### 2.7.10 Harvesting

Harvesting is done by cutting the grass 10 cm above the ground level, with the help of sickles. The number of harvests in a year depends on the climatological factors such as temperature, rainfall and humidity and level of soil fertility. Generally the crop thrives best in humid condition (Handa and Kaul, 1997).

Time of harvesting is one of the major factor to obtain the higher essential oil yield with better quality. Number of harvests accomplishable in a year depends on temperature, humidity and soil condition. As per climatic conditions of Uttar Pradesh three harvests are possible because of high soil fertility with warm and humid climate, though in Assam and Kerala four harvests are obtained due to mild temperature and high humidity. In North India only two main harvests are feasible because of low temperature during winter season (Singh *et al.*, 1999).

Cutting can begin as soon as the night dews have evaporated from the plants, as wet grass left for later distillation quickly ferments. Sunny days are preferable, since cloudy and misty conditions tend to depress leaf oil content.

Chandra *et al.* (1970) have suggested first harvest at 75 days after planting, second at 120-130 days after first harvest and the third at150-160 days after second harvest. However, Nair *et al.* (1979) and Shiva (1998) have suggested that first harvest can be taken at 90 days after planting and subsequent harvest at 50-55 days interval up to 5-6 years from the same crop. Rao *et al.* (2005) reported five months for the citral content to reach a maximum for the first and the sixth harvest.

During the first year of planting, three cuttings are obtained and subsequently 5-6 cuttings per year (Subramanyam and Gajanana, 2001). The harvesting season begins in May and continues till the end of January. An herbage yield of 10-15 t/ha/harvest was obtained. The herb yield of lemongrass differed significantly between years. The yield in the second year was significantly higher than that of the first, third, fourth and fifth year (Singh, 1999).

Baydar and Erbas (2009) carried out an experiment to investigate the effect of harvesting time on essential oil properties in lavandin which was harvested in four dates (8, 15, 22 and 29 July 2005). They revealed that the maximum essential oil content (8.25%) was

obtained in first harvest and minimum essential oil content was obtained at the fourth harvesting (7.30%).

Chauhan *et al.* (2011) investigated the effect of harvesting time on growth and yield of thyme and the results obtained showed that the highest plant height (42 cm) and essential oil content (0.74%) was obtained at first harvesting (115 days after planting) and highest number of branches (316.62), fresh herbage yield (147.13 q/ha), dry herbage yield (17.35 q/ha) was obtained at fourth harvesting (175 days after planting).

Solomon and Beemnet (2011) studied the effect of harvesting age affect agronomic characteristics and essential oil yield of Japanese mint. The experiments comprised of three harvestings at (60, 90 and 120 days after planting) and they reported that the maximum fresh leaf weight (5778.6 kg/ha), leaf to stem ratio (1.8) and moisture content (79.6%) was obtained in first harvesting (60 DAP) and maximum dry leaf weight (1319 kg/ha), fresh biomass weight (8250.7 kg/ha), essential oil content (2.0%) and essential oil yield (24.8 kg/ha) was obtained in the fourth harvesting (120 DAP).

Mekonnen and Kassahun (2011) carried out a field experiment to investigate the effect of harvesting time on growth and essential oil yield of spearmint. The experiment consisted of five harvestings at different times (60, 90, 120, 150 and 180 days after transplanting). The results obtained concluded that the highest fresh leaf weight (7478 kg/ha), leaf to stem ratio (1.98) and moisture content (86.71%) was obtained in first harvesting and maximum fresh stem weight (8233 kg/ha), fresh biomass yield (13391 kg/ha) and essential oil yield was obtained in fourth harvesting at (150 DAT).

Jimayu and Gebre (2017) conducted a field experiment to study the influence of harvesting age on yield and yield related traits of lemongrass. The treatments were five harvesting schedules at 45, 60, 75, 90 and 105 days after planting. They observed that the highest fresh herbage yield/ha (15043 kg/ha), dry herbage yield/ha (3864.4 kg/ha) and essential oil yield (59.03 kg/ha) was obtained when harvesting was done after 105 days after planting and the minimum yield was obtained when harvesting was done after 45 days after harvesting.

Wang *et al.* (2021) investigated the effects of harvest time on the yield, quality and active substances of *Torreya grandis.* The experiment consists five harvesting at different

dates and they observed that the highest kernel moisture content (41.98 %) was obtained in first harvesting; kernel yield (70.72) and Kernel oil content (48.40 %) were obtained in the fifth harvesting.

### 2.7.11 Benefit cost ratio

Thakur (2018) reported that the highest benefit cost ratio (1.88) was obtained with the application of 100% RDN through Farm Yard Manure in *Phaseolus vulgaris.*

Gaisinmeilu (2019) observed that the maximum benefit cost ratio (1.66) was recorded with the combined application of vermicompost and NPK in clary sage.

Shraddha (2020) revealed that highest benefit cost ratio (1.93) was observed with the combined application of Jeevamrit and inorganic fertilizers *Brassica oleracea* L.

Sharma (2020) reported that application of Jeevamrit @ 10% drenching gives the highest benefit cost ratio (2.86) in Radish.

# *Chapter-3*

# MATERIALS AND METHODS

The present investigations entitled **"Studies on the effect of organic manures, fertilizers and harvesting schedules on growth and yield of lemongrass (*Cymbopogon flexuosus*)"** were carried out in the experimental area of department of Forest Products, Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan during 2020-2021. The material for conducting these studies was taken from department of Forest Products. The research methodologies used during these investigations are detailed under following heads:

**3.1 Conduct of experiment**

**3.2 Morphological studies of *Cymbopogon flexuosus* (Nees ex. Steud) Wats**

**3.3 Effect of different organic manures, fertilizers and harvesting schedules on *Cymbopogon flexuosus***

**3.4 Economic analysis**

## 3.1 CONDUCT OF EXPERIMENT

### 3.1.1 Location

The experimental farm of department of Forest Products falls under mid-hill zone of Himachal Pradesh. The geographical location of this area is as follows:

Altitude : 1250 m

Latitude : $30^0$52'N

Longitude : $77^0$11'E

### 3.1.2 Climate and weather conditions

The area falls in subtemperate, subhumid agroclimatic zone of Himachal Pradesh, India. There is considerable variation in the seasonal and diurnal temperature of the experimental site. It is situated 15 km south east of Solan town and represents transitional zone between subtropical and subtemperate region of Himachal Pradesh.

## 3.2 MORPHOLOGICAL STUDIES OF *Cymbopogon flexuosus* (Nees ex. Steud) Wats

The different morphological characters were studied as per the standard morphological literature given by Hussain *et al.* (1988), Farooqi and Sreeramu (2001) and Marigowda *et al*. (2016).

### 3.2.1 Habit

The habit was studied by observing the general growth features of the plant like height, type of the shoot and flowering period etc. The plant height was measured from base to tip of leaf. The data was recorded in centimeters and has been reported as mean. The flowering period was determined by recording the date of first and last flower opening.

### 3.2.2 Type and dimension of roots and stems

Various qualitative parameters pertaining to type of roots and stems were studied on the basis of the morphological features of plants as given by Hussain *et al.* (1988), Farooqi and Sreeramu (2001) and Marigowda *et al*. (2016).

### 3.2.3 Leaf shape and arrangement

Leaves were studied for their qualitative characters as per the standard morphological literature given by Hussain *et al.* (1988), Farooqi and Sreeramu (2001) and Marigowda *et al*. (2016).

### 3.2.4 Inflorescence type

Data on inflorescence type, structure and arrangement of various floral parts was done on the basis of description of such parameters given by Hussain *et al.* (1988), Farooqi and Sreeramu (2001) and Marigowda *et al*. (2016).

### 3.2.5 Floral characters

The structure and arrangement of various floral parts was studied on the basis of description given by Hussain *et al.* (1988), Farooqi and Sreeramu (2001) and Marigowda *et al*. (2016).

### 3.2.6 Fruit type and seed characteristics

These observations were made at maturity stage on the basis of description of such parameters given by Hussain *et al.* (1988), Farooqi and Sreeramu (2001) and Marigowda *et al*. (2016).

## 3.3 EFFECT OF DIFFERENT ORGANIC MANURES, FERTILIZRES AND HARVESTING SCHEDULES ON *Cymbopogon flexuosus*

The experiment was conducted under Randomized Block design (RBD) with three replications and thirty-two treatments. The slips were planted in the raised beds of size 4.5m

× 3.6m at 60cm × 45cm spacing between rows and plants. Irrigation was done after planting of slips and light irrigation was given at 15-20 days interval in summers. The field was kept free from weeds by doing manual weeding operation.

The details of treatments is given below:

| **Treatments** | | **Dose** |
|---|---|---|
| $T_1$ | Control | |
| $T_2$ | NPK | 60:45:45 kg/ha |
| $T_3$ | FYM | 9.6 t/ha (N content equivalent to RDF) |
| $T_4$ | Vermicompost | 3.3 t/ha (N content equivalent to RDF) |
| $T_5$ | Jeevamrit | Soil application at 25, 40 and 55 DAP |
| $T_6$ | FYM + NPK | 9.6 t/ha + 60:45:45 kg/ha |
| $T_7$ | Vermicompost + NPK | 3.3 t/ha + 60:45:45 kg/ha |
| $T_8$ | Jeevamrit + NPK | Soil application at 25, 40 and 55 DAP + 60:45:45 kg/ha |

**Harvesting Schedule**

| | |
|---|---|
| H1 (1st Harvesting) | 90 days after planting |
| H2 (2nd Harvesting) | 150 days after planting |
| H3 (3rd Harvesting) | 210 days after planting |
| H4 (4thHarvesting) | 270 days after planting |

**Treatments** **:** 32

**Design** **:** Randomized Block Design (Factorial)

**Replications** **:** Three

**Spacing** **:** 60 cm × 45 cm (Between rows and plants)

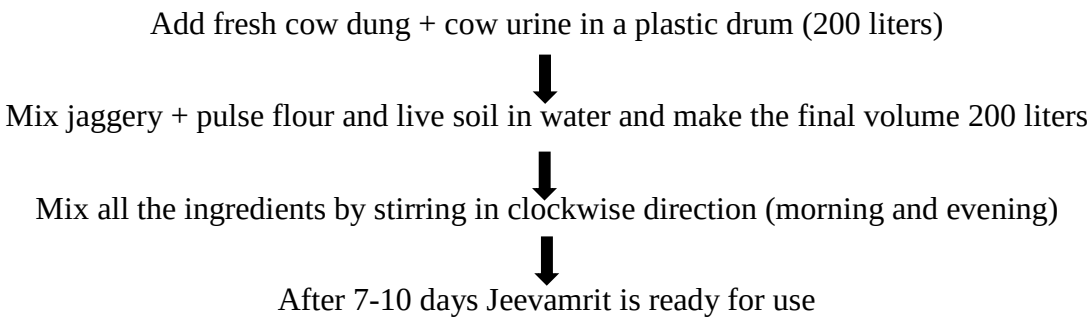
**Harvesting** **:** As per treatment

**Preparation and application of Jeevamrit:**

Jeevamrit was prepared by dissolving the following ingredients in the ratio as given below:

| **Ingredients** | **Quantity** |
|---|---|
| Cow Dung | 10 kg |
| Cow Urine | 10 liters |
| Jaggery | 2 kg |
| Pulse Flour | 2 kg |
| Live Soil | 1 kg |
| Water | 200 liters |

**Flow chart for the preparation of Jeevamrit:**




All the material required for its preparation were easily available. Jeevamrit @ 5 per cent (500 ml per 10 liters of water) was applied as soil drenching 25, 40 and 55 days after planting.

**Observations recorded**

**1. Plant height (cm)**

Plant height was measured from ground level to the top of longest leaf at the time of harvesting with the help of measuring scale. The height of five randomly selected plants from each plot was measured and the average value was expressed in centimeters.

**2. Number of leaves per plant**

All the fully grown leaves were counted. The number of leaves were counted from five randomly selected plants from each plot and averaged to get number of leaves per plant.

**3. Number of off-shoots per plant**

The number of off-shoots were counted from five randomly selected plants from each plot and their average value was worked out to get the number of off-shoots per plant.

**4. Fresh herbage weight per plant (g)**

Five randomly selected plants from each plot were harvested and their weight was recorded and averaged to get the weight per plant in grams.

**5. Dry herbage weight per plant (g)**

Five randomly selected plants from each plot were harvested, dried and their weight was recorded. Their average value was expressed in grams.

**6. Estimated fresh herbage yield (kg/ha)**

Five randomly selected plants were harvested from each plot and their weight was recorded. The mean value was worked out. Fresh herbage yield was estimated on per hectare basis.

**7. Estimated dry herbage yield (kg/ha)**

Five randomly selected plants from each plot were harvested, dried and their weight was recorded. The mean value was worked out. Dry herbage yield was estimated on per hectare basis.

**8. Essential oil content (%)**

The extraction of essential oil was carried out in the laboratory by hydro-distillation method. The dry leaves were used for extraction of essential oil and reported in percentage.

**9. Estimated essential oil yield (kg/ha)**

Essential oil yield was calculated by multiplying leaf yield into essential oil content in the leaves.

## 3.4 ECONOMIC ANALYSIS

Economic analysis was done by calculating the cost of cultivation, gross, net returns per hectare and B:C ratio. All the parameters were calculated on the basis of market price prevailing at the time of termination of experiment.

### 3.4.1 Cost of cultivation

The cost of cultivation was analyzed on per hectare basis. The requirement of labour and expenses of different operations such as ploughing, harrowing, weeding and harvesting were calculated on the basis of the prevalent labour charges. Cost of inputs like slips, manure was calculated based on the actual amounts applied to land use system.

### 3.4.2 Gross return

The prevailing local market prices were used to convert the yield of the crop.

### 3.4.3 Net return

Net returns were calculated by deducting total costs from the gross return.

### 3.4.4 B:C ratio

B:C ratio was calculated by dividing net return by cost of cultivation.

## STATISTICAL ANALYSIS

The data recorded was subjected to statistical analysis under Randomized Block Design. Analysis of variance was worked out and critical difference at 5 per cent level of significance was calculated with the help of latest computer software by using MS-Excel and OPSTAT.

# *Chapter-4*

# RESULTS AND DISCUSSION

The results obtained during the present investigations on "**Effect of different organic manures and fertilizers and harvesting schedules on growth and yield of *Cymbopogon flexuosus*"** are reported in this chapter under the following headings:

**4.1 Morphological studies of lemongrass**

**4.2 Effect of different organic manures and fertilizers and harvesting schedules on growth and yield of lemongrass**

## 4.1 MORPHOLOGICAL STUDIES OF LEMONGRASS

**Table 1: Morphological features of *Cymbopogon flexuosus* (Nees ex. Steud) Wats**

| Plant part | Characters |
|---|---|
| Habit | Perennial, tall, erect aromatic plant with a height 94.56 cm to 154.56 cm |
| Root | Adventitious, Fibrous and 15-30 cm long |
| Stem | Short, erect, smooth, cylindrical in shape and dark purple in color |
| Leaves | Blade like, slender, long, linear, tapering at both ends, alternate with parallel venation and glaucous green in colour |
| Inflorescence | Axis was upto 12 nodded, joints were smooth and glabrous, about 30-50 cm long, florets were arranged in alternate manner on the central axis, rachilla bears the florets; spatheole was elliptic, highly nerved and glaucous green in color; peduncle was smooth and glabrous but shortly hairy near the tip; spikelet consists of two bracts at the base called glumes |
| Flower | Floret was made up of two bracts called lemma and palea, lemma beared a long stiff hair known as awn, styles were two in number, plumose and purple stigma; anthers were three, bilobed, elliptic acuminate. |
| Fruit | Caryopsis type |
| Time of flowering | January to February |

The morphological features of *Cymbopogon flexuosus* in the present studies are in conformity with the earlier reports of Hussain *et al*. (1988); Farooqi and Sreeramu (2001); Joy *et al*. (2006). Habit, stem, leaf shape, root type, inflorescence, flower and fruit type

investigated in the present studies are in agreement with the findings of Srivastava *et al*. (2013); Marigowda *et al*. (2016).

### 4.1.1 Habit

*Cymbopogon flexuosus* is a tall, erect, perennial aromatic plant with a height of 9.4-1.5 m. The plant has dark purple colored short stem. which is hollow except at the nodes and cylindrical in shape also known as culms.

### 4.1.2 Type and dimensions of stem and root

#### 4.1.2.1 Stem

Lemongrass grows in dense clumps and has several stiff stems. The stem is short, erect, smooth, cylindrical in shape, globous at the nodes and according to RHS color chart, it was of purple colour (70 C). Stem have hollow internodes and solid nodes.

#### 4.1.2.2 Roots

The roots of the species are adventitious, fibrous and are pale yellow in colour (162 D) according to RHS colour chart. The roots are 15-30 cm long.

### 4.1.3 Leaf shape and arrangement

The leaves of lemongrass are slender, blade like, long, linear, tapering at both ends and olive green (137 A) in colour according to RHS colour chart. The pattern of the leaves is alternate with a parallel venation. Each leaf is differentiated into a lower sheath that hugs the stem and margins are smooth. The upper surface of the leaf is finely haired, while the lower surface is slightly hairy. The leaf sheaths are very loose, long and become leathery, curl fall away from the culms and are purplish in colour. At the joining point of leaf sheath and leaf blade, a membranous attachment of hairs is present, which is known as ligule. Ligules prevent water and insects from entering into the sheaths.

### 4.1.4 Inflorescence type

The inflorescence is large about 30-50 cm, loose with many long flexuosus branches. The axis of the inflorescence is up to 12 nodded, joints are smooth and glabrous. The spikes bear spikelets in pairs of which one is sessile and the other is pedicellate each spikelet have one or more florets. The part of spikelet that bears the floret is called rachilla. The florets are

**Plate 1: Field view of *Cymbopogon flexuosus***

**Plate 1.1: *Cymbopogon flexuosus***

**Plate 1.2: Roots**

**Plate 1.3: Stem**

**Plate 1.4: Leaves**

**Plate 1.5: Leaf blade**

**Plate 1.6: Leaf sheath and ligule Plate**

**1.7: Flowering Spike**

**Plate 1: Morphological features of different parts of *Cymbopogon flexuosus***


**Plate 2.1: Leaf colour**

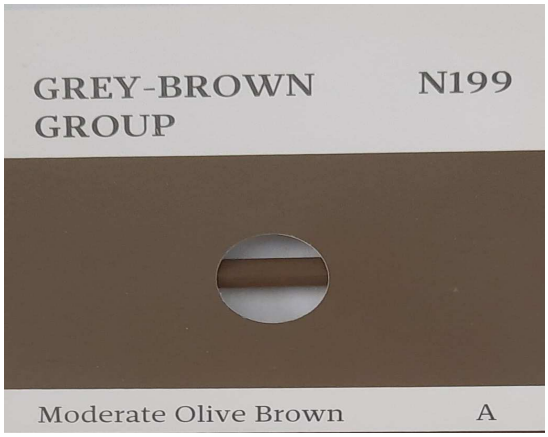



**Plate 2.2: Stem colour**


**Plate 2.3: Root colour**


**Plate 2.4: Lower Stem colour**

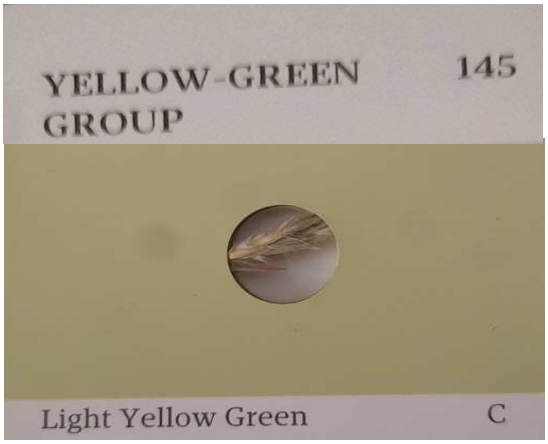



**Plate 2.5: Flower colour**

**Plate 2: Colour of different parts of *Cymbopogon flexuosus***

Plate 3.1: Inflorescence

Plate 3.2: Florets with spathe

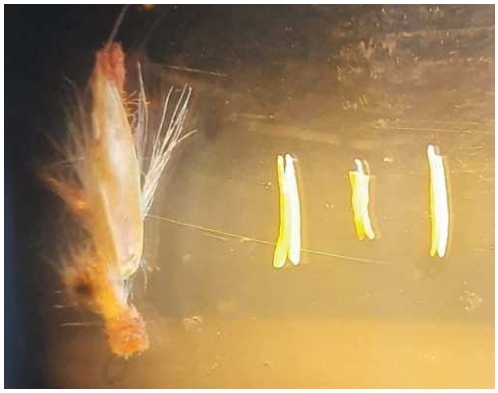


Plate 3.3: Three anthers in one floret

Plate 3.4: Anthers

Plate 3.5: Plumose type of stigma

Plate 3.6: Single floret

**Plate 3: Microscopic studies of different parts of inflorescence of *Cymbopogon flexuosus***

arranged in alternate or opposite manner on the central axis. The spatheole is narrowly elliptic acuminate, highly nerved, glaucous green and turns brownish red. The peduncle is smooth and glabrous but shortly hairy near the tip. The pedicle is similar but shorter. A spikelet consists of two bracts at the base called glumes. The glumes are placed one above the other on the opposite sides. The lower one is known as the first glume, while the higher one is known as the second glume. The lower glume is smooth and glabrous, with a shallow concave shape. The upper glume of the spikelet is boat shaped, rounded on the back, smooth and glabrous.

### 4.1.5 Floral character

According to RHS colour chart flowers were of light yellow green (145 C) in colour. A floret is made up of two bracts, one on the outside called the lemma and the other on the inside called the palea. The lemma bears a long, stiff hair known as awn. Each floret has two styles and stigma is plumose and purple. The stamens are three in numbers, bilobed anthers, elliptic acuminate in shape. The fruit of lemongrass is a caryopsis, in which the seed coat is fused to the fruit wall.

## 4.2 EFFECT OF DIFFERENT MANURES, FERTILIZERS AND HARVESTING SCHEDULES ON GROWTH AND YIELD PARAMETERS OF *Cymbopogon flexuosus*

The experiment was conducted during the year 2020 – 2021 to observe the effect of different organic manures and fertilizers on growth and yield parameters of lemongrass. The experiment comprised eight treatments *viz.,* : $T_1$ (Control), $T_2$ ( NPK (60:45:45 kg/ha)), $T_3$ (FYM (9.6 t/ha)), $T_4$ (Vermicompost (3.3 t/ha)), $T_5$ (Jeevamrit at 25, 40 and 55 days after planting), $T_6$ (FYM + NPK (9.6 t/ha + 60:45:45 kg/ha)), $T_7$ (Vermicompost + NPK (3.3 t/ha + 60:45:45 kg/ha)), $T_8$ (Jeevamrit + NPK (Soil application at 25, 40 and 55 DAP + 60:45:45 kg/ha)) and four harvestings *viz.*, first harvesting at 90 days after planting, second harvesting at 150 DAP, third harvesting at 210 DAP and fourth harvesting at 270 DAP. The data thus obtained is presented in Tables 2-10 and described as under:

### 4.2.1 Plant height

The data presented in Table 2 revealed that among different treatments maximum plant height was recorded in $T_8$ (123.50 cm) followed by $T_7$ (112.47 cm) which was

statistically at par with $T_6$ (109.70 cm). The minimum plant height was recorded in $T_1$ (78.06 cm).

Among harvesting schedules, the maximum plant height was obtained in $H_4$ (124.01 cm) which was statistically different from all other treatments. It was followed by $H_3$ (119.97 cm). The minimum plant height (80.94 cm) was recorded in $H_2$ which was statistically at par with $H_1$ (82.66 cm).

The interaction between the factors resulted in significant difference in plant height of lemongrass. The maximum plant height (154.56 cm) was observed in treatment combination $T_8H_4$ which was statistically at par with $T_8H_3$ (149.67 cm) whereas the minimum plant height (56.22 cm) was recorded in $T_1H_2$.

In the present study the maximum plant height was recorded in the treatment combination of Jeevamrit and NPK (60:45:45 kg/ha). It showed 58.21% increase in plant height over control. This may be due to increase in the availability of micro and macro plant nutrients throughout the growth period that helps to increase the plant height. Inorganic fertilizers contain the readily available form of nitrogen, phosphorus and potassium as a basic nutrient for the plant growth and development. An adequate supply of these basic nutrients is associated with high photosynthetic activity and vigorous growth as they are involved in plant growth processes. Jeevamrutha is the rich source of the beneficial microorganism such as nitrogen fixing and phosphate solubilizing bacteria. Addition of Jeevamrutha also helped to improve efficient microbial association thereby increasing NPK content and plant growth promoting factors.

The present findings are in consensus with the report of El-Mahrouk *et al.* (2018) where they administered that adequate supply of NPK increases the plant height in lemongrass. Mastan *et al.* (2020) also revealed that the application of 100% RDN through inorganic fertilizers gives the highest plant height in senna. Sutar *et al.* (2018) reported that application of jeevamrutha irrespective of other organic preparations recorded the highest plant height (65.60 cm) in cowpea. Jeevamrutha and NPK combination also resulted an increase in plant height due to higher availability of plant growth nutrients. Kumar *et al.* (2016) reported that soil application of jeevamrit (1000 l/ha) recorded the highest plant height in french bean.

**Table 2: Effect of different organic manures, fertilizers and harvesting schedules on plant height of *C. flexuosus***

| Plant height (cm) | | | | | |
|---|---|---|---|---|---|
| **Organic manures and fertilizers** | **Harvesting schedules** | | | | |
| | **H1** | **H2** | **H3** | **H4** | **Mean** |
| **$T_1$ – Control** | 69.11 | 56.22 | 92.33 | 94.56 | 78.06 |
| **$T_2$ – NPK (60:45:45 kg/ha)** | 83.22 | 88.22 | 120.78 | 128.11 | 105.08 |
| **$T_3$ – FYM (9.6 t/ha)** | 78.33 | 69.00 | 108.89 | 110.78 | 91.75 |
| **$T_4$ – Vermicompost (3.3 t/ha)** | 81.46 | 71.05 | 110.98 | 112.90 | 94.10 |
| **$T_5$ – Jeevamrit (25, 40, 55 DAP)** | 82.45 | 80.45 | 117.33 | 121.75 | 100.49 |
| **$T_6$ - FYM (9.6 t/ha) + NPK (60:45:45 kg/ha)** | 85.00 | 92.33 | 127.33 | 134.11 | 109.70 |
| **$T_7$ - Vermicompost (3.3 t/ha) + NPK (60:45:45 kg/ha)** | 88.45 | 93.67 | 132.44 | 135.33 | 112.47 |
| **$T_8$ - Jeevamrit (25, 40, 55 DAP) + NPK (60:45:45 kg/ha)** | 93.22 | 96.55 | 149.67 | 154.56 | 123.50 |
| **Mean** | 82.66 | 80.94 | 119.97 | 124.01 | |
| **$CD_{0.05}$** | Organic manures and fertilizers | | | 4.58 | |
| | Harvesting schedules | | | 3.24 | |
| | Organic manures and fertilizers ×Harvesting schedules | | | 9.16 | |

**$H_1$** : First harvesting at 90 DAP.
**$H_2$** : Second harvesting at 150 DAP.
**$H_3$** : Third harvesting at 210 DAP.
**$H_4$** : Fourth harvesting at 270 DAP.

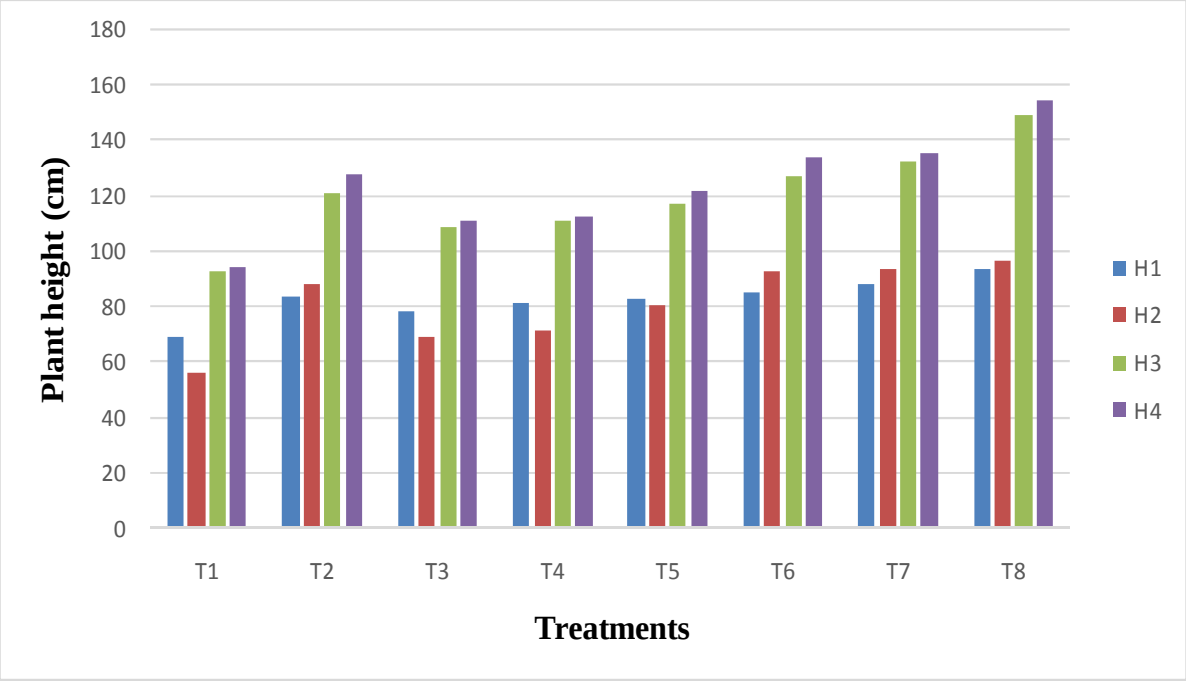



**Fig. 1: Effect of different organic manures, fertilizers and harvesting schedules on plant height of *C. flexuosus***

### 4.2.2 Number of leaves per plant

The data presented in the Table 3 revealed that different organic manures, fertilizers and harvesting schedules exhibited significant effect on number of leaves in lemongrass. With regard to organic manures and fertilizers, the maximum number of leaves per plant were recorded in $T_8$ (92.98) which was significantly different from all other treatments. It was followed by $T_7$ (87.54) which was statistically at par with $T_6$ (85.62). The minimum number of leaves were recorded in $T_1$ (65.44).

With regard to harvesting schedules maximum number of leaves per plant were recorded in $H_4$ (130.61) closely followed by $H_3$ (128.51), and minimum number of leaves were recorded in $H_1$ (30.86) followed by $H_2$ (35.60). $H_4$ was statistically superior to all other treatments.

Interaction between organic manures, fertilizers and different harvesting schedules exerted significant effect on number of leaves per plant. The maximum number of leaves per plant were recorded in treatment combination $T_8H_4$ (144.11) which was statistically at par with $T_8H_3$ (142.67). However, the minimum number of leaves per plant were recorded in $T_1H_1$ (21.84) which was statistically at par with $T_1H_2$ (21.95) and $T_3H_1$ (25.28).

**Table 3: Effect of different organic manures, fertilizers and harvesting schedules on number of leaves per plant**

| Number of leaves per plant | | | | | |
|---|---|---|---|---|---|
| **Organic manures and fertilizers** | **Harvesting schedules** | | | | |
| | **H1** | **H2** | **H3** | **H4** | **Mean** |
| **$T_1$ – Control** | 21.84 | 21.95 | 107.34 | 110.63 | 65.44 |
| **$T_2$ – NPK (60:45:45 kg/ha)** | 31.28 | 36.11 | 132.71 | 134.93 | 83.76 |
| **$T_3$ – FYM (9.6 t/ha)** | 25.28 | 30.00 | 120.08 | 121.22 | 74.15 |
| **$T_4$ – Vermicompost (3.3 t/ha)** | 27.56 | 32.56 | 129.18 | 131.04 | 80.08 |
| **$T_5$ – Jeevamrit (25, 40, 55 DAP)** | 30.78 | 34.50 | 129.59 | 131.48 | 81.59 |
| **$T_6$ - FYM (9.6 t/ha) + NPK (60:45:45 kg/ha)** | 34.28 | 39.89 | 133.00 | 135.30 | 85.62 |
| **$T_7$ - Vermicompost (3.3 t/ha) + NPK (60:45:45 kg/ha)** | 37.34 | 43.17 | 133.48 | 136.15 | 87.54 |
| **$T_8$ - Jeevamrit (25, 40, 55 DAP) + NPK (60:45:45 kg/ha)** | 38.50 | 46.62 | 142.67 | 144.11 | 92.98 |
| **Mean** | 30.86 | 35.60 | 128.51 | 130.61 | |
| **$CD_{0.05}$** | Organic manures and fertilizers | | | | 2.30 |
| | Harvesting schedules | | | | 1.62 |
| | Organic manures and fertilizers ×Harvesting schedules | | | | 4.59 |

In the present investigations, treatment combination of Jeevamrit and NPK (60:45:45 kg/ha) had resulted 42.08% increase in number of leaves per plant over control, which may be due to activity of basic plant nutrients which are in easily available form during the growth period. Application of jeevamrutha increased the nitrogen fixers population and jeevamrutha contains enormous amount of microbial load which multiplies in the soil and acts as tonic to enhance microbial activity in the soil. Verma *et al.* (2019) revealed that in turmeric significant increase in number of leaves was found with the increase in inorganic fertilizer doses. Similar results were reported by Tiwari *et al.* (2003) in turmeric. Jeevamrutha is also responsible to increase the biological efficiency of the crop and increasing the growth parameters. Vishwajith and Devakumar (2018) indicated that the increase in number of leaves per plant was due to the combined use of organic manures in okra.

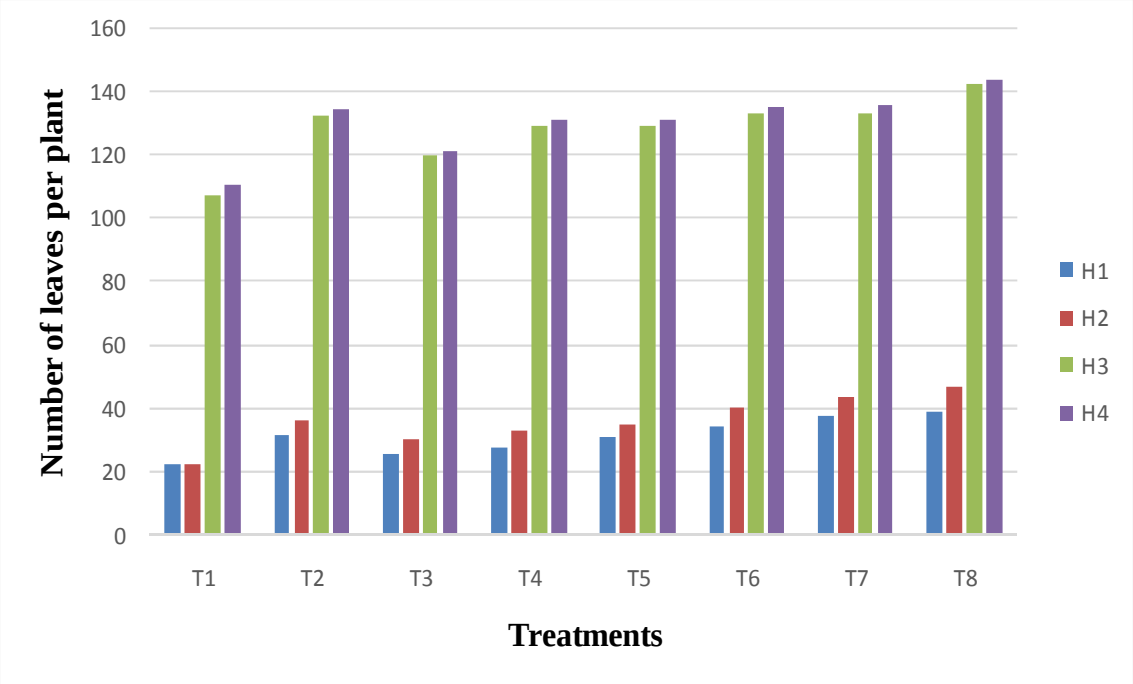



**Fig. 2: Effect of different organic manures, fertilizers and harvesting schedules on number of leaves per plant of *C. flexuosus***

### 4.2.3 Number of off-shoots per plant

Different organic manures, fertilizers and harvesting schedules exerted significant effect on number of off-shoots per plant in lemongrass. The data presented in Table 4 showed that with regard to organic manures and fertilizers maximum number of off-shoots were recorded in $T_8$ (25.72) which was statistically at par with $T_7$ (24.81), $T_6$ (23.88). Whereas, the minimum number of off-shoots were recorded in $T_1$ (15.53).

With regard to harvesting schedules the maximum number of off-shoots were obtained in $H_4$ (35.69) and it was statistically different from other treatments. It was followed by $H_3$ (33.60). However, the minimum number of off-shoots were recorded in $H_2$ (5.58).

The interaction between different organic manures, fertilizers and harvesting schedules exhibited significant effect on number of off-shoots per plant in lemongrass. The maximum number of off-shoots were recorded in treatment combination $T_8H_4$ (40.95) which was statistically at par with treatment combinations $T_7H_4$ (40.89), $T_6H_4$ (38.56), and $T_8H_3$ (37.84). The minimum number of off-shoots were recorded in treatment combination $T_1H_2$ (3.89) which was statistically at par with $T_3H_2$ (4.66), $T_4H_2$ (5.22), $T_5H_2$ (5.44), $T_2H_2$ (5.56), $T_6H_2$ (6.08), $T_7H_2$ (6.78), $T_8H_2$ (7.00) and $T_1H_1$ (7.67).

**Table 4: Effect of different organic manures, fertilizers and harvesting schedules on number of off-shoots per plant**

| Number of off-shoots per plant | | | | | |
|---|---|---|---|---|---|
| **Organic manures and fertilizers** | **Harvesting schedules** | | | | |
| | **H1** | **H2** | **H3** | **H4** | **Mean** |
| **$T_1$ – Control** | 07.67 | 03.89 | 26.23 | 24.34 | 15.53 |
| **$T_2$ – NPK (60:45:45 kg/ha)** | 12.35 | 05.56 | 36.34 | 36.78 | 22.76 |
| **$T_3$ – FYM (9.6 t/ha)** | 10.96 | 04.66 | 29.72 | 32.11 | 19.37 |
| **$T_4$ – Vermicompost (3.3 t/ha)** | 11.22 | 05.22 | 31.50 | 35.73 | 20.92 |
| **$T_5$ – Jeevamrit (25, 40, 55 DAP)** | 11.89 | 05.44 | 34.17 | 36.17 | 21.92 |
| **$T_6$ - FYM (9.6 t/ha) + NPK (60:45:45 kg/ha)** | 14.45 | 06.08 | 36.45 | 38.56 | 23.88 |
| **$T_7$ - Vermicompost (3.3 t/ha) + NPK (60:45:45 kg/ha)** | 15.00 | 06.78 | 36.56 | 40.89 | 24.81 |
| **$T_8$ - Jeevamrit (25, 40, 55 DAP) + NPK (60:45:45 kg/ha)** | 17.11 | 07.00 | 37.84 | 40.95 | 25.72 |
| **Mean** | 12.58 | 05.58 | 33.60 | 35.69 | |
| **$CD_{0.05}$** | Organic manures and fertilizers | | | | 1.99 |
| | Harvesting schedules | | | | 1.41 |
| | Organic manures and fertilizers × Harvesting schedules | | | | 3.98 |

In the present studies combined effect of jeevamrit and NPK resulted in highest number of off-shoots per plant. It showed 65.61% increase in number of off-shoots over control in lemongrass. This may be due to the higher availability of the nutrients which are required for growth of the plant. The higher number of off-shoots may also be due to adequate availability of nitrogen and plant height which resulted in a greater number of off-

shoots. Verma *et al.* (2010) also reported significant increase in growth parameters in *Salvia sclarea* using nitrogen and phosphorus fertilizers. Punam *et al.* (2012) revealed that combined application of organic manures showed the maximum number of off-shoots in lemongrass. Ramesh *et al.* (2018) observed that the application of jeevamrutha at 5% showed the maximum increase in plant growth parameters as compared to the other organic preparations in maize.

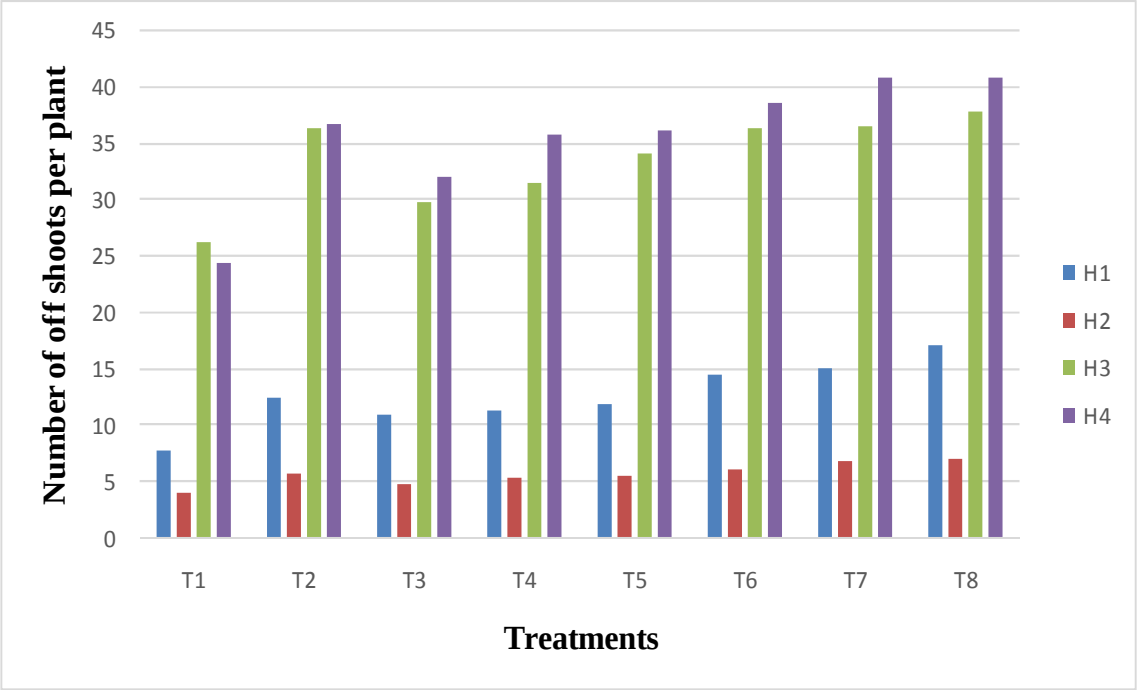



**Fig. 3: Effect of different organic manures, fertilizers and harvesting schedules on number of off-shoots per plant of *C. flexuosus***

### 4.2.4 Fresh herbage weight per plant

Different organic manures, fertilizers and harvesting schedules exhibited significant effect on fresh herbage weight per plant in lemongrass. A perusal of data presented in Table 5 revealed that significantly highest fresh herbage weight was recorded in $T_8$ (83.68 g). It was followed by $T_7$ (77.36 g) which was statistically at par with $T_6$ (76.00 g) and $T_2$ (75.10 g). However, the minimum value was recorded in $T_1$ (58.12 g) followed by $T_3$ (66.27 g).

With respect to harvesting schedules maximum fresh herbage weight was recorded in $H_4$ (119.76 g) which was followed by $H_3$ (117.75 g). Minimum fresh herbage weight was obtained in $H_2$ (23.02 g).

The interaction between organic manures, fertilizers and harvesting schedules exerted significant effect on fresh herbage weight per plant in lemongrass. The value of fresh herbage weight per plant ranged from 16.33 g to 134.59 g. The maximum fresh herbage weight per plant was obtained in treatment combination $T_8H_4$ (134.59 g) which was statistically at par with treatment combination $T_8H_3$ (132.18 g). Treatment combinations $T_7H_4$ (125.22 g), $T_6H_4$ (124.92 g), $T_2H_4$ (123.85 g), $T_7H_3$ (122.37g), $T_6H_3$ (121.41 g), $T_5H_4$ (121.30 g) and $T_2H_3$ (121.04 g) were statistically at par with each other. The minimum fresh herbage weight was obtained in treatment combination $T_1H_2$ (16.33 g) which was statistically at par with treatment combinations $T_1H_1$ (19.73 g) and $T_3H_2$ (20.50 g).

**Table 5: Effect of different organic manures, fertilizers and harvesting schedules on fresh herbage weight per plant**

| Fresh herbage weight per plant (g) | | | | | |
|---|---|---|---|---|---|
| **Organic manures and fertilizers** | **Harvesting schedules** | | | | |
| | **H1** | **H2** | **H3** | **H4** | **Mean** |
| **$T_1$ – Control** | 19.73 | 16.33 | 97.41 | 99.00 | 58.12 |
| **$T_2$ – NPK (60:45:45 kg/ha)** | 32.17 | 23.34 | 121.04 | 123.85 | 75.10 |
| **$T_3$ – FYM (9.6 t/ha)** | 26.00 | 20.50 | 108.37 | 110.19 | 66.27 |
| **$T_4$ – Vermicompost (3.3 t/ha)** | 29.17 | 22.23 | 119.37 | 119.04 | 72.45 |
| **$T_5$ – Jeevamrit (25, 40, 55 DAP)** | 30.89 | 22.67 | 119.85 | 121.30 | 73.68 |
| **$T_6$ - FYM (9.6 t/ha) + NPK (60:45:45 kg/ha)** | 33.39 | 24.28 | 121.41 | 124.92 | 76.00 |
| **$T_7$ - Vermicompost (3.3 t/ha) + NPK (60:45:45 kg/ha)** | 35.73 | 26.12 | 122.37 | 125.22 | 77.36 |
| **$T_8$ - Jeevamrit (25, 40, 55 DAP) + NPK (60:45:45 kg/ha)** | 39.23 | 28.72 | 132.18 | 134.59 | 83.68 |
| **Mean** | 30.79 | 23.02 | 117.75 | 119.76 | |
| **$CD_{0.05}$** | Organic manures and fertilizers | | | | 2.40 |
| | Harvesting schedules | | | | 1.69 |
| | Organic manures and fertilizers × Harvesting schedules | | | | 4.79 |

During the present investigations combined effect of jeevamrit and NPK (60:45:45 kg/ha) had resulted 43.97% increase in fresh herbage weight per plant over control, which may be due to the better nutrition through the application of jeevamrit and NPK. Rajan *et al.* (1984) also reported that higher levels of nitrogen had a tendency to increase plant height and number of tillers and these might have lead to the significant increase in the fresh herbage yield. Boraiah *et al.* (2017) also revealed that the highest fresh fruit yield was obtained with the application of jeevamrutha in capsicum, which was due to higher microbial load and

growth hormones which might have enhanced the soil biomass thereby sustaining the availability and uptake of applied as well as native soil nutrients which ultimately resulted in better growth and yield.

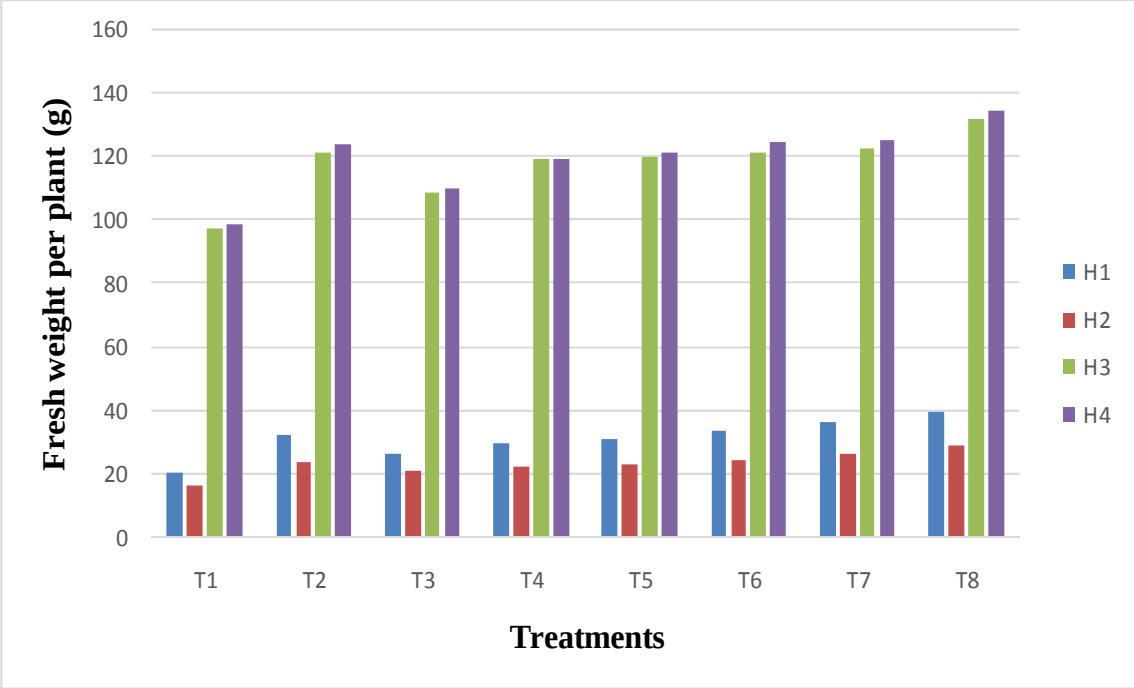



**Fig. 4: Effect of different organic manures, fertilizers and harvesting schedules on fresh weight per plant of *C. flexuosus***

### 4.2.5 Dry herbage weight per plant

The data presented in Table 6 revealed that different organic manures, fertilizers and harvesting schedules exhibited significant effect on dry herbage weight per plant in lemongrass. The maximum dry herbage weight per plant was recorded in $T_8$ (59.40 g) which was statistically at par with $T_7$ (57.82 g). Whereas, the minimum dry herbage weight per plant was obtained in $T_1$ (43.67 g).

With regard to harvesting schedules the maximum dry herbage weight was recorded in $H_4$ (94.87 g) which was statistically at par with $H_3$ (93.22 g) but different from other values. The minimum herbage weight (11.63 g) was registered in $H_2$.

The interaction between organic manures, fertilizers and harvesting schedules exerted significant effect on dry herbage weight per plant in lemongrass. The value of dry herbage weight per plant ranged from 8.41 g to 102.87 g. The maximum dry herbage weight per plant was recorded in treatment combination $T_8H_4$ (102.87 g) which was statistically at par with

treatment combinations $T_7H_4$ (100.56 g), $T_8H_3$ (100.21 g) and $T_7H_3$ (98.28 g). The minimum dry herbage was recorded in treatment combination $T_1H_2$ (8.41 g) which was statistically at par with treatment combinations $T_1H_1$ (9.80 g), $T_3H_2$ (10.18 g), $T_4H_2$ (10.70 g), $T_5H_2$ (11.42 g), $T_2H_2$ (12.01 g), $T_6H_2$ (12.60 g), $T_7H_2$ (13.41 g) and $T_3H_1$ (14.08 g).

In the present findings highest dry herbage weight per plant was recorded with the treatment combination of jeevamrit and NPK. It showed 36.02% increase in dry weight per plant over control. This may be due to more amount of beneficial microbes present in jeevamrit that have helped in decomposition of organic matter and thus releasing available nutrients for easy uptake and utilization by the plant. Silva *et al.* (2003) also reported that application of organic and inorganic fertilizers produced highest dry herbage weight in lemongrass. Similar results were given by Sumathi *et al.* (2012) in patchouli. Hameedi *et al.* (2018) also reported the highest yield with the application of jeevamrutha in combination with other organic manures in bell pepper.

**Table 6: Effect of different organic manures, fertilizers and harvesting schedules on dry herbage weight per plant**

| **Dry herbage weight per plant (g)** | | | | | |
|---|---|---|---|---|---|
| **Organic manures and fertilizers** | **Harvesting schedules** | | | | |
| | **H1** | **H2** | **H3** | **H4** | **Mean** |
| **$T_1$ – Control** | 9.80 | 8.41 | 77.63 | 78.85 | 43.67 |
| **$T_2$ – NPK (60:45:45 kg/ha)** | 16.89 | 12.01 | 95.00 | 95.83 | 54.59 |
| **$T_3$ – FYM (9.6 t/ha)** | 14.08 | 10.18 | 92.52 | 93.57 | 52.57 |
| **$T_4$ – Vermicompost (3.3 t/ha)** | 15.50 | 10.70 | 92.55 | 95.32 | 53.52 |
| **$T_5$ – Jeevamrit (25, 40, 55 DAP)** | 15.63 | 11.42 | 93.50 | 95.51 | 54.02 |
| **$T_6$ - FYM (9.6 t/ha) + NPK (60:45:45 kg/ha)** | 18.83 | 12.60 | 96.05 | 96.44 | 55.98 |
| **$T_7$ - Vermicompost (3.3 t/ha) + NPK (60:45:45 kg/ha)** | 19.03 | 13.41 | 98.28 | 100.56 | 57.82 |
| **$T_8$ - Jeevamrit (25, 40, 55 DAP) + NPK (60:45:45 kg/ha)** | 20.21 | 14.32 | 100.21 | 102.87 | 59.40 |
| **Mean** | 16.25 | 11.63 | 93.22 | 94.87 | |
| **$CD_{0.05}$** | Organic manures and fertilizers | | | | 2.85 |
| | Harvesting schedules | | | | 2.02 |
| | Organic manures and fertilizers × Harvesting schedules | | | | 5.70 |

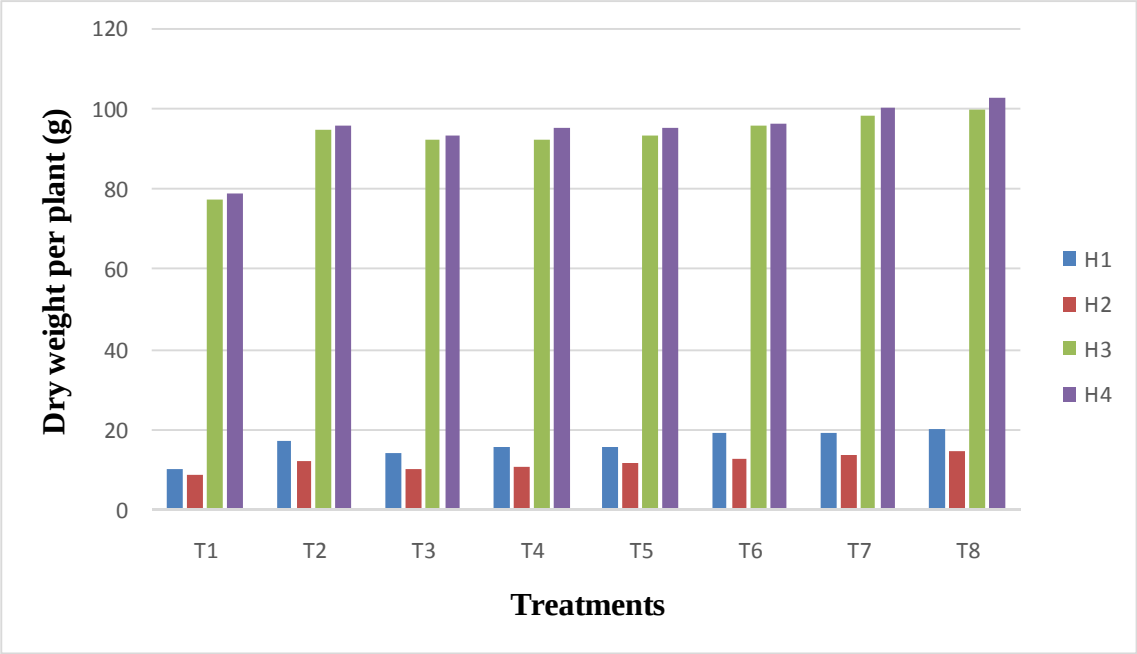



**Fig. 5: Effect of different organic manures, fertilizers and harvesting schedules on dry weight per plant of *C. flexuosus***

### 4.2.6 Estimated fresh herbage yield

The perusal of data presented in the Table 7 revealed that different organic manures, fertilizers and harvesting schedules exerted significant effect on estimated fresh herbage yield in lemongrass. The value of estimated fresh herbage yield ranged from 21.52 q to 30.99 q. The maximum estimated fresh herbage yield was obtained in $T_8$ (30.99 q) which was significantly higher than all other values. It was followed by $T_7$ (28.65 q) and treatment $T_7$ was statistically at par with $T_6$ (28.15 q) and $T_2$ (27.81 q). The minimum fresh herbage yield was obtained in $T_1$ (21.52 q).

With regard to harvesting schedules the highest estimated fresh herbage yield was registered in $H_4$ (44.36 q) and it was at par with $H_3$ (43.61 q), while minimum value was recorded in $H_2$ (8.53 q).

The interaction between organic manures, fertilizers and harvesting schedules exerted significant effect on estimated fresh herbage yield in lemongrass. The value of estimated fresh herbage yield ranged from 6.05 q to 49.85 q. The maximum estimated fresh herbage yield was recorded in treatment combination $T_8H_4$ (49.85 q) which was statistically at par with $T_8H_3$ (48.96 q) but significantly different from other values. It was followed by $T_7H_4$ (46.38 q) which was statistically at par with treatment combinations $T_6H_4$ (46.27 q), $T_2H_4$

(45.87 q), $T_7H_3$ (45.32 q), $T_6H_3$ (44.97 q) and $T_5H_4$ (44.92 q) and $T_2H_3$ (44.83 q). The minimum fresh herbage yield was recorded in $T_1H_2$ (6.05 q) which was statistically at par with $T_1H_1$ (7.30 q) and $T_3H_2$ (7.59 q).

In the present studies maximum estimated fresh herbage yield per hectare was obtained in the treatment combination of Jeevamrit and NPK (60:45:45 kg/ha). In this experiment treatment combination of Jeevamrit and NPK (60:45:45 kg/ha) showed 44.00% increase in estimated fresh herbage yield over control. This might be due to the availability of nitrogen from the inorganic fertilizers required for the better growth of the plant and jeevamrutha increases the nitrogen fixing bacteria in the soil which helps in the growth of the plant. Singh *et al.* (2002) observed that the proper supply of nitrogenous fertilizers increases the herbage yield in lemongrass. Significant results were reported by Chaudhary *et al.* (2017) in ashwagandha that when organic manures were applied in combination with jeevamrutha gives the highest fresh root yield.

**Table 7: Effect of different organic manures, fertilizers and harvesting schedules on fresh herbage yield**

| **Estimated fresh herbage yield (q/ha)** | | | | | |
|---|---|---|---|---|---|
| **Organic manures and fertilizers** | **Harvesting schedules** | | | | |
| | **H1** | **H2** | **H3** | **H4** | **Mean** |
| **$T_1$ – Control** | 7.30 | 6.05 | 36.08 | 36.67 | 21.52 |
| **$T_2$ – NPK (60:45:45 kg/ha)** | 11.91 | 8.64 | 44.83 | 45.87 | 27.81 |
| **$T_3$ – FYM (9.6 t/ha)** | 9.63 | 7.59 | 40.14 | 40.81 | 24.54 |
| **$T_4$ – Vermicompost (3.3 t/ha)** | 10.80 | 8.23 | 44.21 | 44.09 | 26.83 |
| **$T_5$ – Jeevamrit (25, 40, 55 DAP)** | 11.44 | 8.39 | 44.39 | 44.92 | 27.29 |
| **$T_6$ - FYM (9.6 t/ha) + NPK (60:45:45 kg/ha)** | 12.37 | 8.99 | 44.97 | 46.27 | 28.15 |
| **$T_7$ - Vermicompost (3.3 t/ha) + NPK (60:45:45 kg/ha)** | 13.23 | 9.67 | 45.32 | 46.38 | 28.65 |
| **$T_8$ - Jeevamrit (25, 40, 55 DAP) + NPK (60:45:45 kg/ha)** | 14.53 | 10.64 | 48.96 | 49.85 | 30.99 |
| **Mean** | 11.40 | 8.53 | 43.61 | 44.36 | |
| **$CD_{0.05}$** | Organic manures and fertilizers | | | | 0.89 |
| | Harvesting schedules | | | | 0.63 |
| | Organic manures and fertilizers × Harvesting schedules | | | | 1.78 |

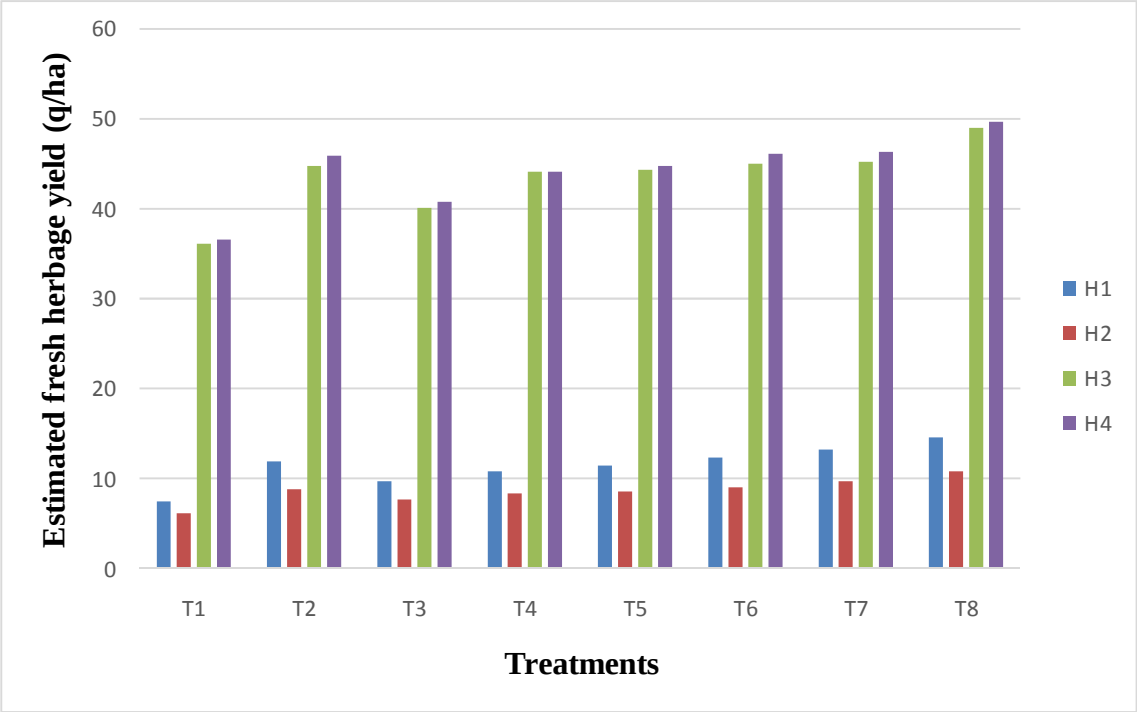



**Fig. 6: Effect of different organic manures, fertilizers and harvesting schedules on estimated fresh herbage yield of *C. flexuosus***

### 4.2.7 Estimated dry herbage yield

The data presented in Table 8 revealed that different organic manures, fertilizers and harvesting schedules exerted significant effect on estimated dry herbage yield in lemongrass. The value of estimated dry herbage yield ranged from 16.17 q to 22.00 q. The maximum estimated dry herbage yield was recorded in $T_8$ (22.00 q) which was statistically at par with $T_7$ (21.42 q) but significantly different from other treatments. The minimum dry herbage yield was recorded in $T_1$ (16.17 q) followed by $T_3$ (19.48 q) which was statistically at par with $T_4$ (19.82 q), $T_5$ (20.01 q) and $T_2$ (20.34 q).

With regard to harvesting schedules the maximum dry herbage yield was recorded in $H_4$ (35.14 q) which was statistically at par with $H_3$ (34.53 q). The minimum estimated dry herbage yield was recorded in $H_2$ (4.31 q).

The interaction between organic manures, fertilizers and harvesting schedules exerted significant effect on estimated dry herbage yield in lemongrass. The value of estimated dry herbage yield ranged from 3.11 q to 38.10 q. The maximum dry herbage yield was recorded in treatment combination $T_8H_4$ (38.10 q) which was statistically at par with treatment

combinations $T_7H_4$ (37.24 q), $T_8H_3$ (37.12 q) and $T_7H_3$ (36.40 q). Whereas, the minimum dry herbage yield was recorded in treatment combination $T_1H_2$ (3.11 q) which was at par with treatment combination $T_1H_1$ (3.63 q), $T_3H_2$ (3.77 q), $T_4H_2$ (3.96 q), $T_5H_2$ (4.23 q), $T_2H_2$ (4.45 q), $T_6H_2$ (4.67 q), $T_7H_2$ (4.97 q) and $T_3H_1$ (5.21 q).

During the present studies combined application of jeevamrit and NPK showed 36.05% increase in dry herbage yield per hectare over control, which was due to the availability of macro and micro nutrients during the whole growth period of the plant. The presented results are in accordance with the findings of Singh *et al.* (2005) who reported higher fresh and dry yield with the application of inorganic fertilizers in lemongrass. Unal and Cavusoglu (2005) also reported higher fresh and dry weight with the application of inorganic fertilizers in saffron. Chaudhary *et al.* (2017) also reported the highest dry root yield with the application of jeevamrutha in combination with other organic manures.

**Table 8: Effect of different organic manures, fertilizers and harvesting schedules on dry herbage yield**

| **Estimated dry herbage yield (q/ha)** | | | | | |
|---|---|---|---|---|---|
| **Organic manures and fertilizers** | **Harvesting schedules** | | | | |
| | **H1** | **H2** | **H3** | **H4** | **Mean** |
| **$T_1$ – Control** | 3.63 | 3.11 | 28.75 | 29.20 | 16.17 |
| **$T_2$ – NPK (60:45:45 kg/ha)** | 6.25 | 4.45 | 35.18 | 35.49 | 20.34 |
| **$T_3$ – FYM (9.6 t/ha)** | 5.21 | 3.77 | 34.26 | 34.66 | 19.48 |
| **$T_4$ – Vermicompost (3.3 t/ha)** | 5.74 | 3.96 | 34.28 | 35.31 | 19.82 |
| **$T_5$ – Jeevamrit (25, 40, 55 DAP)** | 5.79 | 4.23 | 34.63 | 35.37 | 20.01 |
| **$T_6$ - FYM (9.6 t/ha) + NPK (60:45:45 kg/ha)** | 6.97 | 4.67 | 35.58 | 35.72 | 20.73 |
| **$T_7$ - Vermicompost (3.3 t/ha) + NPK (60:45:45 kg/ha)** | 7.05 | 4.97 | 36.40 | 37.24 | 21.42 |
| **$T_8$ - Jeevamrit (25, 40, 55 DAP) + NPK (60:45:45 kg/ha)** | 7.48 | 5.30 | 37.12 | 38.10 | 22.00 |
| **Mean** | 6.02 | 4.31 | 34.53 | 35.14 | |
| **$CD_{0.05}$** | Organic manures and fertilizers | | | | 1.06 |
| | Harvesting schedules | | | | 0.75 |
| | Organic manures and fertilizers × Harvesting schedules | | | | 2.11 |

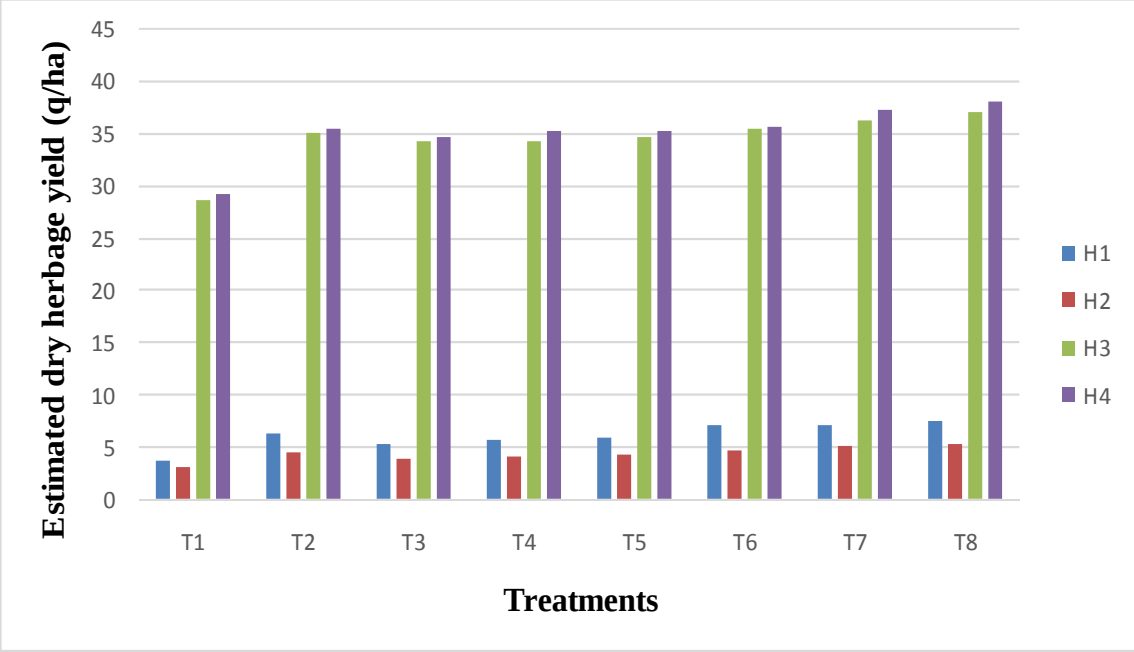



**Fig. 7: Effect of different organic manures, fertilizers and harvesting schedules on estimated dry herbage yield of *C. flexuosus***

### 4.2.8 Essential oil content

The effect of different organic manures and fertilizers on essential oil content showed the significant results. The perusal of data presented in Table 9 revealed that the maximum essential oil content was obtained in $T_8$ (2.31 %) which was significantly higher that all other treatments. It was followed by $T_7$ (2.21 %) and $T_6$ (2.11 %). The minimum essential oil content was recorded in $T_1$ (1.60 %).

With respect to harvesting schedules, the significantly higher essential oil content was recorded in $H_4$ (2.24 %) followed by $H_3$ (2.17 %). The minimum essential oil content was recorded in $H_1$ (1.51 %).

The interaction between different organic manure, fertilizers and harvesting schedules showed the significant effect on essential oil content in lemongrass. The value of essential oil content ranged from 1.07 % to 2.53 %. The maximum essential oil content was recorded in treatment combination $T_8H_4$ (2.53 %) which was statistically at par with treatment combinations $T_8H_3$ (2.48 %) and $T_7H_4$ (2.46 %). The minimum essential oil content was recorded in treatment combination $T_1H_1$ (1.07 %) which was statistically at par with treatment combination $T_3H_1$ (1.11 %).

In the present studies jeevamrit and NPK in combination showed 44.37% increase in essential oil content over control in lemongrass. The reason of higher essential oil content was the presence of soil microbes in jeevamrit which increases the nutrients in soil for better growth of the plant. Nitrogenous fertilizers also help to increase in essential oil content. The present findings are in congruence with the reports of Ghose and Chatterjee (1976) who observed that the essential oil content of *Cymbopogon spp.* have been enhanced by adequate supply of NPK fertilizers. Similar results have been observed by Pal *et al.* (1992) in *Cymbopogon*. Punam *et al.* (2012) also reported that oil content enhanced with the combined application of organic manures in lemongrass.

**Table 9: Effect of different organic manures, fertilizers and harvesting schedules on essential oil content**

| Oil percentage | | | | | |
|---|---|---|---|---|---|
| **Organic manures and fertilizers** | **Harvesting schedules** | | | | |
| | **H1** | **H2** | **H3** | **H4** | **Mean** |
| **$T_1$ – Control** | 1.07 (1.44)* | 1.40 (1.55)* | 1.92 (1.71)* | 2.02 (1.74)* | 1.60 (1.61)* |
| **$T_2$ – NPK (60:45:45 kg/ha)** | 1.46 (1.57)* | 1.94 (1.72)* | 2.16 (1.78)* | 2.15 (1.78)* | 1.93 (1.71)* |
| **$T_3$ – FYM (9.6 t/ha)** | 1.11 (1.45)* | 1.72 (1.65)* | 1.89 (1.70)* | 2.03 (1.74)* | 1.71 (1.64)* |
| **$T_4$ – Vermicompost (3.3 t/ha)** | 1.17 (1.47)* | 1.84 (1.69)* | 2.02 (1.74)* | 2.11 (1.76)* | 1.77 (1.66)* |
| **$T_5$ – Jeevamrit (25, 40, 55 DAP)** | 1.62 (1.62)* | 2.03 (1.74)* | 2.22 (1.79)* | 2.26 (1.81)* | 2.03 (1.74)* |
| **$T_6$ - FYM (9.6 t/ha) + NPK (60:45:45 kg/ha)** | 1.76 (1.66)* | 2.05 (1.75)* | 2.30 (1.82)* | 2.33 (1.82)* | 2.11 (1.76)* |
| **$T_7$ - Vermicompost (3.3 t/ha) + NPK (60:45:45 kg/ha)** | 1.91 (1.71)* | 2.09 (1.76)* | 2.38 (1.84)* | 2.46 (1.86)* | 2.21 (1.79)* |
| **$T_8$ - Jeevamrit (25, 40, 55 DAP) + NPK (60:45:45 kg/ha)** | 1.95 (1.72)* | 2.28 (1.81)* | 2.48 (1.87)* | 2.53 (1.88)* | 2.31 (1.82)* |
| **Mean** | 1.51 (1.58)* | 1.92 (1.71)* | 2.17 (1.78)* | 2.24 (1.80)* | |
| **$CD_{0.05}$** | Organic manures and fertilizers | | | | 0.03 |
| | Harvesting schedules | | | | 0.02 |
| | Organic manures and fertilizers × Harvesting schedules | | | | 0.07 |

***** indicates the square root transformation value of essential oil content

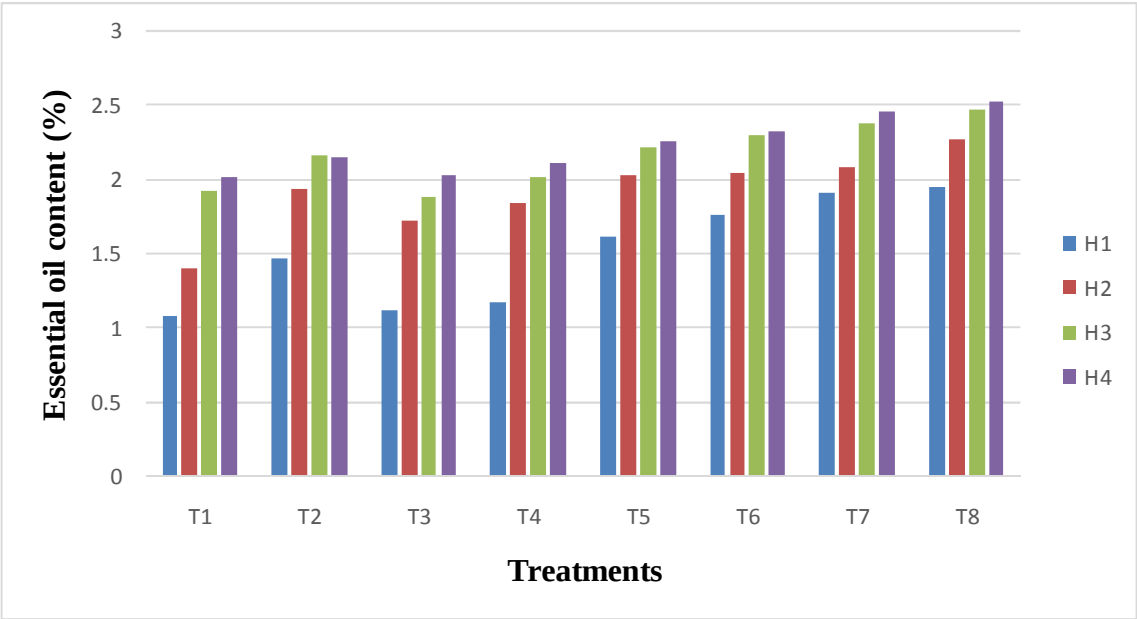



**Fig. 8: Effect of different organic manures, fertilizers and harvesting schedules on essential oil content of *C. flexuosus***

### 4.2.9 Estimated essential oil yield

A perusal of data presented in Table 10 depicted that different organic manures, fertilizers and harvesting schedules exerted significant effect on essential oil yield in lemongrass. The value of estimated essential oil yield ranged from 30.55 kg to 53.78 kg. The maximum essential oil yield was recorded in $T_8$ (53.78 kg) which was statistically at par with $T_7$ (50.53 kg) but significantly higher than all other values. Treatments $T_2$(42.54 kg), $T_5$(43.77 kg) and $T_6$(46.71 kg) were statistically at par with each other. The minimum essential oil yield was recorded in $T_1$ (30.55 kg).

With respect to harvesting schedules maximum essential oil yield was recorded in $H_4$ (79.03 kg) and it was significantly different from all other treatments. This was closely followed by $H_3$ (75.38 kg). The minimum essential oil yield was recorded in $H_2$ (8.43 kg) which was statistically at par with $H_1$ (9.39 kg).

The interaction between organic manures, fertilizers and harvesting schedules exerted significant effect on estimated essential oil yield in lemongrass. The value of estimated essential oil yield ranged from 3.84 kg to 96.52 kg. The maximum essential oil yield was registered in treatment combination $T_8H_4$ (96.52 kg) which was statistically at par with $T_8H_3$ (91.86 kg) and $T_7H_4$ (91.78 kg). The minimum essential oil yield was recorded in treatment combination $T_1H_1$ (3.84 kg) which was statistically at par with treatment combinations $T_1H_2$

(4.37 kg), $T_3H_1$ (5.76 kg), $T_3H_2$ (6.49 kg), $T_4H_1$ (6.75 kg), $T_4H_2$ (7.32 kg), $T_5H_2$ (8.59 kg), $T_2H_2$ (8.65 kg), $T_2H_1$ (9.19 kg), $T_5H_1$ (9.39 kg), $T_6H_2$ (9.58 kg), $T_7H_2$ (10.36 kg), $T_8H_2$ (12.11 kg) and $T_6H_1$ (12.16 kg).

In the present investigations maximum estimated essential oil yield was obtained with the combined treatment of jeevamrit and NPK (60:45:45 kg/ha). It showed 76.03% increase in essential oil yield per hectare over control in lemongrass. This might be due to higher plant growth and essential oil content as a result of availability of plant nutrient with growth regulators leads to higher essential oil yield. The increase in yield was obtained due to the application of jeevamrit and NPK which results in higher vegetative growth and essential oil yield. Sigaye *et al.* (2019) also revealed that application of nitrogen and phosphorus fertilizers have increased the essential oil yield in lemongrass. Ram *et al.* (2018) also reported that liquid organic manures like jeevamrit increase the yield and quality attributes in the crops because they could have beneficial microbes which could improves soil fertility, crop productivity and produce quality. Manjunatha *et al.* (2009) also revealed that application of jeevamrit in combination with other organic manures gives the highest yield as compared to other treatments.

**Table 10: Effect of different organic manures, fertilizers and harvesting schedules on essential oil yield**

| **Estimated essential oil yield (kg/ha)** | | | | | |
|---|---|---|---|---|---|
| **Organic manures and fertilizers** | **Harvesting schedules** | | | | |
| | **H1** | **H2** | **H3** | **H4** | **Mean** |
| **$T_1$ – Control** | 3.84 | 4.37 | 55.13 | 58.86 | 30.55 |
| **$T_2$ – NPK (60:45:45 kg/ha)** | 9.19 | 8.65 | 76.02 | 76.31 | 42.54 |
| **$T_3$ – FYM (9.6 t/ha)** | 5.76 | 6.49 | 65.04 | 70.51 | 36.95 |
| **$T_4$ – Vermicompost (3.3 t/ha)** | 6.75 | 7.32 | 69.41 | 75.06 | 39.63 |
| **$T_5$ – Jeevamrit (25, 40, 55 DAP)** | 9.39 | 8.59 | 76.97 | 80.13 | 43.77 |
| **$T_6$ - FYM (9.6 t/ha) + NPK (60:45:45 kg/ha)** | 12.16 | 9.58 | 82.00 | 83.09 | 46.71 |
| **$T_7$ - Vermicompost (3.3 t/ha) + NPK (60:45:45 kg/ha)** | 13.41 | 10.36 | 86.56 | 91.78 | 50.53 |
| **$T_8$ - Jeevamrit (25, 40, 55 DAP) + NPK (60:45:45 kg/ha)** | 14.64 | 12.11 | 91.86 | 96.52 | 53.78 |
| **Mean** | 9.39 | 8.43 | 75.38 | 79.03 | |
| **$CD_{0.05}$** | Organic manures and fertilizers | | | | 4.44 |
| | Harvesting schedules | | | | 3.14 |
| | Organic manures and fertilizers × Harvesting schedules | | | | 8.88 |

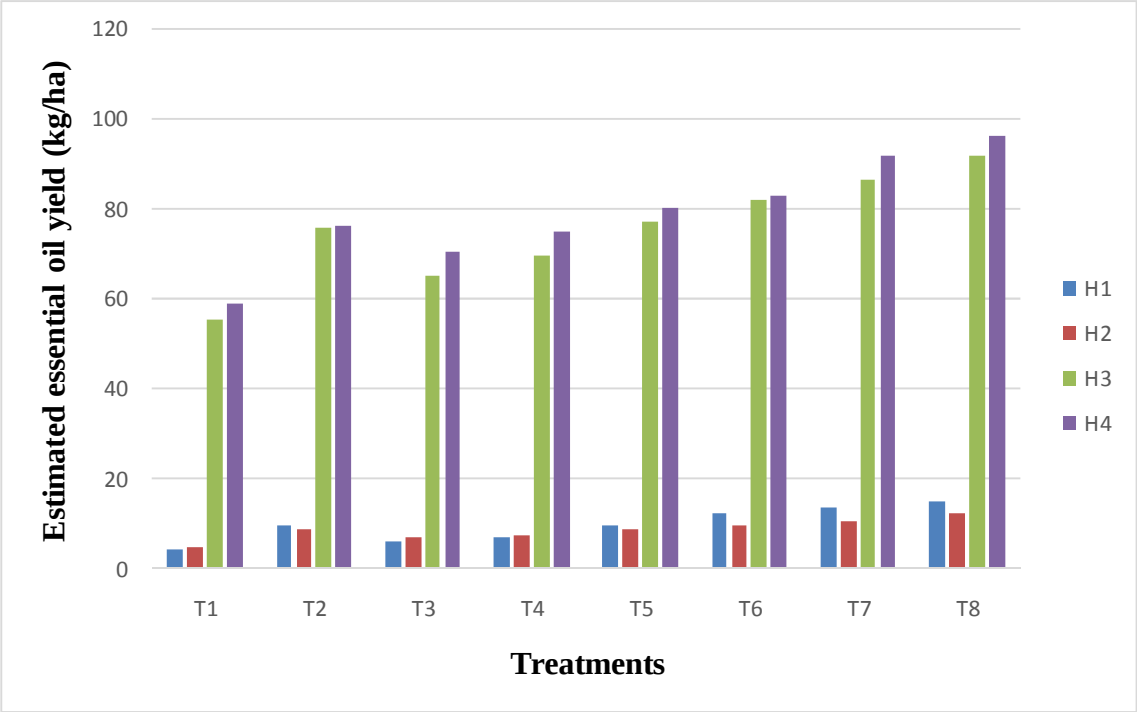



**Fig. 9: Effect of different organic manures, fertilizers and harvesting schedules on estimated essential oil yield of *C. flexuosus***

### 4.2.10 Economic analysis of *Cymbopogon flexuosus*

The cost of cultivation was carried out on **"Effect of different organic manures and fertilizers on growth and yield of *Cymbopogon flexuosus*"**. The cost of cultivation included all inputs like seed costs, labour charges involved in bed preparation, intercultural operations until the last harvesting of the crop which were considered in terms of total money in Rupees. Similarly, while calculating the return, total fresh herbage yield was multiplied with prevailing market rate of fresh herbage of *Cymbopogon flexuosus*. Cost of cultivation and net return are two most important indicators to evaluate the economic feasibility of an activity. The cost of cultivation and essential oil production of lemongrass is presented in table 11.

#### 4.2.10.1Cost of cultivation

The perusal of data recorded in Table 11 revealed that the maximum cost of cultivation was recorded in $T_7$ (Rs. 2,24,498.30). It was followed by $T_4$ (Rs. 2,17,698), $T_6$ (Rs. 2,13,868.30) and $T_3$ (Rs. 2,07,068). The minimum cost of cultivation was recorded in $T_1$ (Rs. 1,74,878) followed by $T_5$ (Rs. 1,79,827.25), $T_2$ (1,82,439.93) and $T_8$ (Rs. 1,87,389.18).

#### 4.2.10.2 Gross income

The data presented in the Table 11 revealed that the highest gross income was recorded in $T_8$ (Rs. 4,95,920) which was followed by $T_7$ (Rs. 4,58,400), $T_6$ (Rs. 4,50,400) and $T_2$ (Rs. 4,45,000). The minimum gross income was recorded in $T_1$ (Rs. 3,44,400).

#### 4.2.10.3 Net Return

It can be inferred from the Table 11 that highest net return was recorded in $T_8$ (Rs. 3,08,530.82) followed by $T_2$ (Rs. 2,62,560.07), $T_5$ (Rs. 2,56,732.75) and $T_6$ (Rs. 2,36,531.70) and the lowest net return was recorded in $T_1$ (Rs. 1,69,522).

#### 4.2.10.4 B:C ratio

The perusal of data presented in Table 11 revealed that the highest B:C ratio was recorded in $T_8$ (1.64) which was followed by $T_2$ (1.43) and the minimum B:C ratio was recorded in $T_3$ (0.89).

The economic analysis of cost of cultivation of *Cymbopogon flexuosus* showed that the highest B:C ratio was obtained in treatment combination of jeevamrit + NPK due to less cost of cultivation and higher yield as compared to all other treatments. Cost of jeevamrit + NPK was estimated Rs. 12,511 that produces 123.98 q/ha of fresh herbage. The market has high monetary value for lemongrass herbage due to its extensive uses for commercial purposes. Due to the easy availability of material for jeevamrit and its low cost and further high oil yield of lemongrass led to increased B:C ratio.

**Table 11: Economics of cost of cultivation, gross income, net income and B:C ratio of *Cymbopogon flexuosus***

| Sr. No. | Treatments | Cost of cultivation (Rs/ha) | Fresh herbage yield (q/ha) | Average price (Rs/q) | Gross income (Rs/ha) | Net return (Rs/ha) | B:C ratio |
|---|---|---|---|---|---|---|---|
| 1. | $T_1$ | 1,74,878 | 86.10 | 4000 | 3,44,400 | 1,69,522 | 0.96 |
| 2. | $T_2$ | 1,82,439.93 | 111.25 | 4000 | 4,45,000 | 2,62,560.07 | 1.43 |
| 3. | $T_3$ | 2,07,068 | 98.17 | 4000 | 3,92,680 | 1,85,612 | 0.89 |
| 4. | $T_4$ | 2,17,698 | 107.33 | 4000 | 4,29,320 | 2,11,622 | 0.97 |
| 5. | $T_5$ | 1,79,827.25 | 109.14 | 4000 | 4,36,560 | 2,56,732.75 | 1.42 |
| 6. | $T_6$ | 2,13,868.30 | 112.6 | 4000 | 4,50,400 | 2,36,531.70 | 1.10 |
| 7. | $T_7$ | 2,24,498.30 | 114.6 | 4000 | 4,58,400 | 2,33,901.70 | 1.04 |
| 8. | $T_8$ | 1,87,389.18 | 123.98 | 4000 | 4,95,920 | 3,08,530.82 | 1.64 |

The present studies revealed that organic manures like FYM and vermicompost had lower B:C ratio as compared to combination with inorganic fertilizers due to the higher cost and low yield. The cost of cultivation with the use of FYM (9.6 t/ha) was estimated as Rs. 2,07,068 which produced 98.17 q/ha of fresh herbage. Whereas, with vermicompost (3.3 t/ha) cost was estimated as Rs. 2,17,698 and it produced 107.33 q/ha fresh herbage. Vermicompost had higher B:C than FYM because of higher yield. Jeevamrit alone had higher B:C ratio than vermicompost and FYM in combination with inorganic fertilizers due to lower cost of cultivation. Vermicompost and FYM in combination with inorganic fertilizers produced higher yield than jeevamrit but cost of cultivation is higher. Mansour *et al*. (2017) reported highest B: C ratio with the application of organic manures + NPK in french basil. Similar results were reported by Amala *et al*. (2019) in turmeric, Bhutia (2019) in sweet flag and Kumar (2020) in *Lepidium sativum.*

# *Chapter-5*

# SUMMARY AND CONCLUSIONS

The present investigations entitled **"Effect of different organic manures, fertilizers and harvesting schedules on growth and yield of *Cymbopogon flexuosus"*** were carried out in the experimental farm field of department of Forest Products, College of Forestry, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during 2020-2021. The brief summary and conclusions are summarized below.

## 5.1 MORPHOLOGICAL STUDIES OF *Cymbopogon flexuosus*

*Cymbopogon flexuosus* was found to be a tall, perennial aromatic plant which grows upto a height of 1.5 m. The stem was short, erect, smooth, cylindrical in shape, hollow at internodes, solid at nodes and dark purple in color. The roots were adventitious, fibrous and light brown in color with their length 15-30 cm. Leaves were slender, blade like, long, linear, tapering at both ends and glaucous green in color. Leaf sheaths were long and leathery and at the joining point of leaf sheath and blade a membranous attachment of hairs was present which is known as ligule. The inflorescence was large with a length of 30-50 cm and the axis of the inflorescence up to 12 nodes was recorded. The florets were arranged alternatively on the central axis. The spatheole was narrow, elliptic, highly nerved, glaucous green and turned brownish red. A spikelet consisting of two bracts called glumes were found which were smooth, concave and glabrous. A floret had lemma on the outer side with hair known as awn and palea on the inner side. Two styles with plumose and purple colored stigma and three bilobed stamens were present in a floret. The fruit was a caryopsis.

## 5.2 EFFECT OF DIFFERENT ORGANIC MANURES, FERTILIZERS AND HARVESTING SCHEDULES ON GROWTH AND YIELD OF *Cymbopogon flexuosus*

The experiment comprised of eight treatments *viz.*, : $T_1$ (Control), $T_2$ ( NPK (60:45:45 kg/ha)), $T_3$ (FYM (9.6 t/ha)), $T_4$ (Vermicompost (3.3 t/ha)), $T_5$ (Jeevamrit at (25, 40 and 55 days after planting)), $T_6$ (FYM + NPK (9.6 t/ha + 60:45:45 kg/ha)), $T_7$ (Vermicompost + NPK (3.3 t/ha + 60:45:45 kg/ha)), $T_8$ (Jeevamrit + NPK (Soil application at 25, 40 and 55 DAP + 60:45:45 kg/ha)) and four harvestings *viz.*, first harvesting at 90 days after planting,

second harvesting at 150 DAP, third harvesting at 210 DAP and fourth harvesting at 270 DAP.

Treatment combination of Jeevamrit + NPK during fourth harvesting had resulted in highest plant height (154.56 cm), number of leaves per plant (144.11), number of off-shoots per plant (40.95), fresh weight per plant (134.59 g), dry weight per plant (102.87 g), estimated fresh herbage yield/ha (49.85 q/ha), estimated dry herbage yield/ha (38.10 q/ha), essential oil content (2.53%) and estimated essential oil yield/ha (96.52 kg/ha). Highest benefit cost ratio (1.64) was obtained with the application of treatment (jeevamrit + NPK) and minimum B:C ratio was recorded in $T_3$ (FYM 9.6 t/ha) (0.89).

**CONCLUSIONS:**

- *Cymbopogon flexuosus* was found to be tall, perennial aromatic plant with a height of 1.5 m. Stem was short, erect, purple coloured; roots were fibrous and adventitious, leaves were slender, long, tapering at both ends and green in colour, inflorescence was 30-50 cm long spike which spikelets and each spikelet had one or more florets. The fruit was caryopsis type.
- Integrated nutrient application of Jeevamrit + NPK (60:45:45 kg/ha) resulted in maximum growth, yield and essential oil content in lemongrass in fourth harvesting.
- Maximum benefit cost ratio (1.64) was obtained with the application of jeevamrit + NPK which was followed by the application of NPK with a B:C ratio of (1.43) and minimum B:C ratio was registered in $T_3$(0.89).
- Hence, Jeevamrit + NPK (60:45:45 kg/ha) can be recommended for the cultivation of *Cymbopogon flexuosus* for economic benefits.

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# APPENDIX-1

**Analysis of variance (ANOVA) for comparing the mean for different parameter**

**Analysis of variance table for plant height of *Cymbopogon flexuosus***

| Source of Variation | DF | Sum of Squares | Mean Squares | F-Calculated |
|---|---|---|---|---|
| Replication | 2 | 130.232 | | |
| Factor A | 7 | 16,603.708 | 2,371.958 | 75.629 |
| Factor B | 3 | 39,006.565 | 13,002.188 | 414.569 |
| Interaction A X B | 21 | 2,034.899 | 96.900 | 3.090 |
| Error | 62 | 1,944.516 | 31.363 | |
| Total | 95 | 59,719.920 | | |

**Analysis of variance table for number of leaves per plant of *Cymbopogon flexuosus***

| Source of Variation | DF | Sum of Squares | Mean Squares | F-Calculated |
|---|---|---|---|---|
| Replication | 2 | 1.184 | | |
| Factor A | 7 | 6,050.213 | 864.316 | 109.799 |
| Factor B | 3 | 223,014.981 | 74,338.327 | 9,443.600 |
| Interaction A X B | 21 | 511.296 | 24.347 | 3.093 |
| Error | 62 | 488.053 | 7.872 | |
| Total | 95 | 230,065.728 | | |

**Analysis of variance table for number of off shoots of *Cymbopogon flexuosus***

| Source of Variation | DF | Sum of Squares | Mean Squares | F-Calculated |
|---|---|---|---|---|
| Replication | 2 | 0.829 | | |
| Factor A | 7 | 908.337 | 129.762 | 21.929 |
| Factor B | 3 | 16,327.612 | 5,442.537 | 919.734 |
| Interaction A X B | 21 | 258.850 | 12.326 | 2.083 |
| Error | 62 | 366.886 | 5.918 | |
| Total | 95 | 17,862.513 | | |

**Analysis of variance table for fresh weight per plant of *Cymbopogon flexuosus***

| Source of Variation | DF | Sum of Squares | Mean Squares | F-Calculated |
|---|---|---|---|---|
| Replication | 2 | 1.885 | | |
| Factor A | 7 | 4,967.418 | 709.631 | 82.697 |
| Factor B | 3 | 203,245.332 | 67,748.444 | 7,895.041 |
| Interaction A X B | 21 | 820.957 | 39.093 | 4.556 |
| Error | 62 | 532.031 | 8.581 | |
| Total | 95 | 209,567.623 | | |

**Analysis of variance table for dry weight per plant of *Cymbopogon flexuosus***

| Source of Variation | DF | Sum of Squares | Mean Squares | F-Calculated |
|---|---|---|---|---|
| Replication | 2 | 159.347 | | |
| Factor A | 7 | 1,889.647 | 269.950 | 22.255 |
| Factor B | 3 | 154,289.788 | 51,429.929 | 4,239.987 |
| Interaction A X B | 21 | 484.111 | 23.053 | 1.901 |
| Error | 62 | 752.044 | 12.130 | |
| Total | 95 | 157,574.938 | | |

**Analysis of variance table for estimated fresh herbage yield per hectare of *Cymbopogon flexuosus***

| Source of Variation | DF | Sum of Squares | Mean Squares | F-Calculated |
|---|---|---|---|---|
| Replication | 2 | 0.255 | | |
| Factor A | 7 | 681.544 | 97.363 | 82.643 |
| Factor B | 3 | 27,882.597 | 9,294.199 | 7,889.019 |
| Interaction A X B | 21 | 112.608 | 5.362 | 4.552 |
| Error | 62 | 73.043 | 1.178 | |
| Total | 95 | 28,750.048 | | |

**Analysis of variance table for estimated dry herbage yield per hectare of *Cymbopogon flexuosus***

| Source of Variation | DF | Sum of Squares | Mean Squares | F-Calculated |
|---|---|---|---|---|
| Replication | 2 | 21.859 | | |
| Factor A | 7 | 259.355 | 37.051 | 22.276 |
| Factor B | 3 | 21,165.761 | 7,055.254 | 4,241.883 |
| Interaction A X B | 21 | 66.425 | 3.163 | 1.902 |
| Error | 62 | 103.121 | 1.663 | |
| Total | 95 | 21,616.521 | | |

**Analysis of variance table for essential oil content of *Cymbopogon flexuosus***

| Source of Variation | DF | Sum of Squares | Mean Squares | F-Calculated |
|---|---|---|---|---|
| Replication | 2 | 0.012 | | |
| Factor A | 7 | 0.469 | 0.067 | 38.085 |
| Factor B | 3 | 0.710 | 0.237 | 134.603 |
| Interaction A X B | 21 | 0.074 | 0.004 | 1.993 |
| Error | 62 | 0.109 | 0.002 | |
| Total | 95 | 1.372 | | |

**Analysis of variance table for estimated essential oil yield per hectare of *Cymbopogon flexuosus***

| Source of Variation | DF | Sum of Squares | Mean Squares | F-Calculated |
|---|---|---|---|---|
| Replication | 2 | 349.228 | | |
| Factor A | 7 | 4,684.037 | 669.148 | 22.736 |
| Factor B | 3 | 112,099.542 | 37,366.514 | 1,269.632 |
| Interaction A X B | 21 | 1,697.207 | 80.819 | 2.746 |
| Error | 62 | 1,824.720 | 29.431 | |
| Total | 95 | 120,654.735 | | |

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## ABSTRACT

The present research entitled **"Studies on the effect of organic manures, fertilizers and harvesting schedules on growth and yield of lemongrass (*Cymbopogon flexuosus* Nees ex. Steud Wats)"** were carried out in the experimental field as well as in laboratory of Department of Forest Products, COF, UHF, Nauni, Solan (HP) during 2020-2021. In the first experiment 'Morphological studies of *Cymbopogon flexuosus*' lemongrass was found to be a tall, perennial aromatic plant which grows upto a height of 1.5 m. Stem was short, erect, smooth, cylindrical in shape, hollow at internodes, solid at nodes and dark purple in color. Roots were adventitious, fibrous and light brown in color with their length 15-30 cm. Leaves were slender, blade like, long, linear, tapering at both ends and glaucous green in color. The inflorescence was large with a length of 30-50 cm and the axis of the inflorescence was up to 12 nodes recorded. The florets were arranged alternatively on the central axis. A spikelet consists of two bracts called glumes were found which were smooth, concave and glabrous. A floret had lemma on the outer side with hair known as awn and palea on the inner side. Two styles with plumose and purple coloured stigma and three bilobed stamens were present in a floret, fruit is a caryopsis. In second experiment on 'Effect of different organic manures, fertilizers and harvesting schedules on growth and yield of *Cymbopogon flexuosus*' the growth and yield parameters were investigated. In this experiment eight treatments consisting of $T_1$ (Control), $T_2$ (NPK (60:45:45 kg/ha)), $T_3$ (FYM (9.6 t/ha)), $T_4$ (Vermicompost (3.3 t/ha)), $T_5$ (Jeevamrit at 25, 40 and 55 days after planting), $T_6$ (FYM + NPK (9.6 t/ha + 60:45:45 kg/ha)), $T_7$ (Vermicompost + NPK (3.3 t/ha + 60:45:45 kg/ha)), $T_8$ (Jeevamrit + NPK (Soil application at 25, 40 and 55 DAP + 60:45:45 kg/ha)) and four harvestings *viz.*, first harvesting at 90 days after planting, second harvesting at 150 DAP, third harvesting at 210 DAP and fourth harvesting at 270 DAP were evaluated in RBD design with three replications in the field. The combined application of Jeevamrit (500 l/ha) + NPK (60:45:45 kg/ha)gave the maximum value of plant height (154.56 cm), number of leaves per plant (144.11), number of off shoots per plant (40.95), fresh weight per plant (134.59 g), dry weight per plant (102.87 g), estimated fresh herbage yield/ha (49.85 q/ha), estimated dry herbage yield/ha (38.10 q/ha), essential oil content (2.53%) andestimated essential oil yield/ha (96.52 kg/ha)and benefit:cost ratio (1.64)which was followed by the combination of Vermicompost (3.3 t/ha) + NPK (60:45:45 kg/ha). Results revealed that combined application of organic manures and inorganic fertilizers produced higher herbage and oil yield as compared to control and sole application.

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