

Studies on growth, development and yield of young tea plants (*Camellia sinensis* (L.) O. Kuntze) under organic cultivation

A Thesis
submitted to the
Uttar Banga Krishi Viswavidyalaya
in partial fulfilment of the requirement for the
award of Degree of Doctor of Philosophy (Horticulture)

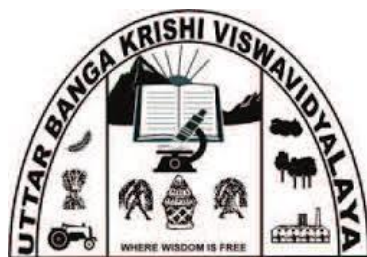
in

PLANTATION CROPS AND PROCESSING

By

VANNAM YUGANDHAR

(Regn. No.: H-2014-05-D)



**DEPARTMENT OF PLANTATION CROPS AND PROCESSING
FACULTY OF HORTICULTURE
UTTAR BANGA KRISHI VISWAVIDYALAYA
PUNDIBARI - 736 165, COOCH BEHAR,
WEST BENGAL**

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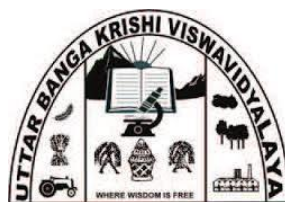
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2017

DEDICATED

DEDICATED

TO MY BELOVED

TO MY BELOVED

PARENTS

PARENTS

AND

AND

TEACHERS

TEACHERS



**DEPARTMENT OF PLANTATION CROPS AND PROCESSING
UTTAR BANGA KRISHI VISWAVIDYALAYA
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Certificate

This is to certify that the work incorporated in the thesis entitled “**Studies on growth, development and yield of young tea plants (*Camellia sinensis* (L.) O. Kuntze) under organic cultivation**” submitted by Sri. **VANNAM YUGANDHAR** in the partial fulfilment of the requirement for the Degree of Doctor of Philosophy (Horticulture) in Plantation Crops and Processing of the Faculty of Horticulture of Uttar Banga Krishi Viswavidyalaya, is the faithful and bonafide research work carried out under my personal supervision and guidance.

Results of the investigation reported in the thesis have not been submitted for any other Degree or Diploma. The assistance and help received during the course of investigation have been duly acknowledged.

Date:

.....

Place: Pundibari, Cooch Behar

(Dr. H. Bhattacharjee)
Chairman
Advisory Committee

**APPROVAL OF EXAMINERS FOR THE AWARD OF THE
DEGREE OF DOCTOR OF PHILOSOPHY (HORTICULTURE) IN
PLANTATION CROPS AND PROCESSING**

We, the undersigned, having been satisfied with the performance of Sri. **VANNAM YUGANDHAR**, in the viva-voce Examination on Final Evaluation of thesis, conducted today, the **24th Oct, 2017**, recommended that the thesis entitled **“Studies on growth, development and yield of young tea plants (*Camellia sinensis* (L.) O. Kuntze) under organic cultivation”** be accepted for the award of the Degree of Doctor of Philosophy (Horticulture) in Plantation Crops and Processing of Uttar Banga Krishi Viswavidyalaya.

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Title : “Studies on growth, development and yield of young tea plants (*Camellia sinensis* (L.) O. Kuntze) under organic cultivation”.

Name of student : Vannam Yugandhar (H-2014-05-D)

Major Subject : Plantation Crops and Processing

Chairman Advisory Committee : Dr. H. Bhattacharjee, Professor

ABSTRACT

India, the second largest producer of tea with 1.233.14 m.kg from an area of about 5.80 lakh ha exported 232.92 m.kg worth US\$ 686.67 m during 2015-16, out of which only 64,000 ha was under organic tea. During last 50 years, considerable increase in production, productivity and quality of tea achieved because of using various chemical inputs like fertilizers and plant protection chemicals. However, indiscriminate use of chemical inputs degraded soil health and product quality and the environment. Organically produced tea without any hazardous chemicals and residues are better in quality and fetches premium price, make a perfect health drink .Organic tea cultivation is gaining momentum. The feasibility of organic cultivation depends right from planting though recommended dose for organic tea cultivation, particularly for terai region, is not there. So, the present investigation was carried out from 2015 to 2017 with the objectives- (i) to observe various growth parameters of young tea plants under organic cultivation (ii) to compare the yield and yield attributes of young tea plants under organic management practices (iii) to find out the most remunerative treatment combination of organics for *Terai* zone of West Bengal and (iv) to evaluate the economics of growing tea organically in the initial years. Various treatments were - T₁: Control (without any organic matter and inorganic fertilizer); T₂: Conventional (NPK @ recommended doses); T₃:Vermicompost@1.0 kg; T₄: Vermicompost@1.0 kg +(Azotobacter +PSB + *Fl.pseudomonas* + *Azospirillum*) each @ 5.0 g/plant; T₅: Vermicompost @ 1.0 kg (Azotobacter + VAM + *Fl.Pseudomonas* + *Azospirillum*) each @ 5.0 g/plant; T₆: FYM @ 2.5 kg; T₇: FYM @ 2.5kg + (Azotobacter + PSB + *Fl.pseudomonas* + *Azospirillum*) each @ 5.0 g/plant; T₈: FYM @ 2.5 kg (Azotobacter + VAM + *Fl.pseudomonas* + *Azospirillum*) each @ 5.0 g/plant, replicated thrice and laid out in completely randomized block design. Observations on various growth parameters (time taken to reach tipping height, weight of pruning litter; total number of leaves, number of branches, girth at collar, leaf area, canopy spreading per plant), yield parameters (total number, fresh and dry weight of two leaves and a bud harvested, number and percentage of growing and dormant bud, volume of two leaf and a bud, number and density of plucking points, leaf period, and yield) and quality parameters (total chlorophyll, polyphenol oxidase, caffeine and tannin contents in leaf) were recorded at 3 months interval. Analyses of results with respect to growth, yield and quality parameters showed significant variations among all the treatments. Among the treatments, T₄ gave best results with respect to all growth (total number of leaves-243.78, 41.73-branches per plant, girth at collar-4.14 cm and canopy spreading-961.44 cm²), yield parameters (total number, fresh and dry weight of two leaf and a bud harvested- 1271.3, 345.03 and 86.26g, respectively while number and percentage of growing and dormant bud were 98.27% and 1.73%, volume of two leaf and a bud- 12.43cc, total number and density of plucking points 1271.33 and 30.78 per 625 cm², and a yield of 0.269 kg/plot/1st yr and 1.871 kg /plot/2nd yr) and quality parameters (leaf total chlorophyll – 57.66 SPAD units, PPO-16.60 per min/g, caffeine 3.86% and tannin contents 2.95%, respectively). Evaluation of economics including fixed costs and variable costs among the organic treatments T₄ was observed to be the best with an income per ha for two years was Rs. 67,876 followed by T₅ with Rs. 61,862 per ha. So, from the investigation, by observing the young tea plants only for two years, though it is premature to conclude, it was observed that T₄ was the most remunerative treatment of organics for *Terai* zone of West Bengal.

Signature of Major Advisor

Signature of Student

LIST OF ABBREVIATIONS USED

%	=	per cent
&	=	and
/	=	per (or) or
@	=	at the rate
µg	=	micro gram
°C	=	degree(s) Celsius
AM	=	arbuscular mycorrhiza.
BF	=	bio-fertilizer
C	=	carbon
C.D	=	critical difference
Ca	=	calcium
CAN	=	calcium ammonium nitrate
cc	=	cubic centimeters
cm	=	centimetre(s)
cm ²	=	square centimetre(s)
Cu	=	copper
EC	=	electrical conductivity
<i>et al</i>	=	and others
Fe	=	iron
Fig	=	figure
FYM	=	farm yard manure
g	=	gram
ha	=	hectare
i.e.,	=	that is
INM	=	integrated nutrient management
IPM	=	integrated pest management
K	=	potassium
kg	=	kilogram(s)
m	=	metre(s)
m	=	million

MAP	=	months after planting
Max	=	maximum
Mg	=	magnesium
mg	=	milligram
Mg	=	magnesium
Min	=	minimum
min	=	minute
ml	=	milliliter(s)
ml-1	=	milliliter per litre
mm	=	millimeter(s)
MOP	=	muriate of potash
N	=	nitrogen
NFB	=	nitrogen fixing bacteria
nm	=	nano meter
No.	=	number
NS	=	non significant
P	=	phosphorus
PGPR	=	plant growth promoting rhizobacteria
pH	=	negative <i>log</i> of H ⁺ ion concentration
PN	=	photosynthetic rate
ppm	=	parts per million
PPO	=	poly phenol oxidase
PSB	=	phosphate solubilizing bacteria
r	=	correlation coefficient
RDF	=	recommended dose of fertilizer
RH	=	relative humidity
RP	=	rock phosphate
Rs	=	rupees
S.Em	=	Standard Error of mean
sq.ft	=	square feet
<i>sp</i>	=	species
SSP	=	single super phosphatet

t	=	tonnes
t	=	tonnes
TRA	=	Tea Research Association
TV	=	Tocklai vegetative
US \$	=	United States dollars
VAM	=	vesicular arbuscular mycorrhiza
VC	=	vermicompost
<i>viz.</i> ,	=	namely
wt	=	weight

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Chapter-I

Introduction

Chapter I

INTRODUCTION

Tea is the second most popular drink in the world after water (Van der Wal, 2008). It is made from young tender leaves and unopened buds of the evergreen tea plant (*Camellia sinensis* (L.) O. Kuntze), belonging to the family Theaceae. It is a perennial, in the natural state, grows to a small or medium-sized tree, but in commercial plantations it is pruned and trimmed to form a many-branched low bush, grown under a wide range of soil and climatic conditions. At present more than 60 countries spread over all the continents except North America within 44° North to 34° South latitude, 120° East to 60° West longitude and up to 2400 m above mean sea level. Tea in plain areas grows luxuriantly under shade, prefers acidic soil with a pH range of 4.5 to 5.5, ambient temperature range of 30° ± 5° C with about 75% RH, and annual rainfall varying from 115.0 to 500.0 cm, well distributed though out the year. Major tea producing countries are India, China, Sri Lanka, Kenya, Malawi, Vietnam and Bangladesh, contributing the maximum share to the global production. India is the second largest producer with a production about 1233.14 million kg from a total area of about 5.80 lakh ha during 2015-16 only next to china and largest consumer. The major tea growing states in the country are Assam, West Bengal, Tamil Nadu and Kerala. West Bengal accounted for a production of about 323.38 million kg of tea from about 1.41 lakh ha during 2015-16. During 2015-16, India ranked fourth in terms of export of tea to the tune of 232.92 million kg and valued at US\$ 686.67 million (IBEF, 2016). Currently, India produces 23% of total world production and consumes about 21% of total world consumption of tea; nearly 80% of the tea produced is consumed within India. Over the last 20 years, India's world ranking as an exporter of tea has come down from number one to number four, in the face of stiff competition from Sri Lanka, Kenya, and China (Majumdar *et al.*, 2012). Recent trends showed drastic reduction in tea exports from India, as the importing countries preferred residue free and superior quality tea.

Stimulative effect of tea is due to the presence of caffeine and considered to be a health drink because of presence of vitamin B-complex, folic acid, polyphenols and anti-

oxidants. It reduces blood cholesterol, hypertension and stone formation due to presence of polyphenols and anti-oxidants. Because of its refreshing, health and medicinal properties it gained the status of National drink in our country. At present day, commercial plantation composed of three different races namely Assam, China and Cambod type. Only about one per cent of total tea produced in India was organic tea. However, organic tea constituted only two per cent of the total organic products exported from India during 2012-13 (FAO, 2014).

There has been a significant increase in production and productivity of tea during last fifty years, using various chemical inputs for nutrition and plant protection. Indiscriminate use of chemical inputs like fertilizers and pesticides indeed boost up crop production initially however, gradually it causes decrease in fertilizer use efficiency. Application of chemical fertilizer as such without conservation of soil fertility, not only results in depletion of soil nutrient reserves but also disrupt the biological eco balance of soil - plant system, product quality and the environment. Tea is grown mainly for young tender apical two leaves and a bud, so, quality is very crucial with regard to human health.

Organic farming is defined as a production system, which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators and livestock additives. To the maximum extent feasible, organic farming system rely up on crop rotation, crop residues, animal manures, legumes, green manures, off farm organic wastes, mechanical cultivation, nutrient bearing rocks and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients and to control insects, weeds and other pests. This is the most widely recognised alternative farming system in the modern era (USDA 1980). Organically produced tea without any hazardous chemicals and residues is better in quality and fetches premium price - about 30 to 40 % more than conventionally grown teas. Organically produced teas have longer shelf-life, better keeping quality, higher antioxidant activity and make them a perfect health drink (Parmar, 2008). Organic tea cultivation is gaining momentum and many tea plantations in the world including India are transforming to organic, conversion of traditional estate to organic estate is a complex operation involving risk and problems. A minimum of three years is needed for an established conventional garden to be converted to organic, which

has to be certified by a certifying agency. The problems for conversion to organic are twofold yield drop up to an extent of 44 per cent and over 65 per cent increase in cost of production as compared to the conventional cultivation (FAO, 2014; Goswami, 2015). In India, the cultivation of organic tea started during 1986 and gradually spread to the tea areas of Assam and South India (Prayukth, 2005).

The feasibility of organic tea cultivation depends right from the initial years after planting, maintaining health and vigour, development of a good frame, proper nutrition and protection from pests and diseases are utmost necessary (Barthakur, 2004, Phukan *et al.*, 2011). Organic manures are main source of plant nutrition in organic farming due to its multiple functions in soil (Mamaril *et al.*, 1986). Various organic amendments are crop residues, vermicompost, farm yard manure and green manure. Use of these inputs are increasingly becoming important aspects of environmentally sound sustainable agriculture (Timsina and Connor, 2001). The basic principle of plant nutrition is universal but optimum fertilizer requirement will vary with plant types and nature of soil. Nitrogen, phosphorus and potassium are the major nutrients required by the plants while calcium, sulphur and magnesium are minor nutrients along with the micro nutrients like manganese, copper, zinc, boron, molybdenum and iron. Nitrogen is an important constituent of chlorophyll, amino acids, proteins and nucleic acids. Phosphorus is one of the vital nutrient. It is responsible for cell division and plays a key role in the formation of new wood and root that could be limiting in tea soils. While, potassium plays a key role as an activator of enzymes involved in carbohydrate and protein metabolism, membrane permeability and stomatal opening (Marschner, 2012).

Biofertilizers are carrier based preparations containing beneficial microorganisms in a viable state (Baby *et al.*, 2001), they improve soil fertility and help in plant growth by improving nutrient availability. Nitrogen fixers and phosphate solubilizers are naturally present in almost all soils but their population level may not be sufficient to bring out these biological processes to a significant level (Mishra *et al.*, 1996). Addition of efficient strains of these microorganisms is successfully practiced in many crops. The use of biofertilizers and organic manure offer a great opportunity to increase the crop productivity with less cost. Therefore, inputs chosen for better establishment of young tea

plants also play key role to guarantee the desired crop performance and economic returns to the farmers but in organic tea culture. (Singh *et al.*, 2011).

Most of the tea gardens follow conventional cultivation practices using various chemical inputs, like fertilizers and plant protection e.g., insects and pests management. West Bengal, particularly Darjeeling is known all over the world for producing the best quality tea. Reports on systematic field experiments on integrated supply of nutrients through organic and bio-fertilizers are scanty and recommended dose for organic cultural practices is lacking, in West Bengal particularly for *Terai* zone. Keeping this in view the present investigation was conducted with the following objectives:

- 1) To observe various growth parameters of young tea plants under organic cultivation.
- 2) To compare the yield and yield attributes of young tea plants under organic management practices.
- 3) To find out the most remunerative treatment combination of organics for *Terai* zone of West Bengal.
- 4) To evaluate the economics of growing tea organically in the initial years.

Chapter-II

Review of Literature

Chapter II

REVIEW OF LITERATURE

Relevant literature on organic cultivation particularly on nutrient management, effects of organic manures and bio-fertilizers on growth and development of crops; yield, and quality including biochemical parameters have been reviewed.

Nutrient management in tea is important as the young shoots are harvested at regular intervals. In this process, nutrients are removed from the plant-soil system and they should be replenished to maintain the nutrient status of the soil. In tea plantations nutrients are supplied mainly through chemical fertilizers, it is widely accepted that following integrated nutrient management, applying inorganic fertilizers along with organic with efficient use of other inputs is the key to achieve sustainable crop production (Karthikeyini, 2002). Continuous applications of only the major nutrients through chemical fertilizers for a long period has lead to the deterioration of physico-chemical properties of soil. There was a decline in organic matter content of the soil leading to the depletion of beneficial soil microbes, which inturn reduces the productivity of the soil. The application of organic manures and bioinoculants could minimize these problems as they are advantageous over chemical fertilizers to improve soil fertility. To integrate only through organic sources of nutrients *viz.*, organics and bioinoculants, for more efficient and economical productive system in the long run. Generally organic manures contain less amount of major nutrients *i.e.*, N, P and K, however, they contain important micro nutrients so for supplying all the nutrients through organic manures a large quantity is needed. However, it is not possible to supply all the nutrient requirements of crops wholly through organic manures. So there is a wide scope to develop biofertilizers to supplement/substitute the use of organic manures to enhance productivity of plantation crops and their usage should be having many benefits (Tennakoon, 2007; Subba Rao, 1995).

In plantation crop like tea, the use of organic manures and biofertilizers has not yet been explored. Attempts have been made earlier to evaluate various organic manures and commercial formulations of biofertilizers in tea with no fruitful results. Though scientific information on the use of organic manures and bioinoculants in tea is meager. (Balamurugan *et al.*, 2010).

The literature pertaining to the use of organic manures and bioinoculants in tea crop is very much limited. So the literature pertaining, beneficial effects of organic manures, bioinoculants and combined with inorganic fertilizers (curtailed) have been reported by various workers on a different of crops.

2.01. Observe the comparative performance of the organically and conventionally grown crops

Baruah *et al.*, (2011) revealed that the application of organic manures could sustain nutrient status in soil and leaf of tea at par with conventional (140 kg N, 50 kg P₂O₅ and 140 kg K₂O per ha). Mohotti *et al.*, (2008) concluded that organically and conventionally grown tea exhibit similar growth performances, in terms of the responses of the root and shoot systems and revealed that the feasibility of growing tea organically, without affecting the yield or plant performance. Bagchi *et al.*, (2015) conducted organic farming practice in tea; results revealed that soil health, crop performance, yield and quality of tea were higher in organic treatment than tea grown conventionally. Chong *et al.*, (2008) comparative studied of organic and conventional farming system at three different slope sections was conducted in Sabah Tea Plantation and results revealed that soil pH decreased and N, P content in soil and tea leaves growth significantly higher level in organic management practices and slope section. Merina, (1995) concluded that the essential nutrients availability, plant growth and development increased by the application of organics and biofertilizers compared to the conventional in coffee and tea seedlings. The addition of organic manure (20 MT/ha), mulching with organics for 5 cm height immediately after tea planting cuttings for weed management, incorporation of *Trichoderma viride* and *Pseudomonas fluorescens* (each 2.5 kg/ha) and dipping the cuttings in Azospirillum solution for 30 minutes before planting resulted in enhancement

of sprouting, shoot dry weight, leaf dry weight, root number and root length compared to conventional technology (Krishnan, 2008).

Ipinmoroti *et al.*, (2011) reported that the use of the organic fertilizer materials (cocoa husk, cow dung, poultry droppings and tea fluff) both as sole and in combination with urea as organominerals, resulted in better tea plant growth performance than the use of NPK (25:5:5) and control. The poultry droppings followed by cow dung resulted in the cheapest procurement cost both as soles and as organominerals and also enhanced better tea growth performance. In SouthEastern China (Qiu *et al.*, 2014), investigated the effects of fertilization regimes on mature tea yields, soil chemical properties and soil bacterial and fungal communities. Results showed that, compared to the control and conventional treatments, organic manure treatment had the richest diversity of soil bacterial community with Shannon index of 2.542 and the highest levels of soil essential nutrients, including soil organic matter, total nitrogen, total phosphorus, available nitrogen, available phosphorus and available potassium, which appeared the maximal tea yields.

Poobathiraj *et al.*, (2012) stated that the application of organic manures either alone or combination with inorganic fertilisers improves the availability of nutrients, enhance soil enzymes activities (urease and nitrate reductase) and also growth of young tea plants compared to control and conventional (NPK) alone. Vidyavathi *et al.*, (2011) observed that the application of FYM, vermicompost and *Gliricidia* in organic nutrient management practices significantly increased in yield of soybean, groundnut and chilli and it was superior over inorganic nutrient management. Gore and Sreenivasa (2011) studied the influence of liquid organic manures viz., Panchagavya, Jeevamruth and Beejamruth on the growth, nutrient content and yield of tomato. The combinations of Beejamruth+ Jeevamruth +Panchagavya were best treatment and resulted in significantly highest yield as compared to recommended dose of fertilizer alone. Nepolean *et al.*, (2012) observed that combination of biofertilizers (VAM+Azospirillum+ PSB) and individual organisms associated young tea plants increased the growth significantly than the chemical inputs and uninoculated ones. Padmavathy and Poyyamoli (2011) reported that, in organic farming there is increasing yield year by year and decrease in inorganic fields year to year. Yields in organic system increase up to 28-32% than those in the conventional plots. Effect of peat moss-shrimp wastes compost on barley applied alone or

with NPK, showed that the main effect of compost on straw yield, numbers of tillers, plant height, and number of ears was more important than that of fertilizer (Binet and Trehen (1992) and Tiku and Bindro (1996).

2.02. Influence of organic manures on growth, yield and yield attributes of crops

Kumar *et al.*, (2015) studied the effect of combination of organic and inorganic fertilizers on photosynthesis efficiency and associated characteristics and yield of mature tea. The highest photosynthetic rate, stomatal conductance, leaf water potential and made tea yield were recorded with the application of vermicompost 50% @ 2.75 tones + chemical fertilizers 50% (45:22.5:45 kg-ha) compared to 100% (90:45:90 kg-ha) chemical fertilizer. Phukan *et al.*, (2013) studied the effect of four organic manures, viz. cattle manure, vermicompost, decomposed tea waste and decomposed neem cake and their combinations on growth and yield of young tea plants belonging to the clone TV 23. Vermicompost either alone or in combination with neem cake or decomposed tea waste (1:1) was superior organic manure for growth and yield of young tea. Effects of foliar spray of organic formulations on mulberry have been reported. Results revealed that foliar spray of Vermiwash 5% has significantly increased the plant height (87.42 cm and 129.16 cm), shoot length (86.14 cm and 127.15 cm), number of leaves per shoot (16.40 and 22.19), leaf area (138.59 dm² and 522.98 dm²). Vermiwash 5 per cent foliar spray also recorded significantly high amount of chlorophyll 'a' (2.17 and 1.37 mg/g), 'b' (1.02 and 0.89 mg/g) and total chlorophyll (3.13 and 2.16 mg/g). High total sugar was also recorded in Vermiwash 5 per cent (Vivek uppar, 2011).

FYM @ 40 MT/ha recorded significantly higher total soluble carbohydrate in mulberry leaf when compared to application of inorganic fertilizers and increase in content of micronutrients such as iron and zinc on FYM application (Shankar *et al.*, 1994). Study on the use of fertilizers and FYM in mulberry revealed that application of organic manure significantly increased the yield of mulberry (Mishra *et al.*, 1996). Dolui *et al.*, (2014) studied effectivity of different on-farm composts on soil quality and productivity of young tea plants. Results revealed that nutrient content of soil, microflora population, biodegradation process, Soil Development Index and crop yield were highest in Novcom compost and vermicompost treated plots compared to other composts.

Bulluck *et al.*, (2002) examined, the effect of organic fertilizers like composted cotton-gin trash, composted yard waste or cattle manure to tomato field. Results indicate that application of organic fertilizers in second year increases yield of tomato.

Praveenkumar and Allolli (2010) observed that, application of organic inputs like FYM, Poultry manure, Panchagavya, Beejamruth and Jeevamruth with or without biofertilizers (Azospirillum + Phosphorus solubilizing bacteria) results in beneficial effect on growth and yield attributes of onion. Nyasulu, (1995) studied the effect of live and dead mulch on young tea and results revealed that Guatemala grass using dead mulch significantly higher plant survival (%), plant height, bush area and annual yield compared to live mulch treatments. Singh *et al.*, (2011) reported that 75% of recommended dose of fertilizers (90 Kg N, 5 Kg P₂O₅ and 90 Kg K₂O ha⁻¹) in combination with 25% of 90 Kg N through vermicompost performed better to that of 100% recommended dose of fertilizers, in enhancing the growth and leaf yield of tea.

2.03. Influence of microbial inoculants on growth, yield and yield attributes of crops

Phukan *et al.*, (2016) studied the effect of phosphate solubilizing microorganisms on soil available phosphate and growth of young tea plants, the results indicated that application of 50% of the recommended doses of phosphate in combination with either PSB or PSF significantly increased P availability in soil and growth of the tea plant resulting in considerable P-fertilizer savings for the P deficient acidic soils.

P -solubilizing bacteria, *Bacillus megaterium* along with inorganic P improved P nutrition of cashew plants and continual application of AMF, *Azospirillum* and phosphate solubilizers has shown synergistic effect among themselves (Sharma, 2006). Haggag *et al.*, (1994) found that phosphate solubilizing bacteria had significant effect on phosphorous content and dry matter of guava seedlings compared to the compost and full dose of phosphatic fertilizer. Chakraborty *et al.*, (2010) found that *S. marcescens* TRS-1 bacterium increased plant height, emergence of new leaves and branches, as well as increase in leaf biomass besides solubilized phosphate and reduced brown root rot of tea. In the field trials conducted to study the influence of phosphate solubilizing microorganisms viz., *Aspergillus awamori*, *Aspergillus niger*, *Bacillus* sp. in mulberry

nursery, all the inoculants increased the plant height, shoot weight and root biomass significantly as compared to uninoculated saplings. Among different isolates *Aspergillus awamori* was found more efficient. (Nagendrakumar and Sukumar, 2001).

Roy *et al.*, (2002) conducted an experiment to study the VA mycorrhizae in relation to growth of different tea varieties. Results revealed that a good correlation was established between VAM population root colonization and plant growth for the tea cultivars, the six-year old TV-26 had 100% root colonization and good growth, while the three-year-old TV-26 showed only 35% root colonization and very poor growth. Baby *et al.*, (2001) carried out an investigation on microbial dynamics in the rhizosphere of tea clones and reported that there was a significant difference on the population level of phosphobacteria in different clones of tea. Furthermore, they were reported that the population of nitrogen fixing *Azospirillum* and phosphate solubilizing bacteria were higher in young tea fields than older fields. Patgiri and Bezbaruah, (1990) estimated that only 10.86% phosphate solubilizing bacteria were found among the 46 heterotrophic bacteria isolated from the tea soils of Assam. Thus the abundance of PSB in soils in terms of percentage varied widely and ranged between 6 to 42% of the total microflora.

Balamurugan *et al.*, (2010) successfully isolated some phosphate solubilizers from tea soil samples and exploit it very well by tea plantation for its higher productivity. Sieverding and Toro (1987) observed the impact of different isolates of AM fungi on tea and found a three-fold increase in growth parameters compared to non- mycorrhizal plants. Morita and Konishi (1989) reported that the relationship between the VAM infection and the amount of P in tea fields subjected to heavy or light fertilizer application was analyzed and concluded that the percentages of VAM infection was low compared with the other plants.

Singh *et al.*, (2010) studied the effect of inoculation with arbuscular mycorrhizal fungi on growth parameters of tea in acid soils. Results revealed that AMF treated plants showed that highly colonization, growth parameters (root/shoot length, dry weight; r/s ratio) than noninoculated plants. Shousheng *et al.*, (2006) studied the effects of VAM fungi (*Glomus* sp.) on the vegetative growth and physiology of tea trees (*Camellia* sp.). The results showed that infection of tea plants with mycorrhizal fungi markedly raised

the activity of phosphorylase in the soil and the dehydrogenase of their roots, promoted the absorption of P, Cu and Mn, and increased their growth volumes and rates.

Siddiqui *et al.*, (1993) reported that *Azotobacter* inoculation in mulberry significantly increased plant height, number of leaves, number of branches and leaf nitrogen content significantly. Chakraborty *et al.*, (2009) reported that the enhanced growth of the *Ochrobactrum anthropi* TRS-2 (PGPR) treated tea plants, as evidenced by increased in height, the number of shoots and number of leaves per shoot and also decreased brown root rot of tea and concluded that the Talc formulation was as effective as aqueous suspensions in both plant growth promotion and disease suppression. Baby *et al.*, (2002b) reported that inoculation of *Azospirillum* bioformulation or liquid near the rhizosphere of tea seedlings significantly increased growth. In tea, Baby *et al.*, (2002a) studied the effect of artificial inoculation of *Azospirillum*. Incorporation of *Azospirillum* bioformulations resulted in higher growth response of the tea plant, increase in soil and plant total nitrogen and leaf nitrate reductase activity and inoculating *Azospirillum* directly to the nursery in case of transplanted crop like tea which might have the potential of improving the proliferation of the endosymbioant.

Hala *et al.*, (2011) studied the role of rizosphere bacteria in date palm plantlets and revealed that *Klebsiella pneumoniae* significantly increased plant height, number of leaves/plant, root length, number of roots/plant, indole and chlorophyll over other treatments. *Bacillus subtilis*, *Pseudomonas corrugate-1* and *Pseudomonas corrugate-2* microbial inoculants were tested for hardening of tissue-cultured tea plants. Bacterial inoculations resulted in enhanced survival (up to 100, 96, and 88%), as against 50, 52, and 36% survival observed in the corresponding control plants, in rainy, winter and summer seasons, respectively. Rhizoplane and rhizosphere soil analyses showed that the major biotic factor responsible for mortality following the transfer of tissue culture raised plants to soil was fungal attack (*Fusarium oxysporum*). Bacterial inoculations also resulted in plant growth promotion of tissue culture as well as seed raised plants of tea. (Pandey *et al.*, 2000).

Balamurugan *et al.*, (2015) exploited *Pseudomonas* strains for disease control and productivity in tea and results revealed better production of phytohormones, siderophore,

hydrogen cyanide, phosphate solubilization, resistance to agrochemicals and production of antimicrobial substances. Moreover, *Pseudomonas* sp, expressed synergistic activity with other beneficial bioinoculants, improved the soil nutrient status and concluded that the *Pseudomonas* sp, as an ecofriendly and sustainable alternative to the existing chemicals for growth promotion and management of tea diseases. Bagyalakshmi *et al.*, (2012) conducted a field experiment to study the efficacy of indigenous potassium solubilizing bacteria in combination with various dosages of potash fertilizers along with recommended dose of nitrogen and phosphorus fertilizers in tea plants. Among various treatments, plants treated with N₁₀₀ P₁₀₀ K₇₅ + potassium solubilizing bacteria concentration formulation was found to be the best in terms of biometric parameters, biochemical parameters, tea quality parameters, N, P and K contents in the crop shoots and soil, higher yield of the green leaf and economics followed by other treatments. Evaluation of potassium solubilizing bacteria population in soil revealed that wherever potassium solubilizing bacteria was incorporated, there was a significant increase in population level and had coincided with dehydrogenase enzyme activity.

Dutta *et al.*, (2015) evaluated that the efficacy of four rhizobacteria in three different commercially important tea clones TV1, TV19 and TV20 plants and results inferred that tea clone TV19 plants inoculated with the *E. lignolyticus* strain TG1 showed maximum root and shoot biomass production, maximum root and shoot length compared to the uninoculated control plants. The population of nitrogen fixing bacteria and leaf yield of mulberry was notably high in organic manures applied plots compared to the recommended nitrogen supplied through chemical fertilizer (Krishna Naik *et al.*, 2006).

Balasubramaniam *et al.*, (1992) reported that the combined inoculation of Azospirillum and phosphobacteria increased the leaf yield by 7.59% compared to recommended doses of N and P alone in mulberry. Application of P solubilizing bacteria *B. megaterium* with nitrogen fixer *Azotobacter* and VA-mycorrhizal fungus significantly improved the mulberry leaf yield (Chandrashekar *et al.*, 1996).

Anilkumar and John (2000) reported that the combined application of Azospirillum, VAM and PSB in mulberry had significantly improved total fresh leaf production, total leaf dry matter production, total stem dry matter production and total

root dry matter production compared to their individual applications. Sreeramulu *et al.*, (2005) reported that the combined inoculation of *A. brasilense* and *B. megaterium* improved the plant height, number of branches and leaves and leaf yield in mulberry. Swathi and Sujathamma (2005) observed that application of *Azotobacter* and Phosphobacteria improved the qualitative and quantitative parameters in mulberry. Tennakoon *et al.*, (2007) concluded that the potential of *Azospirillum* and *Beijerinckia* enhanced the growth, dry matter accumulation and nutrient uptake of tea plants significantly over an uninoculated control.

Hemavathi *et al.*, (2006) reported that inoculation of *Ocimum basilicum* with *Glomus fasciculatum* and plant growth promoting rhizobacteria namely *Bacillus megaterium* and *Pseudomonas fluorescens* enhanced the plant height, number of branches, herbage yield, phosphorus content, mycorrhizal colonization and spore numbers in the root zone soil. Mohandas (1987) recorded the field response of tomato to inoculation with *Azotobacter vinelandii*. The response of tomato to inoculation with *Azotobacter vinelandii* singly and in combination with other biofertilizers was tested in the field. *Azotobacter vinelandii* significantly increased leaf area, shoot dry weight, nitrogen content, phosphorus content and yield in respect to un-inoculated control.

2.04. Combination effect of organic manures and biofertilizers on growth, yield and yield attributes of crops

Baruah *et al.*, (2011) reported that among the organic treatments, vermicompost 2t/ha + mixed biofertiliser, maintained significantly higher leaf yield, over other organic treatments. Phukan *et al.*, (2015a) conducted, a field experiment at the experimental tea field of Tocklai Tea Research Institute, Jorhat, in newly planted tea under virgin field condition to evaluate the efficiency of different organic inputs in improving soil fertility and leaf yield of tea. Newly planted tea was supplied with enriched organic manure in planting pits, application of 'P' enriched vermicompost @ 300g/pit either alone or in combination with PSB and concluded that microbial enriched vermicompost improved the physical, chemical and microbiological properties of soil compared to other organic treatments besides improved tea green leaf yield. However, soil available potash showed a decline from the initial level.

Debere *et al.*, (2014) conducted experiment to determine the effect of combined application of inorganic nitrogen and organic phosphorus fertilizers on growth of young tea plant. The results showed that combined application of 150 kg ha⁻¹ N (inorganic nitrogen -urea) and 30 kg ha⁻¹ P (organic P - Orga) increased leaf number, plant height, branch number per plant, leaf fresh and dry weight, root length, root fresh and dry weight, yield and quality compared to control treatment. Han *et al.*, (2011) studied effect of bio-fertilizer on soil basic properties and tea yield. Results revealed that biofertilizers alone or combination with rape seed cake improved soil pH, organic matter, microbes population density and leaf yield, compared to control.

Gangwar and Thangavelu (1992) observed that the sprouting, rooting, survivability, height of the plant, number of leaves, branches per plant and protein content of leaves increased in mulberry variety Kanva-2 inoculated with *Azotobacter chroococcum* by using FYM as adherent and bulking medium. Shashidhar *et al.*, (2009) observed that, addition of various organic manures and microbial inoculants on fertility of mulberry garden revealed that there is increase in leaf yield per plant/hectare.

Enhanced shoot growth and nitrogen content of the whole tomato plant was observed by Meunchang *et al.*, (2006) in soil amended with compost (sugar mill by product) inoculated with N₂ fixing bacteria, *Azotobacter vinelandii*, *Bejerinickia dextrii* and *Azospirillum* sp. than uninoculated control. Ranaweera *et al.*, (2010) studied the effect of different organic fertilizers on the growth of coconut, availability of nutrients and soil microbial activities. Results indicated that organic fertilizers including biofertilizers have been able to increase soil microbial activities besides improved availability of nutrients in soil and growth of coconut seedlings.

Bahadur *et al.*, (2006 a) noted that plant growth, yield and quality attributes of garden pea were influenced by organic amendments and biofertilizers. Significantly higher carbohydrate content over conventional fertilization was noted by combined use of organic manures and seed inoculation with *Azotobacter* and phosphate solubilizers. According to them, increase in carbohydrate content with *Azotobacter* inoculation and significantly higher ascorbic acid content with phosphate solubilizers over other treatments. Bahadur *et al.*, (2006 b) observed the effect of organic amendments and

biofertilizers on quality attributes of Chinese cabbage. The quality parameters namely dry matter, carbohydrates, crude fiber, vitamins C and carotenoids content in Chinese cabbage were significantly influenced with the use of organic manures and biofertilizers. Sole application of farm yard manure, digested sludge or its combined use with phosphate solubilizing microorganisms significantly increased the dry matter and total carbohydrate content.

2.05. Influence of organic cultivation on biochemical and quality parameters of crops

Bagchi *et al.*, (2015) conducted organic farming practice in tea. Results revealed that secondary phenolics compounds like total phenolics, GCG, EGCC, ECG and radical scavenging capacity was higher in vermicompost+vermiwash treatment than control. Panwar and Singh (2002) studied the role of biofertilizers in wheat and revealed that N₂ fixing bacteria (*A. brasilense*) and phosphate solubilizing bacteria (*Bacillus subtilis*) significantly increased chlorophyll content, nitrate reductase activity and achieved better quality over other treatments.

Kumar *et al.*, (2012) studied the effect of the organic tea cultivation practices on the biochemical constituents and quality parameters of Darjeeling teas. Results indicated that the biosynthesis of polyphenols, proline, pigment profiles such as chlorophyll 1- a, chlorophyll - b, total carotenes and lipids were greatly influenced under the organic cultivation of tea. Higher antioxidant activity and longer shelf-life were observed high in organic teas as compared to conventional farming. Dasl *et al.*, (2011) studied the effect of organic manures on biochemical parameters of tea, the organic practices revealed that biochemical parameters (concentration of compatible solutes, proline, caffeine content and epicuticular wax contents) were comparatively higher in the experimental plots receiving a combination of biofertilizers with vermicompost. Singh *et al.*, (2010) studied the effect of inoculation with arbuscular mycorrhizal fungi on quality parameters of tea in acid soils. Results revealed that AMF treated plants showed that highly colonization and quality parameters (amino acids, total protein content, total polyphenols, caffeine content and sugar content) than noninoculated plants.

Study by Han *et al.*, (2011) revealed that biofertilizers alone or combination with rape seed cake improved the quality components like amino acids, polyphenols and caffeine compared to control. Han and Yang (2014) observed that organic tea has more health benefit and environmental adaptability than conventional tea. Confirm this, six pairs of organic and conventional teas from eastern China have been studied. The results revealed that organic tea had significantly higher polyphenols, including epigallocatechin gallate, epicatechin gallate and epigallocatechin, water extracts, concentrations of proline and γ -aminobutyric acid compared to the conventional tea.

Shousheng *et al.*, (2006) studied the effects of VAM fungi (*Glomus* sp.) on the quality of tea. The results showed that infection of tea plants, the contents of chlorophyll and caffeine increased, but the activity of peroxidase and the contents of Fe and catechins reduced than noninoculated plants. Chin *et al.*, (2010) noticed that in Sabah Tea Plantation, organic farming system resulted in significantly higher soil pH, leaf length, leaf width as well as caffeine, epicatechin, epicatechin gallate, epigallocatechin content and major polyphenol content in tea shoot as compared to conventional farming system.

Kumar *et al.*, (2015) reported that highest net photosynthetic rate (P_N), leaf water potential, stomatal conductance, transpiration rate, chlorophyll content of young tea plant was recorded in vermicompost 50% @ 2.75 tones + chemical fertilizers 50% (45:22.5:45 kg-ha) than 100% (90:45:90 kg-ha) chemical fertilizer and other treatments.

Inoculation with AM fungi, PSB and *Azospirillum* enhanced the growth of tea seedlings and improved the biochemicals related to quality of tea which were comparable to 100% inorganic fertilizers treated and much higher over un inoculated seedlings under nurseries (Balamurugan *et al.*, 2011).

Palit *et al.*, (2008) inferred that organically grown tea plants produced, higher total phenolics, (-)-epigallocatechin gallate [(-)-EGCG], (-)-gallocatechin gallate [(-)-GCG], and (-)-epicatechin gallate [(-)-ECG], as well as the antioxidant and antidiarrhoeal properties but the tea leaves lowered the content of crude fiber and starch than with inorganically grown tea. Tomanr *et al.*, (2012) observed that higher caffeine content, flavanols (catechins) and highly colonized roots in tea plants inoculated with AM fungal spores over control. Interestingly, lower doses of NPK fertilizers revealed better results in

tea quality. Bahadur *et al.*, (2006b) reported the effect of organic amendments and biofertilizers on quality attributes of Chinese cabbage. The quality parameters, *i.e.* dry matter, carbohydrates, crude fiber, vitamins C and carotenoids content in Chinese cabbage were significantly influenced with the use of organic manures and biofertilizers.

An experiment has been conducted to study the impact of enrichment through combined application of varied sources of organic fertilizers viz., organic sericulture waste, compost, vermicompost, green manure, vesicular arbuscular mycorrhiza and *Azotobacter* on leaf quality. The moisture, chlorophyll and protein content of mulberry leaves were found significantly higher due to organic farming. (Philomena *et al.*, 2006).

2.06. Influence of organic cultivation on soil physical, chemical and biological properties

Baruah *et al.*, (2011) reported that among the organic treatments, vermicompost 2t/ha + mixed biofertiliser, maintained significantly higher available N, P, K and organic carbon in tea soil, over other organic treatments. Organic manures increased the soil N and P content and the biological properties of tea soil that increased the populations build up of beneficial microorganisms *Azospirillum* and PSB (Subba Rao, 1995).

Ipinmoroti *et al.*, (2008) reported that poultry droppings and tea fluff enriched organic manures were enhanced better young tea growth, pruned dry matter yield, soil fertility, nutrient uptake in N, P, K, Ca, Mg and organic carbon buildup, than NPK and control (no fertilizer). Sultana *et al.*, (2014) studied the adoption of integrated natural resource management in tea plantation soil management in Panchagarh district of Bangladesh. Results revealed soil quality, nutrient availability in soil and yield of young tea plants were higher in poultry manure treated plots compare to other organic and chemical fertilizers. Kondagama *et al.*, (2009) conducted experiment in coconut to assess the improvement of nutrients and microbial biomass in soil. After long term application of organic manures, results revealed that the poultry manure recorded the highest microbial biomass content, availability of nutrients such as total nitrogen, exchangeable bases (Sodium, Potassium, Calcium and Magnesium) total micro nutrients and available micro nutrients (Copper, Zinc, Iron and Manganese) and leaf chemical properties such as

total nitrogen, phosphorous, calcium, magnesium and total micro nutrients over the organic manures, chemical fertilizer and control.

Dasl *et al.*, (2011) studied the effect of organic manures on soil properties of tea, the organic practices revealed that soil properties (soil total N and soil available P, K) were comparatively higher in the experimental plots receiving a combination of biofertilizers with vermicompost. Louis Mary *et al.*, (2015) concluded that application of vermicompost+ biofertilizers enhanced the soil fertility in terms of macro-nutrients, secondary nutrients and microbial population in mulberry treated plants compared to other organic manures, biofertilizers plots. Chandrakumar *et al.*, (2008) revealed that organic treatments, vermicompost + biofertilizer (Silica solubilising bacteria, *Azotobacter* and Arbuscular mycorrhiza fungi) + neemcake showed significantly increased bacterial and fungal populations 94.33 and 25.33 colonies/g of soil compared to inorganic NPK applied plots and untreated control.

Das and Dkhar (2012) observed that, application of different organic inputs like plant compost, vermicompost, farm yard manure and integrated plant compost resulted in increase in rhizosphere microbial population. The fungal population was greater in vermicompost plot and bacterial population in vermicompost in first crop cycle and FYM for second crop cycle.

A systematic comparison between organic and conventional tea production has been conducted and results showed that soil pH, total organic carbon and nitrogen contents were higher in organic fields of all five comparative pairs of tea fields. The organic carbon content in organic fields was 7.2 percent higher on average than its conventional ones. The carbon sequestered in the organic soil is one percent more annually than its conventional counterpart. In addition, the biomass carbon, ninhydrin-nitrogen, and ratios of biomass carbon to total organic carbon, biomass ninhydrin-nitrogen to total nitrogen were significantly higher in organic fields in most of the comparison (Han *et al.*, 2013). Bongale and Dandin (1993) studied the efficient utilization of nitrogen fixing bacterial systems in mulberry cultivation and reported that the soil organic matter content has to be maintained for regulating the efficacy of biofertilizers. Among different groups of nitrogen fixing bacteria, the species of

Azotobacter and Azospirillum were found to be effective in supplementing the nitrogen requirement substantially in mulberry cultivation.

Li and Ding (1992) studied the effect of organic fertilizers on the organic matter of tea soils and results revealed that vermicompost+biofertilizers plots received higher organic matter status compared to other organic and conventional plots. Ping *et al.*, (2014) observed that soil bulk density, porosity, relative water content, soil organic matter, total N and total P in organic tea gardens were relatively rich and reaching the soil standard of tea gardens with high yield and good quality compared to ecological tea gardens and non-ecological tea gardens. Phukan *et al.*, (2015b) observed that soil organic matter fractions in different tea soils and results revealed that humus, fulvic acid, non-humic carbon contents were higher in the high yielding tea fields compared to low yielding fields. Correlation of these fractions with yield and available nutrients was also studied. Easwaran *et al.*, (2003) demonstrated that vermicompost is considerably superior than compost and conventional with regard to physical, biological and chemical processes of soil which have their bearings on tea plant's growth.

Manjunatha *et al.*, (2006) revealed that application of 75% recommended dose of fertilizer + vermicompost increased the organic carbon, cation exchange capacity and water holding capacity and decreased the bulk density, pH and electrical conductivity of the sapota soil. Kalpana *et al.*, (2006) studied that, soil organic carbon content, available N, P, K and soil microbial population (bacteria, fungi and actinomycetes) were highest in application of composted coir pith (2.83 t/ha), biodigested slurry (2.58 t/ha), vermicompost (1.25 t/ha) and Azospirillum (2 kg/ha) + PSB (2 kg/ha) followed by FYM, biocompost and neem cake combination compared to all the other treatments.

An experiment has been conducted to study the impact of enrichment through combined application of varied sources of organic fertilizers viz., organic sericulture waste, compost, vermicompost, green manure, vesicular arbuscular mycorrhiza and Azotobacter on soil fertility. The organic carbon, nitrogen, carbon nitrogen ratio, moisture content and soil phosphorus were found significantly higher due to organic farming (Philomena *et al.*, 2006).

In SouthEastern China, investigated the effects of fertilization regimes on mature tea yields, soil chemical properties and soil bacterial and fungal communities. Results showed that, compared to the control and conventional treatments, organic manure treatment had the richest diversity of soil bacterial community with Shannon index of 2.542 and the highest levels of soil essential nutrients, including soil organic matter, total nitrogen, total phosphorus, available nitrogen, available phosphorus and available potassium, which appeared the maximal tea yields (Qiu *et al.*, 2014).

De Silva, (2008) conducted two trials to study the suitability of the commonly available mulching materials with varying C/N ratios and their influence on soil micro-organisms on young tea and mature tea after pruning in the field. The results indicated that refuse tea and dadap mulches enhanced soil pH, organic carbon, microbial biomass carbon and soil respiration and also showed suppression of gram negative bacteria which are mostly pathogenic, one year after the application of treatments. The suitable mulching materials to accelerated the microbial activity were those with C/N ratios below 20 and low in lignin and unoxidisable polyphenols. Sarmah *et al.*, (2011) observed that the positive effect of vermicompost on carbon sequestration in tea soil at Tocklai was also observed building up of soil organic carbon as well as humus carbon, biomass production and yield of young tea plants than to other manures.

Singh *et al.*, (2011) reported that 75% of recommended dose of fertilizers (90 Kg N, 5 Kg P₂O₅ and 90 Kg K₂O ha⁻¹) in combination with 25% of 90 Kg N through vermicompost performed better to that of 100% recommended dose of fertilizers increased soil organic carbon, available N, P, K whereas bulk density, pH was reduced.

Poobathiraj *et al.*, (2012) stated that the application of organic manures either alone or combination with inorganic fertilisers improves the availability of nutrients, enhance soil enzymes activities (urease and nitrate reductase) and also growth of young tea plants compared to control and conventional (NPK) alone. Phukan *et al.*, (2013) studied the effect of four organic manures; *viz.* cattle manure, vermicompost, decomposed tea waste and decomposed neem cake and their combinations on nutrient availability and uptake of young tea plants belonging to the clone TV 23. Vermicompost

either alone or in combination with neem cake or decomposed tea waste (1:1) was superior organic manure for nutrient uptake and availability in young tea soil.

A study conducted on okra revealed that combination of organic fertilizers, vermicompost and vermiwash had great influence on the biochemical characteristics of the soil with marked improvement in soil micronutrients. The combination treatment was found to be better suggesting qualitative improvement in the physical and chemical properties of the soil, which is substantiated by composite, index for vermicompost and vermiwash combination with composite. This biological method of crop cultivation is sustainable and improves soil health rather than conventional methods based on the earlier observations (Abdullah Adil Ansari, 2008, Venugopal, *et al.*, 2010).

Tharmaraj *et al.*, (2011) stated that the effect of vermicompost on soil chemical and physical properties was evaluated during samba rice cultivation studies. The physical properties such as pH, electrical conductivity, porosity, moisture content, water holding capacity and chemical properties like N, P, K, Ca and Mg were found distinctly enhanced in vermicompost treated soil, where as the corresponding physico-chemical values in control were minimum. Purkayastha *et al.*, (2011) observed a trend of depletion of organic matter status nutrient indices (1-15%) in different sub-areas of Barak Valley tea soils, concluded that improvement of soil organic matter status through extraneous applications of compost manures, cattle manures, de-oiled neem cakes, mulching and commercial formulations and reported that derived from composting of organic wastes were found to be promising in building up of the nutrient indices in respect of organic matter to maintain the soil in a healthy condition.

Safique *et al.*, (2015) conducted experiment to evaluate the potential of high nitrogen (N) - containing pruning's as an organic amendment and observed that tea pruning's in shredded form enhanced microbial activity, which in turn increased the rate of decomposition and nutrient release in tea soil. Along with N, available phosphorus content and phosphorus-solubilizing bacterial population in soil also increased.

Saikia *et al.*, (2011) reported that in mature tea field, conservation of all bio-mass like pruning litters, shade tree droppings and cheeled weed mass enhanced the amount of organic matter and resulted in reduction of inorganic N fertilizer up to 30%. Retention of

all bio-mass + NPK produced the highest yield in young as well as mature tea, which was equivalent with use of bio-fertilizer consortium of *Azospirillum*, PSB, arbuscular michorhiza and *Trichoderma viride*. Sun *et al.*, (2011) studied the effects of different mulching modes on the soil water, nutrient dynamics and young tea plant growth. Results revealed that straw mulching increased young tea growth and yield through increased significantly water and yield water use efficiency, soil organic matter, available-N, nitrate-N, and ammonium-N, leaf nitrate-N content, nitrate reductase activity increased and made the peak period of bud growth appeared earlier compared with other mulches and control (no mulching) and concluded that the tea growth and yield, water and nutrient use efficiency, environment safety and economic benefit, straw mulching could be an effective ground surface mulching mode for young tea garden.

2.07. Influence of organic cultivation on economics of crops

Bhattacharyya *et al.*, (2016) reported that the application of potash mobilizing microorganisms might serve as a cost-effective and alternate viable technology to mobilize insoluble K-source in tea soil for sustainable crop improvement.

Sharma, (2002) studied the effect of *Azospirillum* and different doses of nitrogen on yield of cabbage. The treatments included 3 levels of biofertilizers and 4 levels of nitrogen. A treatment combination of *Azospirillum* application with 60 kg N/ha resulted in maximum yields/ha with benefit : cost ratio 2.9. Kumar *et al.*, (2015) studied the effect of organic and inorganic fertilizers on yield of tea. Highest net returns was recorded with the application of vermicompost 50% @ 2.75 tones + chemical fertilizers 50% (45:22.5:45 kg-ha) compared to 100% (90:45:90 kg-ha) chemical fertilizer. Reddy *et al.*, (2006) conducted a study in Tiptur taluk of Tumkur district, Karnataka to workout economics of vermicompost use in coconut with a sample size of 40 vermicompost user farmers and 20 non-vermicompost user farmers. In general, vermicompost users incurred lower expenditure on inputs especially on fertilizer and plant protection chemicals. The Cobb- Douglas production function revealed that area under the crop and plant protection chemicals were positively associated with copra output. The variable vermicompost, though not statistically significant, had positive association with the output. The application of vermicompost to coconut farms resulted in many environmental benefits

such as reduction in fertilizer use, plant protection chemicals and number of irrigations given to the crop.

Kumar *et al.*, (2012) studied the effect of the organic tea cultivation practices on the growth and yield of Darjeeling teas. Results indicated that the net profit greatly influenced under the organic cultivation of tea as compared to conventional farming. Chinnappa, Reddy *et al.*, (2007) analyzed economics of vermicompost production and economic gains from its application to the crops like, banana, coconut, coffee, ginger, and pepper. The study was carried out Coorg, Mysore, Hassan, Kolar, Mandya, Tumkur and Bangalore districts. The study focused on two types vermicompost production namely, vat method and heap method with regards the vermicompost production. The results pointed out that in respect of ginger, the farmers realized 3.26 percent higher yield with vermicompost compared to farmers who did not use vermicompost. The net returns per acre from vermicompost applied ginger were Rs. 25,034 as against Rs. 20,287 from the produce without vermicompost. In the case of banana also yield and net returns were higher among the farmers who applied vermicompost. While vermicompost users realized a net income of Rs. 84,000 per acre, non users of vermicompost realized a net income of Rs. 66,000.

In a study conducted near Nagpur in Maharashtra it has been reported that vermicompost application would improve the yield of citrus by 21 per cent, with B: C ratio of 3.21. The adoption of vermicompost application increased from 3 per cent to 28 per cent over five years. Economic analysis of vermicompost production under heap system revealed that a farmer could get around Rs.46, 000 net profits, besides 33 human-days work per ha of citrus cultivation as additional employment. The rate of return of vermicompost worked out to be 2.92 (Ramamurthy *et al.*, 2007).

A study was undertaken to work out the economics on the use of varied sources of organic manures (vermicompost, enriched vermicompost, farm yard manure, coir pith compost, urban solid waste compost and biodigested slurry) on irrigated mulberry (variety V-1) to meet nitrogen requirement (100%) and its impact was studied on silk cocoon production in two silkworm hybrids (PM x CSR2 and PM x NB 4D2) during 2004-05. The economics of mulberry production differed considerably when mulberry

received nitrogen through varied sources of organic manures. (Ramakrishna Naika *et al.*, 2012). Devi *et al.*, (2003) conducted experiment to assay effect of different sources of nitrogen on yield and economics of cabbage, it was revealed among the various treatments including application of poultry manure and biofertilizers with *Azospirillum brassilense* could save 25 per cent nitrogen where cost benefit ratio was 1:4.30. And application of poultry manure and biofertilizers, *Azotobacter chroococcum* saved 25 per cent nitrogen in cabbage with cost benefit ratio of 1:4.30.

Sinha *et al.*, (2000) studied the effect of *Azotobacter* on nitrogen fixation in mulberry and reported that the application of *Azotobacter* @ 10 kg/ha/year in two splits per crop recorded an increase of 9.23% in leaf yield than untreated ones indicating that *Azotobacter* can alone significantly supplement the nitrogen requirement to the mulberry plants. They also reported that *Azotobacter* not only helps in curtailing the dependence on chemical fertilizers but is also economical with cost benefit ratio of 1:4.

Manjunathas *et al.*, (2009) studied, effect of farm yard manure with jeevamruth on yield and economics of sunflower result revealed that, application of farm yard manure @ 7.5 t ha⁻¹ with jeevamruth recorded highest (Rs.27,384 ha⁻¹) net profit compared to the treatment 100 per cent recommended dose of fertilizer (Rs. 25,475 ha⁻¹).

It is reported (Susheelamma *et al.*, 2008) that, high requirement of nitrogenous and phosphatic fertilizers in mulberry escalates the cost of cultivation. They found that the application of 500 kg neem leaves + 25 kg *Tridax sinensis* + 5 MT FYM + 4 kg biofertilizers/ac/crop effectively reduced the weed and pest population besides improving the soil health cutting down the expenditure on nitrogenous fertilizer increased net profit and highest B: C ratio (3.91:1) was observed.

Chapter- III

Material and Methods

Chapter III

MATERIALS AND METHODS

The details of material used, methodologies adopted and experimental techniques employed for the study have been outlined in this chapter.

3.01. Location, climate and soil characteristics of the experimental site

3.01.01. Location

The experiment was carried out from March, 2015 to May, 2017 at the Instructional Plots of the Department of Plantation Crops and Processing, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India. Geographically, the experimental site was located at 26⁰19'86" North Latitude and 89⁰23'53" East Longitude and at an elevation of 43 m above mean sea level.

3.01.02. Climate

The experimental site falls under *Terai* agro climatic zone of West Bengal. The place experienced hot and humid summer, rainy and cool winter season. Subtropical humid climate prevailed in the zone, with a prolonged rainy season. Pre-monsoon rain starts from April, followed by May, heavy monsoon rains from June and continues up to September. The yearly rainfall of the zone varies from 2300 to 3400 mm and 80% of the total rainfall is distributed between June to October (Fig.3.03). The temperature ranged from minimum of 7-8 °C to maximum of 36-39 °C (Fig.3.01) with high relative humidity. The humid warm climate prevails throughout the year except during the month of December to February (Fig.3.02). The winter is sufficiently prolonged with considerable number of foggy days. Month wise meteorological parameters during the period of experimentation have been presented in Annexure-I.

3.01.03. Soil

The topography of the experimental land area was medium high. The experimental site was under natural vegetation and no cultivation was done for several decades. Jungle and weeds were cleared during winter of 2015 consisted of acidic, sandy

loam soil and more or less coarse textured. The water holding capacity of the soil was somewhat poor due mainly to considerably high sand content. Composite soil samples (to a depth of 0-30 cm) were drawn from the experimental area before planting and was analyzed for physical-chemical and biological properties have been presented in Table 3.01.

Table. 3.01. Physico-chemical and biological characteristics of soil samples at initiation of the experiment

Physico-chemical and biological characteristics of soil samples	
Ph	5.56
Organic carbon (%)	0.64
Total carbon (%)	1.16
Bulk density(g/cc)	1.21
Available N (kg/ ha)	153.13
Total N (kg/ ha)	608.52
Available P (kg/ ha)	18.92
Available K (kg/ ha)	121.81
<i>Azotobacter</i> (C.F.U) per g soil	3.15×10^4
<i>Azospirillum</i> (C.F.U) per g soil	4.74×10^5
PSB (C.F.U) per g soil	1.92×10^4
<i>Fl. pseudomonas</i> (C.F.U) per g soil	3.21×10^4

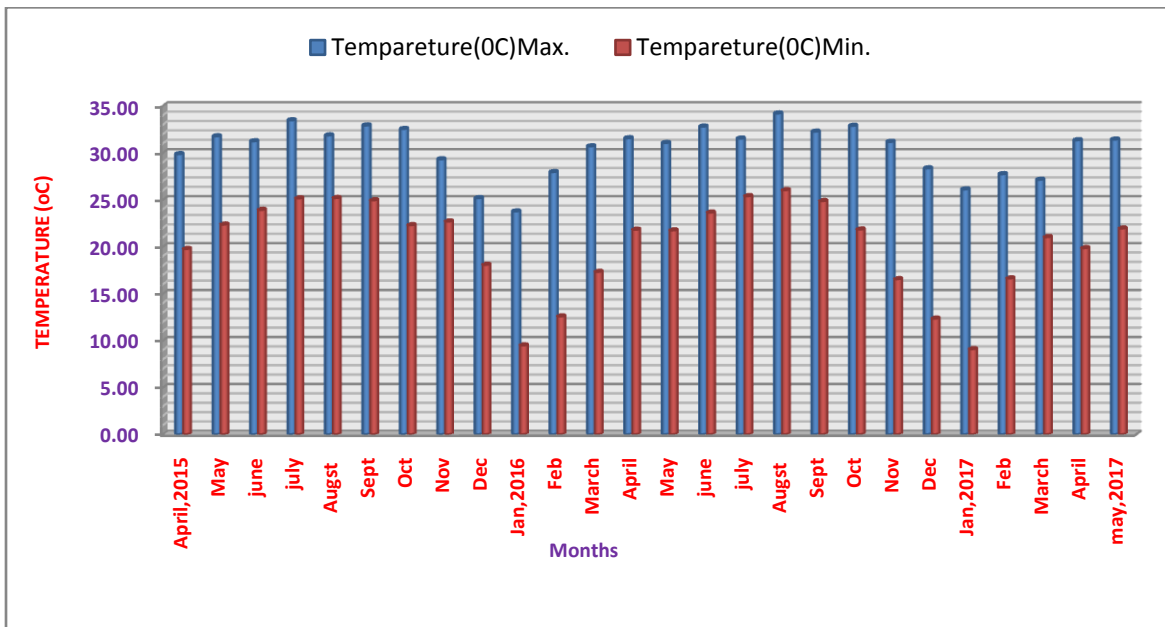


Fig. 3.01: Month wise mean temperatures prevailed during the period of study (April, 2015 to May, 2017)

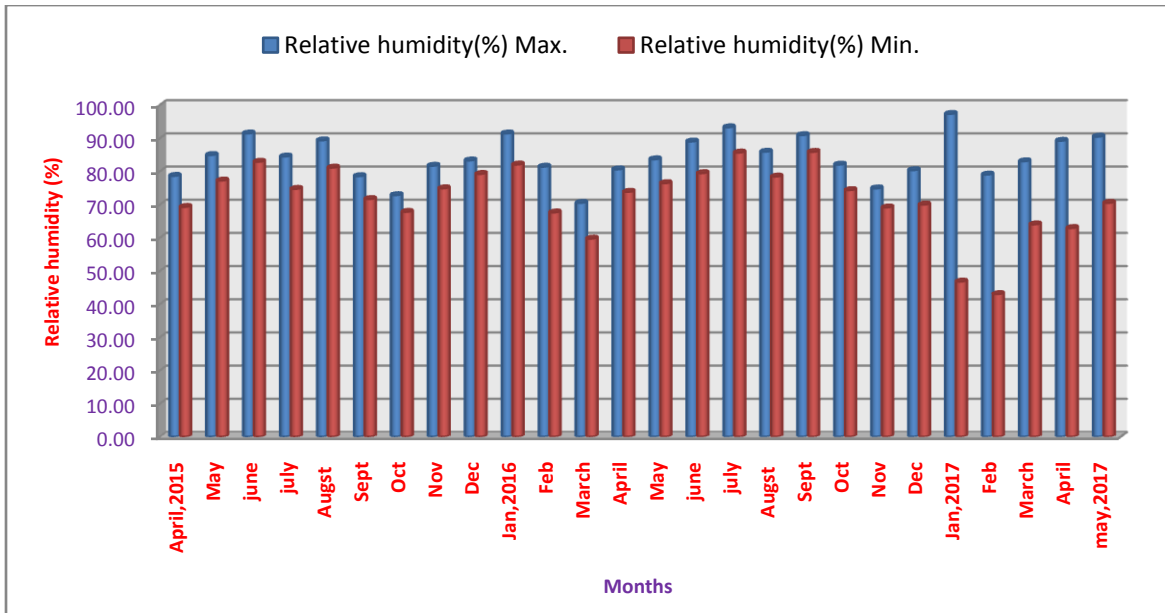


Fig. 3.02: Month wise mean relative humidity prevailed during the period of study (April, 2015 to May, 2017)

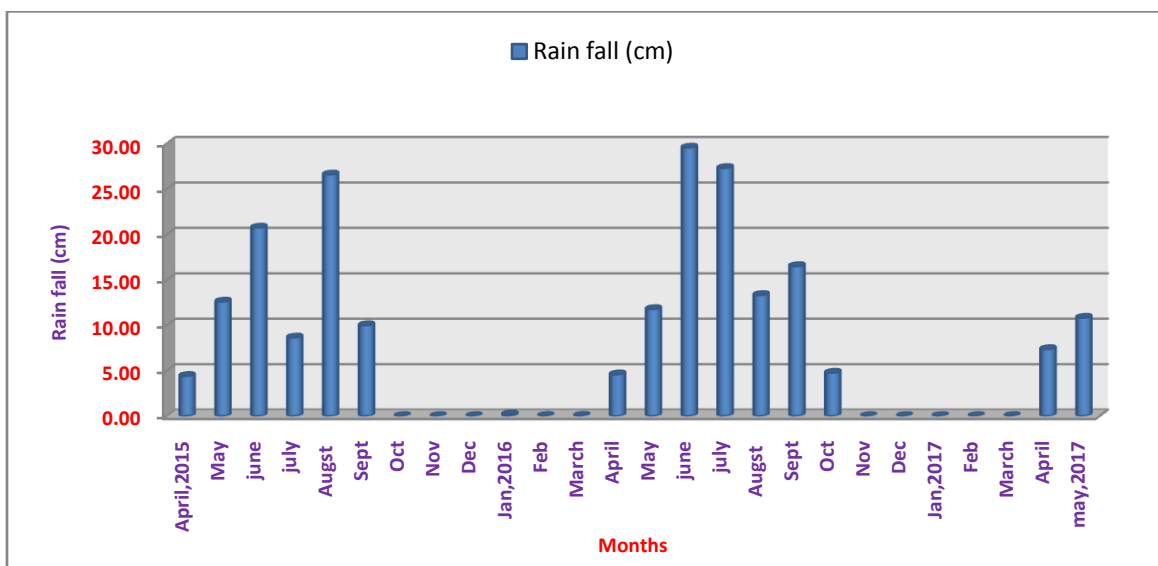


Fig. 3.03. Average rain fall rainfall received during the period of study (April, 2015 to May, 2017)

3.02. Details of the experiment

The experiment was carried out on new plantation where TV 26 clone (24 months old) was used as planting material, raised in the Instructional plots of the Department of Plantation Crops and Processing, UBKV in May 2015 at a spacing of 105 cm x 70 cm (single hedge).

1. Duration of experiment : March 2015 to 2017 May
2. Number of treatments : 8
3. Number of replications : 3
4. Total number of plots : 24
5. Effective plot size : 4.15 m x 3.80 m
6. Total experiment plot size : 648.13 m²
7. No. of plants/plot : 20
8. Design of the experiment : Randomized Block Design (RBD)

Table3.02: Treatment details

Treatment	details
T ₁	Control (no manure and fertilizer)
T ₂	Conventional plot (FYM + NPK @ recommended doses)
T ₃	Vermicompost @ 1.0 kg/plant/year
T ₄	Vermicompost @ 1.0 kg + (<i>Azotobacter</i> + PSB + <i>Fl. pseudomonas</i> + <i>Azospirillum</i>) each @ 5.0 g/plant
T ₅	Vermicompost @ 1.0 kg + (<i>Azotobacter</i> + VAM + <i>Fl. pseudomonas</i> + <i>Azospirillum</i>) each @ 5.0 g/plant
T ₆	FYM @ 2.5 kg/plant/year
T ₇	FYM @ 2.5 kg + (<i>Azotobacter</i> + PSB + <i>Fl. pseudomonas</i> + <i>Azospirillum</i>) each @ 5.0 g/plant
T ₈	FYM @ 2.5 kg + (<i>Azotobacter</i> + VAM + <i>Fl. pseudomonas</i> + <i>Azospirillum</i>) each @ 5.0 g/plant

Fig. 3.04: Layout of field experiment

Total plot size: 648.13 m²

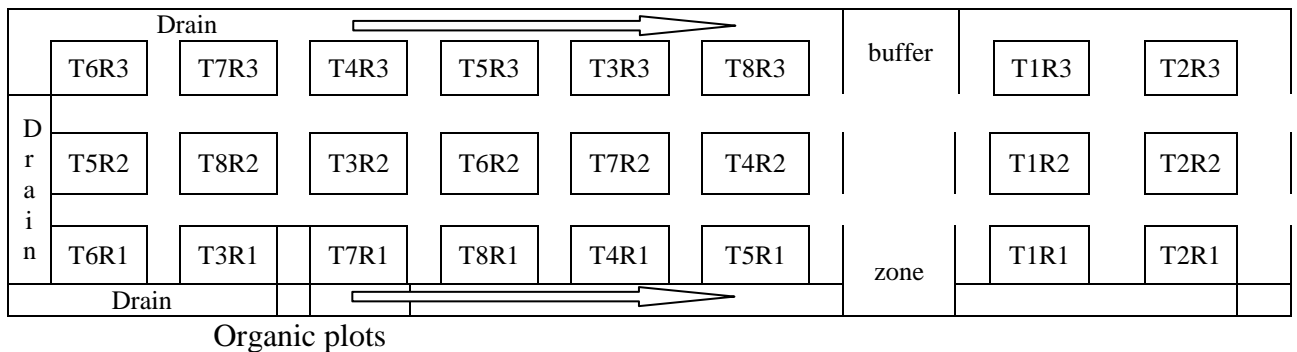
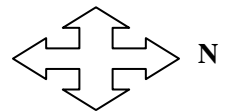




Plate: 3.1. Layout of experimental plot



Plate 3.02: Observations taken in the field and laboratory

3.03. Experimental materials

3.03.01. Planting materials of tea

Plantable plants from vegetative cuttings of TV 26 raised organically in the departmental nursery were used. The tea clone TV 26 was released by Tocklai Tea Research Institute (Tea Research Association), Jorhat, Assam during 1982. It is a Cambod type yield clone, spreading type frame, potential yield 3500 kg made tea per ha, tolerant to drought, manufacturing preference CTC-Orthodox.

3.03.02. Source of nutrients and chemicals

Different organic nutrients sources such as farm yard manure (FYM), vermicompost (VC) and chemical fertilizers were collected from Directorate of Farms, UBKV, Pundibari. Bio- inoculants such as *Azotobacter*, *Azospirillum*, phosphate solubilising bacteria (PSB), *Fl.pseudomonas*, were collected from bio-control unit of the Department of Plant Pathology, UBKV, Pundibari and vesicular arbuscular mycorrhiza (VAM) was collected from RARS Lam, ANGRAU, Guntur, Andra Pradesh. All other chemicals used during investigation for analyses of soil, leaf and biochemical parameters with AR or GR grades of Hi-Media and Merck Mumbai and provided by the Department of Plantation Crops and Processing.

3.04. Cultural practices

The plots were maintained as per treatments, in organic plots only organic cultural practices and in inorganic plots only inorganic practices followed, as recommended by Tea Research Association for *Terai* zone.

3.04.01. Field preparation

After clearing the jungle and weeds, the area was ploughed two times, harrowed with disc to bring the soil into fine tilth and levelled. Roots of weeds and other stubbles were removed from the field and the field was laid into plots as per the layout of the experiment by digging drains in between. Stumps of *Melia azadiractha* was planted as shade trees with a spacing of 6.0 m X 10.0 m for, providing temporary shade.

3.04.02. Planting

Planting was done with a spacing of 105 cm X 70 cm in a single hedge system. The plants were put in middle of the pits and filled up first with top soil and then sub soil mixed with organic manures, bio- fertilizers viz., *Azotobacter*, PSB, VAM, *Fl. pseudomonas*, *Azospirillum* @ 5 g/plant each and chemical fertilizers as per treatments (Table3.02). After planting, mulching and watering were done.

3.04.03. Inter-culture operation

3.04.03.01. Weeding: The experimental plots were kept free from weeds by hand weeding at two to three months interval.

3.04.03.02. Irrigation: Irrigation was given during winter months for overcoming water stress. Generally, water was applied at an interval of 15 days during December to March.

3.04.03.03. Manures and fertilizer application: Organic manures- fym and vermicompost were applied in two splits in a year during April and August. In conventional plots Urea, SSP and M.O.P. fertilizers were applied as YTD 10:5:10 as per the recommendation by Tea Research Association, Tocklia, India, in four equal splits during April, May, July and September by ring method every year.

3.04.03.04. Centering or Lung pruning: After establishment, the young tea plants with branches were cut or the plants with a single stem were broken at 20 cm from ground level in such way that the bark on one side of the stem remains intact for movement of water and nutrients. The broken portion were cut after the branch below it started new growth.

3.04.03.05. Plant protection: For management of various insect pests in organic plots neem oil was sprayed and in inorganic plots TRA recommended insecticides were sprayed as and when needed.

3.05. Parameters recorded

3.05.01. Growth parameters: For observing various growth parameters six plants were selected excluding the border rows in all the plots and observations were recorded at 3 months interval.

3.05.01.01. Days to attain tipping height: The number of days taken from the date of centering to reach tipping height of 55 cm from the ground level with a scale and were recorded in days.

3.05.01.02. Weight of pruning litter: The weight of pruning litter after centering or lung pruning were taken using a precision balance and expressed in grams per plant.

3.05.01.03. Number of branches: The tagged plants were used for counting the total number of branches including primary, secondary, tertiary branches up to 40 cm from ground level counted at 3 months intervals up to 24 months after planting and their averages were worked out and expressed as number of branches per plant.

3.05.01.04. Number of leaves: Total number of fully opened leaves per plant were counted in the tagged plants and mean number of leaves were worked out at 3 months intervals upto 24 months after planting and expressed as number of leaves per plant.

3.05.01.05. Area of leaf: Observation on five fully expanded third leaf from top from each tagged plant was taken and mean leaf area was worked out at 3 months intervals up to 24 months after planting. Leaf area was measured using a graph paper and expressed in cm^2 .

3.05.01.06. Girth at collar: The diameter of the selected plants was measured at collar region (5 cm from ground level) with Vernier callipers and girth was calculated by multiplying with 3.14 recorded at 3 months intervals up to 24 months after planting and their averages were worked out and expressed in centimeters (cm).

3.05.01.06. Spreading: Spreading of the plants was calculated by multiplying the expansion of branches on East–West and North-South direction and expressed in cm^2 .

3.05.02. Yield and yield attributing characters

3.05.02.01. Number of two leaves and a bud: Total number of two leaves and a bud harvested from the selected plants per plot were counted at 1 month intervals from 3 MAP up to 24 months after planting and expressed in total number of two leaves and a bud per plot, per month.

3.05.02.02. Weight of two leaf and a bud - fresh and dry (g): Fresh weights of two leaf and a bud harvested were taken in the departmental laboratory at 1 month intervals from 3 MAP up to 24 months after planting, using a precision balance and expressed in grams per plot and for dry weight of total harvested leaves were kept in an hot air oven maintaining a temperature of 60°C till constant weight was obtained between two consecutive weighings and expressed in grams per plot.

3.05.02.03. Number and percentage of growing and dormant buds : After plucking growing and dormant buds were separated and counted individually and expressed in percentage (%) of total. It was taken at 1 month intervals from 3 MAP up to 24 months after planting.

3.05.02.04. Volume of two leaves and a bud: For measuring the volume, 20 numbers of two leaves and a bud were taken and volume was measured with the help of a 100 ml graduated measuring cylinder and expressed as cubic centimeters (cc). At 10, 13, 16, 19 and 22 months after planting

3.05.02.05. Number and density of plucking points: A quadrat of size 25cm X 25 cm size was placed at the center of the bush over the plucking table and counting the total number plucking points in the selected tea bushes. The mean number and density of plucking points were taken at 6 months interval.

3.05.02.06. Leaf period: Time taken in days for unfolding of successive appendage was counted in the selected plants and mean leaf period were worked out from 10 MAP to 19 MAP.

3.05.02.07. Green leaf yield: Total yield of green leaf from the plants in a plot was recorded. It was calculated at the end of each plucking season during experiment period and expressed green leaf yield in kg per plot.

3.05.03. Quality parameters

From the selected plants in each replicated plot two leaves and a bud were analyzed for various quality parameters *viz.*, Total chlorophyll, polyphenol oxidase, Caffeine and Tannin.

3.05.03.01. Total chlorophyll (Kumar *et al.*, 2012)

Leaf total chlorophyll content was measured in the third normal leaf (from top), with the help of a chlorophyll meter (SPAD-502 plus by Konica Minolta, Japan) and expressed as SPAD units specified in the catalogue of the instrument.

3.05.03.02. Estimation of polyphenol oxidase

Estimation of polyphenol oxidase (PPO) was done using the method described by Mayer *et al.*, (1965). The enzyme extract was prepared by taking 0.2g leaf samples and 2 ml of 0.1 M sodium phosphate buffer (pH 6.6) by crushing with liquid nitrogen in a mortar with pestle. The homogenate was centrifuged at 20,000 rpm for 30 min at 4°C. The supernatant was used as enzyme source. The reaction mixture consisted of 100 µl of the enzyme extract and 2.4 ml of 0.1 M sodium phosphate buffer (pH 6.0). To start the reaction, 0.5ml of pyrogallol solution was added, and the enzyme activity was expressed as changes in absorbance at 495 nm against a blank 3 ml of phosphate buffer (pH 6.0) at 5 min interval up to 4 numbers. Expressed as Unit ($\Delta 495/\text{min/g}$ fresh wt).

3.05.03.03. Caffeine content

Caffeine content of two leaf and a bud were observed following the method (Chin *et al.*, 2009). 20 g of the green leaf samples were taken and soaked in 25% NH_4OH in a 125 ml round bottom flask, 200 ml of chloroform was added and refluxed for 90 minutes. Separating funnel was taken and filtered through Whatman No.1 filter paper in a 500 ml conical flask. Distilled out chloroform, dissolve crude caffeine in boiled double distilled water, filter made up to 250 ml and diluted 1 ml of filter to 40 times. Absorbance of the solution was measured at 274nm in Perkin Elmer Lambda -35 UV-visible spectrophotometer against chloroform blank. The amount of caffeine was calculated from the calibration graph obtained with 5 to 25 ppm of standard caffeine and expressed in percentage.

3.05.03.04. Tannin content

Pipette out 1 ml of the supernatant and quickly add 5 ml of vanillin hydrochloride reagent. Taken readings in a spectrophotometer at 500 nm after 20 min. Prepared a blank with vanillin hydrochloride reagent alone. Prepared a standard graph was prepared with 20–100 mg catechin using the diluted stock solution. the amount of

catechin, i.e. tannin in the sample was calculated the absorbance values in standard graph and expressed as catechin equivalents (Vanillin Hydrochloride Method).

3.06. Collection and preparation of soil samples

Five soil samples up to 30 cm depth were collected randomly throughout the experimental plots. During the course the study sampling was done at 6 months intervals at a depth of 30 cm from 30 cm away from the stem of the plant (near rhizosphere). Three equidistant spots were selected and the soil samples were drawn from the selected spots with the help of a Dutch Auger (Make: AIC Agro-Industries Private Ltd, Kolkata). In the process, the bulk soil was reduced to 1 kg by following the quartering method. This 1 kg soil sample constituted the composite soil sample. The composite soil samples were then air dried, passed through a 2 mm sieve and stored in clean dry cloth bags with adequate descriptions in attached paper labels. All relevant information and identification marks as required were also recorded. These composite soil samples were analysed in the laboratory for various of soil characteristics.

3.06.01. pH

The pH of soil suspension (1:2.5) was measured by standard potentiometric method with the help of a glass electrode pH meter as described by Jackson (1973).

3.06.02. Bulk density (g/cc)

Bulk density of each treatment before initiation and during experiment, were determined by core sampler method as described by Black (1965).

3.06.03. Organic carbon

The organic carbon content of the soil samples was estimated by the wet digestion method as described by Walkley and Black (1934) and expressed in percent.

3.06.04. Total carbon

The total carbon content of the soil samples was estimated by the colorimetric method as described by Brakes *et al.*, (1976) and expressed in percent.

3.06.05. Available nitrogen

The available nitrogen content of the soil samples were determined by the 'Alkaline permanganate' method as described by Subbiah and Asija (1956).

3.06.06. Total nitrogen (kg/ha)

The Total nitrogen content of the soil samples was determined by the Kjeldhal method by using devardol alloy (catalyst mixture) as described by Jackson (1973).

3.06.07. Available phosphorous (kg/ha)

Available phosphorus was estimated by extracting 2.5 g of each soil sample with a mixture of 25ml of 0.03 M NH_4F and 0.025 M HCl for 5 minutes (Bray and Kurtz, 1945), followed by colour development and estimated.

3.06.08. Available potassium (kg/ha)

The estimation of available potassium content of the experiment soils was done with the help of a flame photometer (Jackson, 1967). Accurately weighed 5 g soil sample was taken in 100 ml conical flasks followed by the addition of 25 ml of 1 N ammonium acetate as the extractant (1:5 ratio). The contents were shaken vigorously for 30 minutes by mechanical shaker and then filtered. The filtrates were used for determination of potassium by using a flame photometer.

3.07. Leaf analysis

(a) Collection of leaf sample

Tagged plants were subjected to leaf analysis; third leaf (index leaf) from tip of young shoots was selected in the 6 tagged plants in each treatment for leaf sampling. Analysis before application of the manures (FYM, vermicompost and bio inoculants) and fertilizers (conventional plots) as well as control plots and subsequently at 6, 12, 18 and 24 months after planting, leaf samples collected for the determination of NPK content of leaf. Third leaf (index leaf) from tip of young shoots was selected for analysis of NPK content in tea plants as proposed by Jones *et al.*, (1991).

(b) Preparation of leaf samples

Leaf samples were collected in polythene bags and brought to the laboratory and washed immediately in tap *water* and then rinsed with 0.1 N HCl. The washed and rinsed samples were dried under shade followed by oven drying at a temperature of 65 ± 5 °C so

as to reduce the chemical and biochemical changes to the minimum. The oven dried samples were powdered and stored in butter paper bags for chemical analyses.

(C) Wet digestion of leaf sample

Accurately 0.5 g oven dried powdered leaf sample was weighed and digested by Wet oxidation by using a triacid mixture (conc. HNO_3 , H_2SO_4 , and HClO_4 in the ratio of 9:4:1) as described by Jackson (1973). After digesting for the required period of time, the digest was made up to 100 ml and filtered through Whatman No. 1 filter paper.

The standard procedures that were adopted for the analysis of the nutrients in the leaf extracts have been mentioned below.

3.07.01. Nitrogen content

Weighed plant samples were placed in Kjeldahl flask and digested by adding conc. H_2SO_4 and catalyst mixture. The digested material was distilled with 40% NaOH and the distilled ammonia collected in 4% boric acid indicator solution was back titrated with standard 0.05(N) H_2SO_4 (Piper, 1996).

3.07.02. Phosphorous content

Plant samples were pre-digested in nitric acid overnight followed by digestion with tri-acid mixture (HNO_3 , HClO_4 , H_2SO_4 : 9:4:3) and P content in the digest was determined by vanadomolybdo phosphoric yellow colour method in nitric acid system (Jackson, 1973).

3.07.03. Potassium content

The tri-acid extract prepared for total P in plant was also used for estimation of total K by flame emission photometry (Piper, 1996).

3.08. To evaluate the economics of growing tea organically in the initial years

Costs of all costs fixed and variable costs of the items were taken- Planting materials, land preparation, digging drains etc., digging pits and planting, application of organic manures, chemical fertilizers, rock phosphate, neem cake and bio-fertilizers, bringing up of young tea plants, irrigation, weed management, mulching, pests and disease management harvesting, etc.

3.09. Statistical analysis

The experimental data was analysed statistically by the method of analysis of variance as outlined by Panse and Sukhatme (1995). Statistical significance was tested by applying F- test at 0.05 level of probability and critical differences were calculated for those parameters which were significant to compare the effects of different treatments. The symbol 'NS' was indicated where ever the treatment differences observed were not significant in the 'F' test.

Chapter-IV

Results

Chapter IV

RESULTS

The mean values of the observations recorded on all the treatments have been presented in this chapter, subdivided in to various sub-heads as per the objectives of the present investigation.

4.01. Growth parameters of young tea plants under organic cultivation

4.01.01. Days taken to attain tipping height of 55 cm

The data recorded on days taken by the plants to reach tipping height of 55 cm have been presented in Table 4.01.01 indicated significant differences among all the eight treatments.

Observations revealed that (Table 4.01.01) a minimum of 62.67 days were taken by 5% of the plants in T₂ (Conventional) to reach 55 cm height after centering or lung pruning at 20 cm from ground level, closely followed by T₄ (VC+Az+P+Pf+As) with 63.97 days, while a maximum of 90.33 days were taken in T₁ (control). Successively, in all the treatments 25 % of the plants per plot took a minimum of 68.67 days in T₂ (Conventional) followed by T₄ (VC+Az+P+Pf+As) with 70.08 days while maximum of 106.67 days in T₁ (control), but T₂ and T₄ were at par with each other. Overall 50, 75 and 100% of the bushes per plot under T₂ (Conventional) showed comparatively less number of days to reach tipping height with 73.67, 79.41 and 87.67 days respectively, closely followed by T₄ (VC+Az+P+Pf+As) with 75.67, 81.33, 90.33 days respectively, but T₂ and T₄ were at par with each other. While T₁ (control) took maximum number of days 122.33, 136.67, 149.33 days respectively. Similar results were also illustrated in Fig.4.01.01

4.01.02. Weight of pruning litter per plant

The weights of pruning litter of young tea plants (centering or lung pruning) after one MAP have been presented in Table 4.01.02. There was no significant difference among the treatments with respect to the weights of pruning litter of young tea plants on one MAP. However, T₅ (VC+Az+V+Pf+As) recorded maximum pruning litter of 20.05

Table 4.01.01: Effect of organic cultivation of tea (TV 26) on days taken to reach tipping height (55 cm)

Treatments	Days to tipping height per plot				
	1 st plant (5%)	5 plants (25%)	10 plants (50%)	15 plants (75%)	20 plants (100%)
T ₁ (Control)	90.33	106.67	122.33	136.67	149.33
T ₂ (Conventional)	62.67	68.67	73.67	79.41	87.67
T ₃ (VC)	79.41	87.67	99.33	112.63	121.67
T ₄ (VC+Az+P+Pf+As)*	63.97	70.08	75.67	81.33	90.33
T ₅ (VC+Az+V+Pf+As)**	69.33	76.67	81.33	89.67	95.63
T ₆ (FYM)	83.33	91.33	104.63	119.67	131.67
T ₇ (FYM+Az+P+Pf+As)*	71.63	76.33	89.67	100.33	111.33
T ₈ (FYM+Az+V+Pf+As)**	74.41	81.67	93.33	107.67	118.63
SEm (±)	0.40	0.54	0.68	0.69	0.98
CD (P=0.05)	1.22	1.63	2.07	2.11	2.99

VC- vermicompost

*Az+P+Pf+As -Azotobacter + PSB + Pseudomonas fluorescens + Azospirillum

**Az+V+Pf+As - Azotobacter+ VAM + Pseudomonas fluorescens + Azospirillum

FYM- farm yard manure

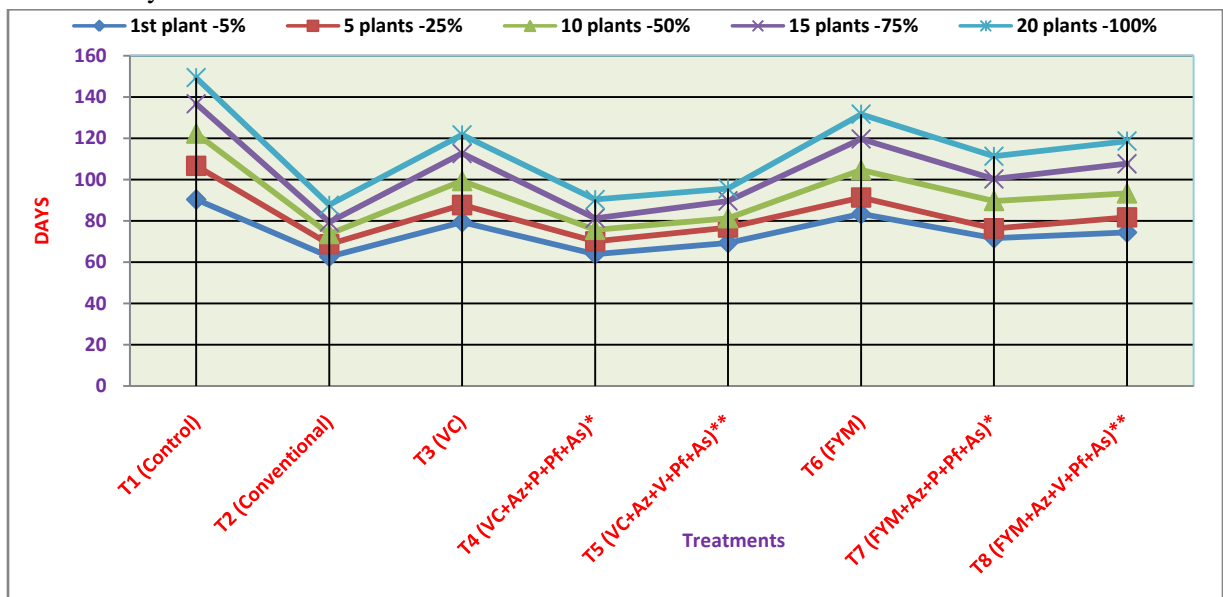


Fig. 4.01.01: Effect of organic cultivation on days taken to reach tipping height

g/plant followed by T₇ (FYM+Az+P+Pf+As) with 18.33 g/plant while, the plants under treatment T₂ (Conventional) has recorded minimum pruning litter of 14.59 g/plant.

Table 4.01.02: Effect of organic cultivation of tea (TV 26) on pruning litter per plant

Treatments	Pruning litter (g) per plant
T ₁ (Control)	15.39
T ₂ (Conventional)	14.59
T ₃ (VC)	17.68
T ₄ (VC+Az+P+Pf+As)*	16.30
T ₅ (VC+Az+V+Pf+As)**	20.05
T ₆ (FYM)	16.25
T ₇ (FYM+Az+P+Pf+As)*	18.33
T ₈ (FYM+Az+V+Pf+As)**	17.97
SEm (±)	0.61
CD (P=0.05)	N.S

VC- vermicompost

*Az+P+Pf+As -*Azotobacter* + PSB + *Pseudomonas fluorescens* + *Azospirillum*

**Az+V+Pf+As - *Azotobacter*+ VAM + *Pseudomonas fluorescens* + *Azospirillum*

FYM- farm yard manure

4.01.03. Total number of branches per plant

Observations on total number of branches- primary, secondary and tertiary branches per plant up to 40 cm from ground level at three months interval of young tea plants have been depicted in Table 4.01.03 and Fig. 4.01.02. It is evident that the total number of branches per plant differed significantly among the all treatments throughout the period of experimentation *i.e* from 3 MAP up to 24 MAP. At the time of planting, the plantable plants of clone TV 26 with uniform characters were chosen and had on an average only 1.01 to 1.28 branches per plant, which were not significantly different. On 3 MAP (Table 4.01.03) highest number 5.98 of total branches per plant were observed in T₂ (conventional) closely followed by T₄ (VC+Az+P+Pf+As) with 5.81 branches. Significantly lowest number 2.49 of branches per plant was recorded in T₁ (control).



Plate 4.01: Photographs showing performance of young tea

(a) Treatment-4

(b) Treatment-5

(c) Treatment-7

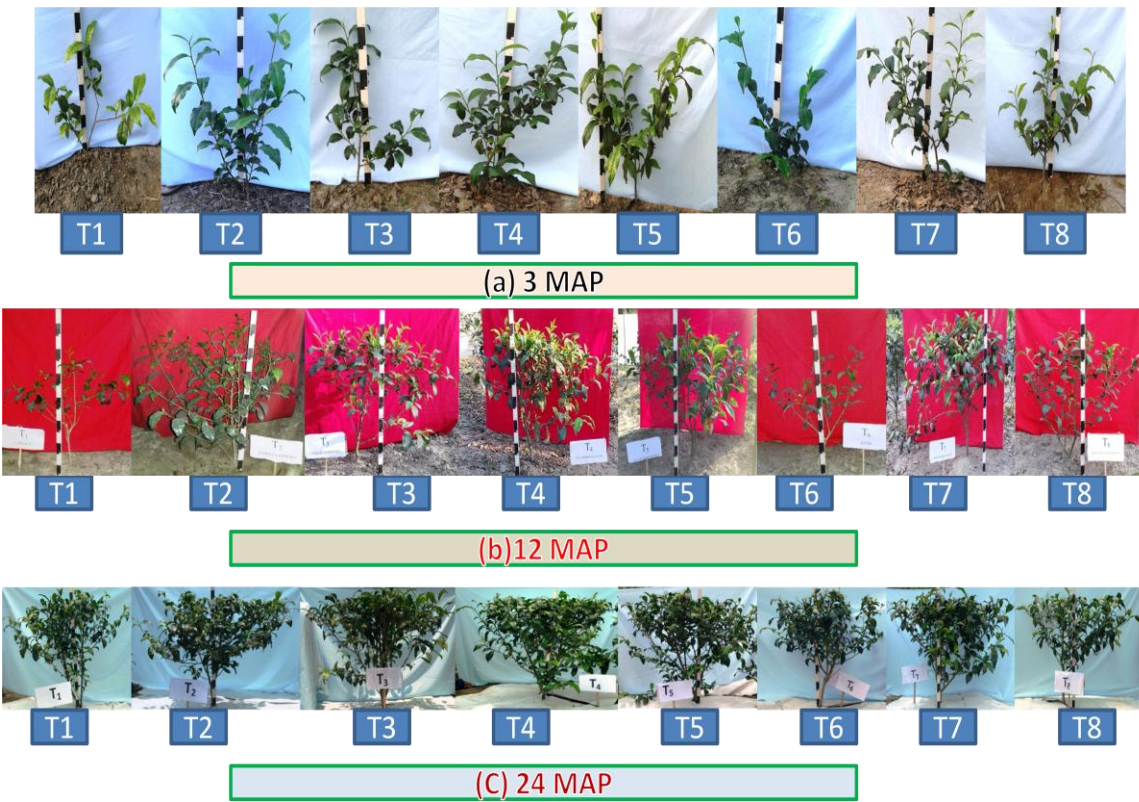


Plate 4.02: Photographs showing growth and development of young tea plants at

different stages (a) 3 MAP (b) 12 MAP(c) 24 MAP

Table 4.01.03: Effect of organic cultivation of tea (TV 26) on total number of branches per plant up to 40 cm from ground level at three months interval

Treatments	Number of branches per plant on months after planting								
	0 [#] (May'15)	3 (Aug'15)	6 (Nov'15)	9 (Feb'16)	12 (May'16)	15 (Aug'16)	18 (Nov'16)	21 (Feb'17)	24 (May'17)
T ₁ (Control)	1.03	2.49	3.88	4.33	6.49	10.69	14.74	15.17	17.70
T ₂ (Conventional)	1.08	5.98	10.10	12.12	17.39	24.91	33.32	35.82	39.92
T ₃ (VC)	1.19	4.65	7.59	8.87	13.12	20.09	25.42	26.76	32.20
T ₄ (VC+Az+P+Pf+As)*	1.17	5.81	10.88	12.89	18.50	25.81	34.55	36.88	41.73
T ₅ (VC+Az+V+Pf+As)**	1.14	5.53	9.47	11.5	17.17	24.09	32.64	34.64	40.12
T ₆ (FYM)	1.28	3.79	5.85	6.61	11.72	16.68	22.59	24.26	29.14
T ₇ (FYM+Az+P+Pf+As)*	1.15	5.36	8.99	9.59	16.19	21.90	27.76	29.43	34.76
T ₈ (FYM+Az+V+Pf+As)**	1.01	5.33	8.72	9.30	15.78	20.99	26.82	28.02	33.53
SEm (±)	0.15	0.11	0.24	0.16	0.32	0.28	0.26	0.33	0.27
CD (P=0.05)	N.S	0.35	0.72	0.5	0.97	0.85	0.78	1.01	0.82

VC- vermicompost; *Az+P+ Pf +As -*Azotobacter* + PSB + *Pseudomonas fluorescens* + *Azospirillum*;

**Az+V+ Pf +As - *Azotobacter*+ VAM + *Pseudomonas fluorescens* + *Azospirillum*; FYM- farm yard manure

- indicate number of branches per plant at the time of planting at 20 cm from ground level

On 6 MAP, plants under treatment T₄ (VC+Az+P+Pf+As) showed maximum number 10.88 total branches per plant followed by T₂ (conventional) with 10.10 branches while, minimum number of 3.88 branches per plant was recorded in T₁ (control). Similar trend of development of new branches was observed from 9 MAP to 21MAP, T₄ (VC+Az+P+Pf+As) recorded highest number of branches per plant ranged from 12.89 to 36.88 followed by T₂ (conventional) with 12.12 to 35.82 branches while lowest number of branches ranging from 4.33 to 15.17 were recorded in T₁ (control). Perusal of data in Table 4.01.03 indicated that on 24 MAP, significantly highest number of branches per plant (41.73) was noticed in T₄ (VC+Az+P+Pf+As) followed by T₅ (VC+Az+V+Pf+As) with 40.12 branches, while lowest number of branches was noticed in T₁ (control) plants with 17.70 branches.

4.01.04. Total number of leaves per plant

Observations on total number of leaves per plant from planting to 24 months at interval of three months in young tea plants under various treatments (T₁ to T₈) have been presented in Table 4.01.04 and Fig 4.01.03. It is evident from data the total number of leaves per plant differed significantly among the treatments through out the period of experimentation *i.e* from 3 MAP up to 24 months. At the time of planting, the plantable plants had only 6.50 to 7.89 leaves per plant, up to 20 cm from ground level which were not significantly difference.

Observations on 3 MAP total number of leaves per plant showed that T₂ (conventional) recorded higher number 43.15 of leaves per plant (Table 4.01.04) compared to rest of the treatments. In treatment T₄ (VC+Az+P+Pf+As) with 42.50 leaves per plant was observed, which was at par with T₂. Minimum number of 20.70 leaves per plant was recorded in T₁ (control). On 6 MAP T₄ (VC+Az+P+Pf+As) recorded significantly maximum with 70.97 of leaves per plant, followed by T₂ (conventional) with 68.99 leaves, while minimum 34.26 number of leaves per plant was recorded in T₁ (control). Similar trend was recorded to number of leaves per plant was during 9 MAP to 21 MAP, treatment T₄ (VC+Az+P+Pf+As) showed maximum number of leaves per plant ranging from 85.07 to 202.11, followed by T₂ (conventional) with 82.40 to 196.11 leaves per plant. While plants under treatment T₁ (control) had minimum number of leaves up to

Table 4.01.04: Effect of organic cultivation of tea (TV 26) on total number of leaves per plant at three months interval

Treatments	Number of leaves per plant on months after planting								
	0 [#] (May'15)	3 (Aug'15)	6 (Nov'15)	9 (Feb'16)	12 (May'16)	15 (Aug'16)	18 (Nov'16)	21 (Feb'17)	24 (May'17)
T ₁ (Control)	7.05	20.70	34.26	45.60	54.59	77.53	95.55	104.74	130.74
T ₂ (Conventional)	6.50	43.15	68.99	82.40	112.86	146.03	184.46	196.11	229.11
T ₃ (VC)	7.89	31.07	50.29	61.62	87.76	115.91	145.27	156.48	175.15
T ₄ (VC+Az+P+Pf+As)*	6.83	42.50	70.97	85.07	115.16	149.26	190.03	202.11	243.78
T ₅ (VC+Az+V+Pf+As)**	7.11	38.85	67.68	79.77	107.51	137.81	176.30	190.66	231.62
T ₆ (FYM)	7.28	27.01	41.31	52.67	74.53	98.63	129.93	140.30	165.30
T ₇ (FYM+Az+P+Pf+As) *	6.83	36.99	61.37	71.24	99.04	129.61	169.95	180.61	207.27
T ₈ (FYM+Az+V+Pf+As) **	7.44	34.13	55.26	65.8	95.07	124.42	164.92	175.35	200.68
SEm (±)	0.33	0.25	0.31	0.59	0.9	1.02	1.34	1.39	1.27
CD (P=0.05)	N.S	0.76	0.94	1.79	2.73	3.09	4.06	4.21	3.84

VC- vermicompost; *Az+P+ Pf +As -*Azotobacter* + PSB + *Pseudomonas fluorescens* + *Azospirillum*;

**Az+V+ Pf +As - *Azotobacter*+ VAM + *Pseudomonas fluorescens* + *Azospirillum*; FYM- farm yard manure

- indicate number of leaves per plant at the time of planting up to 20 cm from ground level

21 MAP ranging from 45.60 to 104.74 leaves. Further perusal of data (Table 4.01.04) revealed that on 24 MAP, T₄ (VC+Az+P+Pf+As) recorded significantly higher number 243.78 of leaves per plant followed by T₅ (VC+Az+V+Pf+As) with 231.62 leaves, while lowest number 130.74 of leaves per plant was recorded in T₁ (control).

4.01.05. Leaf area

Observations on area of third leaf young tea plants at three months interval have been depicted in Table 4.01.05. It was found to be significant among the all treatments up to 24 MAP, observed that overall third leaf area decreased in winter season compared to rainy and summer season and T₄ (VC+Az+P+Pf+As) showed maximum leaf area in all Observations during the experiment.

Observations on 3 MAP leaf area (Table 4.01.05), T₄ (VC+Az+P+Pf+As) significantly showed maximum 19.02 cm² leaf area followed by T₂ (conventional) with 18.11 cm² while T₁ (control) has recorded minimum 11.38 cm² leaf area. Leaf area on 6 MAP and 9 MAP, leaf area decreased compared to 3 MAP, T₄ (VC+Az+P+Pf+As) significantly showed maximum 18.62 cm² and 17.50 cm², respectively followed by T₂ (conventional) with 17.22 cm² and 15.68 cm², respectively. While T₁ (control) was recorded with minimum leaf area 11.14 cm² and 9.63 cm², respectively. On 12 MAP and 15 MAP, leaf area increased compared to 9 MAP, T₄ (VC+Az+P+Pf+As) significantly recorded maximum 19.48 cm² and 21.44 cm², respectively followed by T₂ (conventional) with 18.80 cm² and 19.87 cm², respectively. Minimum leaf area of 11.69 cm² was recorded in T₁ (control) and 11.84 cm², respectively during the same period. on 18 MAP and 21 MAP, leaf area decreased compared to 15 MAP, T₄ (VC+Az+P+Pf+As) significantly showed maximum 21.13 cm² and 18.79 cm², respectively leaf area on 18 MAP and 21 MAP followed by T₂ (conventional) with 19.15 cm² and 17.05 cm², respectively. While T₁ (control) has showed minimum leaf area with 11.23 cm² and 9.94 cm², respectively. On 24 MAP leaf area increased compared to 21 MAP, T₄ (VC+Az+P+Pf+As) recorded significantly maximum leaf area with 21.50 cm², followed by T₅ (VC+Az+V+Pf+As) with 20.82 cm² while minimum 11.82 cm² leaf area was recorded in T₁ (control).

Table 4.01.05: Effect of organic cultivation of tea (TV 26) on leaf area (third leaf) at three months interval

Treatments	Leaf area (cm ²) on months after planting							
	3 (Aug'15)	6 (Nov'15)	9 (Feb'16)	12 (May'16)	15 (Aug'16)	18 (Nov'16)	21 (Feb'17)	24 (May'17)
T ₁ (Control)	11.38	11.14	9.63	11.69	11.84	11.23	9.94	11.82
T ₂ (Conventional)	18.11	17.22	15.68	18.80	19.87	19.15	17.05	20.05
T ₃ (VC)	13.83	13.01	11.02	14.45	14.93	13.95	12.15	15.49
T ₄ (VC+Az+P+Pf+As)*	19.02	18.62	17.50	19.48	21.44	21.13	18.79	21.50
T ₅ (VC+Az+V+Pf+As)**	17.53	17.05	15.37	18.38	19.68	19.05	16.89	20.82
T ₆ (FYM)	12.64	12.09	10.84	13.32	13.91	12.88	11.03	13.36
T ₇ (FYM+Az+P+Pf+As)*	15.83	14.75	12.68	16.91	17.38	16.65	14.30	18.12
T ₈ (FYM+Az+V+Pf+As)**	15.02	13.85	11.78	15.97	16.12	15.57	13.34	16.90
SEm (±)	0.14	0.18	0.12	0.11	0.18	0.17	0.15	0.17
CD (P=0.05)	0.41	0.55	0.36	0.33	0.54	0.52	0.45	0.51

VC- vermicompost; *Az+P+Pf+As -*Azotobacter* + PSB + *Pseudomonas fluorescens* + *Azospirillum*;

**Az+V+Pf+As - *Azotobacter*+ VAM + *Pseudomonas fluorescens* + *Azospirillum*; FYM- farm yard manure

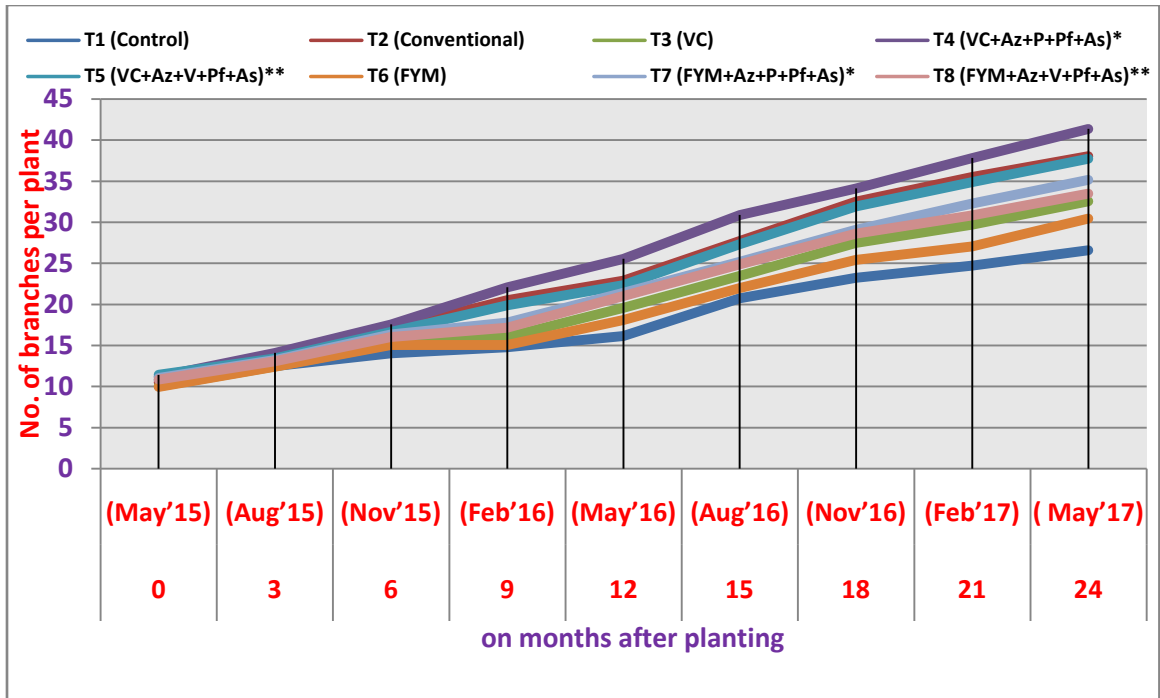


Fig. 4.01.02: Effect of organic cultivation on total number of branches per plant at three months interval upto 24 months after planting

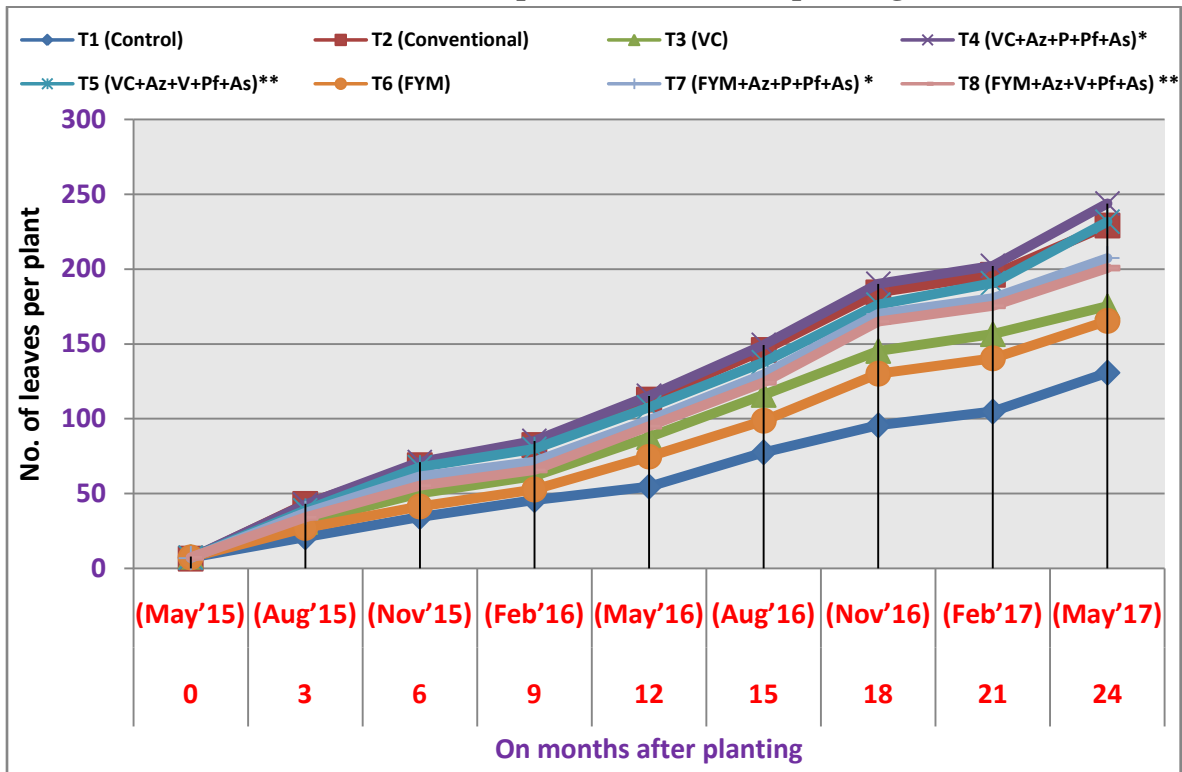


Fig. 4.01.03: Effect of organic cultivation on total number of leaves per plant at three months interval upto 24 months after planting

4.01.06. Girth at collar

Observations on girth of the plants at collar per plant (5 cm above the ground level) at three months interval have been shown in Table 4.01.06. and illustrated in Fig 4.01.04. It is evident from data that the girth at collar per plant differed significantly among the all the treatments throughout the period of experimentation *i.e* from 3 MAP up to 24 MAP. At the time of planting, the plantable plants had only 1.00 cm to 1.12 cm girth at collar per plant, which were not significantly different. On 3 MAP maximum girth at collar of 1.41 cm was observed under T₄ (VC+Az+P+Pf+As) followed by T₂ (conventional) with 1.35 cm, while minimum girth of 1.20 cm was observed under T₁ (control).

Perusal of data (Table 4.01.06) indicated that, similar trend was observed during 6 MAP to 24 MAP where, plants under T₄ (VC+Az+P+Pf+As) observed to be with maximum girth ranging from 1.76 cm to 4.14 cm followed by T₂ (conventional) ranging from 1.70 cm to 3.80 cm. While T₁ (control) has significantly recorded minimum girth at collar per plant up to 24 MAP with the ranging from 1.40 cm to 2.66 cm.

4.01.07. Spreading

Observations on spreading of young tea plants at three months interval upto 24 MAP are presented in Table 4.01.07 and illustrated in Fig. 4.01.05. Plant spreading increased continuously with the advancement of age up to 24 MAP. Among all the treatments, spreading of young tea plants on 3 MAP, the significantly maximum of 649.82 cm² plant spreading was observed in T₂ (conventional) followed by T₄ (VC+Az+P+Pf+As) with 641.74 cm² spreading, they were at par with each other, while lowest spreading was observed in T₁ (control) with 349.76 cm². On 6 MAP, the significantly maximum (832.67 cm²) plant spreading was observed in T₄ (VC+Az+P+Pf+As) followed by T₂ (conventional) with 820.11 cm², while lower plant spreading was observed in T₁ (control) with 462.10 cm². From 9 MAP to 21 MAP similar trend was followed, T₄ (VC+Az+P+Pf+As) significantly maximum plant spreading was noticed ranging from 882.70 cm² to 1823.36 cm² followed by T₂ (conventional) with 870.69 cm² to 1785.74 cm², while minimum plant spreading was recorded in T₁ (control)

Table 4.01.06: Effect of organic cultivation of tea (TV 26) on girth at collar of plant (5 cm from ground level) at three months interval

Treatments	Girth at collar (cm) of plant on months after planting								
	0 [#]	3	6	9	12	15	18	21	24
	(May'15)	(Aug'15)	(Nov'15)	(Feb'16)	(May'16)	(Aug'16)	(Nov'16)	(Feb'17)	(May'17)
T ₁ (Control)	1.08	1.20	1.40	1.48	1.61	2.07	2.32	2.47	2.66
T ₂ (Conventional)	1.05	1.35	1.70	2.05	2.29	2.77	3.25	3.55	3.80
T ₃ (VC)	1.01	1.27	1.51	1.60	1.96	2.35	2.75	2.97	3.26
T ₄ (VC+Az+P+Pf+As)*	1.12	1.41	1.76	2.21	2.56	3.09	3.41	3.78	4.14
T ₅ (VC+Az+V+Pf+As)**	1.12	1.34	1.66	1.99	2.23	2.73	3.19	3.49	3.77
T ₆ (FYM)	1.02	1.24	1.50	1.50	1.81	2.20	2.54	2.70	3.04
T ₇ (FYM+Az+P+Pf+As)*	1.11	1.32	1.63	1.78	2.14	2.52	2.91	3.23	3.51
T ₈ (FYM+Az+V+Pf+As)**	1.08	1.30	1.60	1.71	2.10	2.48	2.86	3.08	3.35
SEm (±)	0.03	0.01	0.01	0.02	0.03	0.02	0.03	0.02	0.03
CD (P=0.05)	N.S	0.04	0.03	0.06	0.09	0.07	0.08	0.06	0.08

VC- vermicompost; *Az+P+ Pf +As -*Azotobacter* + PSB + *Pseudomonas fluorescens* + *Azospirillum*;

**Az+V+ Pf +As - *Azotobacter*+ VAM + *Pseudomonas fluorescens* + *Azospirillum*; FYM- farm yard manure

- indicate girth at collar per plant at the time of planting (5 cm above the ground level)

Table 4.01.07: Effect of organic cultivation of tea (TV 26) on spreading of young tea bush at three months interval

Treatments	Spreading (cm ²) of young tea bush on months after planting							
	3 (Aug'15)	6 (Nov'15)	9 (Feb'16)	12 (May'16)	15 (Aug'16)	18 (Nov'16)	21 (Feb'17)	24 (May'17)
T ₁ (Control)	349.76	462.10	511.67	591.05	768.43	897.51	942.60	1011.33
T ₂ (Conventional)	649.82	820.11	870.69	1177.09	1503.31	1736.82	1785.74	1885.67
T ₃ (VC)	470.67	719.33	750.37	981.54	1237.08	1422.73	1501.67	1613.29
T ₄ (VC+Az+P+Pf+As)*	641.74	832.67	882.70	1192.68	1527.33	1769.28	1823.36	1961.44
T ₅ (VC+Az+V+Pf+As)**	578.68	792.33	829.53	1091.02	1412.30	1696.15	1749.11	1891.08
T ₆ (FYM)	439.35	651.32	678.24	941.21	1167.32	1288.13	1343.33	1488.22
T ₇ (FYM+Az+P+Pf+As)*	518.67	759.66	789.72	1036.67	1349.21	1506.33	1568.86	1696.91
T ₈ (FYM+Az+V+Pf+As)**	491.12	730.21	757.08	1000.84	1307.37	1456.80	1516.69	1653.47
SEm (±)	4.30	3.32	3.31	2.66	2.82	3.15	3.68	3.09
CD (P=0.05)	13.05	10.08	10.03	8.06	8.55	9.55	11.15	9.38

VC- vermicompost; *Az+P+Pf+As -*Azotobacter* + PSB + *Pseudomonas fluorescens* + *Azospirillum*;

**Az+V+Pf+As - *Azotobacter*+ VAM + *Pseudomonas fluorescens* + *Azospirillum*; FYM- farm yard manure

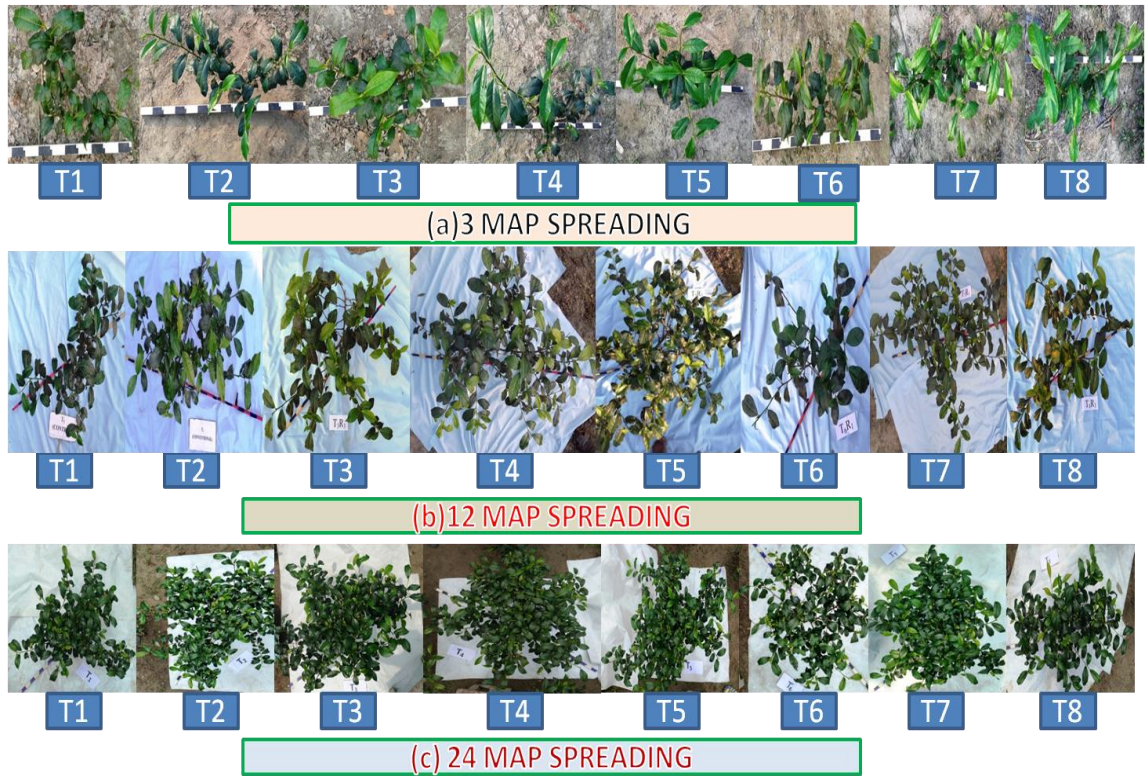


Plate 4.03: Photographs showing spreading of young tea plants at different stages of growth (a) 3 MAP (b) 12 MAP (c) 24 MAP



Plate 4.04: Photographs showing plant infested by a few pests

(a) Tea mosquito bug (*Helopeltis theivora*)

(b) looper (*Biston suppressaria*)

with ranging from 511.67 cm² to 942.60 cm². On 24 MAP, maximum spreading of 1961.44 cm² was observed in T₄ (VC+Az+P+Pf+As) followed by T₅ (VC+Az+V+Pf+As) with 1891.08 cm², while lowest plant spreading was observed in T₁ (control) with 1011.33 cm².

4.02. Yield and yield attributes of young tea plants under organic cultivation

4.02.01. Number of two leaves and a bud harvested per plot

Month wise observations on total number of two leaf and a bud harvested per plot at eight days interval have been presented in Table 4.02.01 and Fig 4.02.01. The data on total number of two leaf and a bud harvested per plot differed significantly among the treatments up to 24 months. It is apparent from Table 4.02.01 that in general, number of two leaf and a bud increased from onset of plucking season in march to August/September and then after, decreased in winter season from September / October, T₄ (VC+Az+P+Pf+As) showed maximum total number of two leaf and a bud harvested per plot in all months from on 5MAP to 24 MAP followed by T₂ (conventional), while minimum in T₁ (control).

Observations on total number of two leaves and a bud harvested per plot on 3 MAP and 4 MAP *i.e.* during the month of August and September, 2015 significantly maximum 51.29 and 110.08 of two leaves and a bud were harvested per plot, respectively in T₂ (conventional) followed by T₄ (VC+Az+P+Pf+As) with 45.41 and 103.14, respectively but they were observed at par with each other on 4 MAP. While, minimum two leaves and a bud of 2.53 and 27.56 harvested per plot, respectively was noticed in T₁ (control). From 5th to 7th MAP, *i.e.* from October to December, 2015 number of two leaves and a bud generally decreased. Plants under treatment T₄ (VC+Az+P+Pf+As) produced maximum number of two leaves and a bud (85.39) during 5 MAP which was at par with T₂ (conventional) producing 78.88 number of two leaves and a bud. Minimum of only 27.22 number of two leaves and a bud were produced in T₁ (control). Similar trend was followed on 6 MAP and 7 MAP. Significantly maximum 70.82 and 65.71 of two

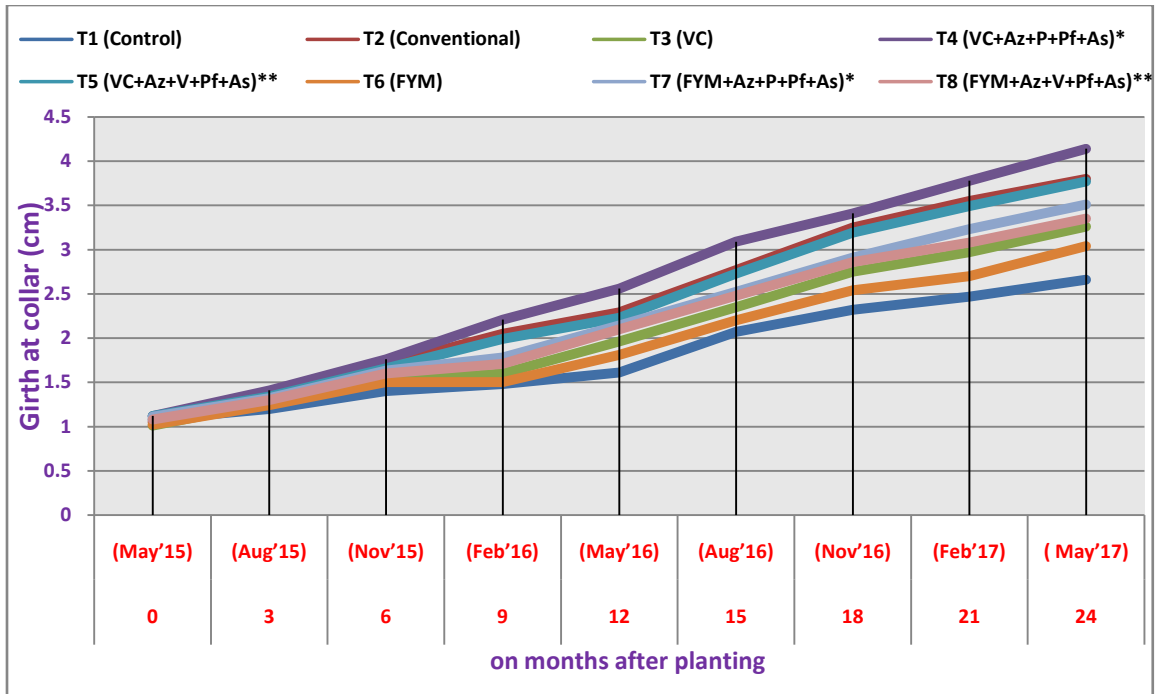


Fig. 4.01.04: Effect of organic cultivation on girth at collar at three months interval upto 24 months after planting

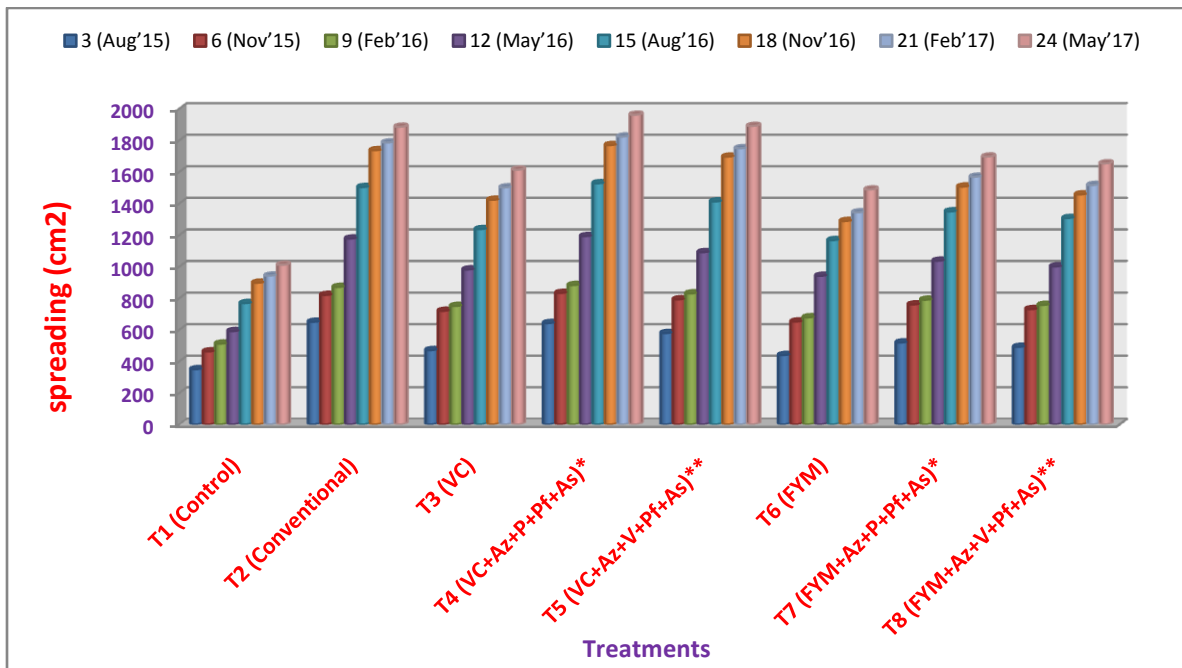


Fig. 4.01.05: Effect of organic cultivation on spreading of bush at three months interval upto 24 months after planting

leaves and a bud harvested per plot, respectively in T₄ (VC+Az+P+Pf+As) followed by T₂ (conventional) with 59.45 and 54.78, respectively while, minimum two leaves and a bud of 19.71 and 14.82 harvested per plot, respectively was noticed in T₁ (control).

On 10 MAP *i.e.* March, 2016 to 15 MAP *i.e.* August, 2016 total number of two leaves and a bud increased. T₄ (VC+Az+P+Pf+As) recorded highest total number of two leaves and a bud harvested per plot ranging from 112.05 to 633.67 followed by T₂ (conventional) ranging from 96.72 to 620.33 while, T₁ (control) has recorded lowest number of two leaves and a bud harvested per plot with the ranging from 46.08 to 327.45. Similar trend was followed from on 16 MAP *i.e.* September, 2016 to 19 MAP *i.e.* December, 2016 total number of two leaves and a bud per plot decreased. T₄ (VC+Az+P+Pf+As) recorded highest total number of two leaves and a bud harvested per plot ranging from 624.67 to 367.67 followed by T₂ (conventional) ranging from 601.17 to 346.33 while, T₁ (control) has recorded lowest number of two leaves and a bud harvested per plot with the ranging from 319.67 to 137.67.

Perusal of data on total number of two leaves and a bud harvested per plot (Table 4.02.01) showed that on 22 MAP *i.e.* March, 2017 and 23 MAP *i.e.* April, 2017 T₄ (VC+Az+P+Pf+As) recorded highest 747.12 and 1000.47 of total number of two leaves and a bud harvested per plot, respectively followed by T₂ (conventional) with 651.67 and 945.33, respectively while, T₁ (control) has recorded lowest 230.53 and 458.07 of total number of two leaves and a bud harvested per plot, respectively. On 24 MAP significantly maximum 1271.33 of two leaves and a bud harvested per plot was observed in T₄ (VC+Az+P+Pf+As) followed by in T₅ (VC+Az+V+Pf+As) with 1186.67 while, lowest 521.67 of two leaves and a bud harvested per plot was observed in T₁ (control).

4.02.02. Fresh weight of two leaves and a bud per plot

Month wise observations on fresh weight of two leaves and a bud harvested per plot have been presented in Table 4.02.02 and Fig 4.02.02. It is evident from data the fresh weight of two leaves and a bud differed significantly among all treatments throughout the period of experimentation *i.e.* from 3 MAP up to 24 months. It is apparent from Table 4.02.02 that, in general, fresh weight of two leaves and a bud increased from

Table 4.02.01: Effect of organic cultivation of tea (TV 26) on number of two leaves and a bud harvested per plot month wise up to 24 months after planting

Treatments	Number of two leaves and a bud on months after planting																	
	2015					2016										2017		
	3 (Aug)	4 (Sep)	5 (Oct)	6 (Nov)	7 (Dec)	10 (Mar)	11 (Apr)	12 (May)	13 (Jun)	14 (Jul)	15 (Aug)	16 (Sep)	17 (Oct)	18 (Nov)	19 (Dec)	22 (Mar)	23 (Apr)	24 (May)
T ₁ (Control)	2.53	27.56	27.22	19.71	14.82	46.08	51.51	75.78	223.64	309.18	327.45	319.67	268.33	194.67	137.67	230.53	458.07	521.67
T ₂ (Conventional)	51.29	110.08	78.88	59.45	54.78	96.72	130.63	175.18	436.04	533.67	620.33	601.17	557.33	510.13	346.33	651.67	945.33	1181.33
T ₃ (VC)	10.28	44.28	40.49	32.43	29.44	63.96	81.95	121.85	329.72	448.67	496.94	462.33	431.67	381.36	232.33	447.33	692.67	945.67
T ₄ (VC+Az+P+Pf+As)*	45.41	103.14	85.39	70.82	65.71	112.05	147.94	194.05	456.16	548.33	633.67	624.67	579.33	529.67	367.67	747.12	1000.47	1271.33
T ₅ (VC+Az+V+Pf+As)**	28.48	79.43	61.14	55.47	51.24	87.45	119.10	167.43	422.29	529.67	611.33	581.67	544.67	507.33	332.67	642.33	935.67	1186.67
T ₆ (FYM)	8.57	37.24	34.9	25.30	18.36	54.93	68.28	99.53	283.44	422.67	445.33	429.67	395.33	360.67	180.67	366.67	575.33	687.33
T ₇ (FYM+Az+P+Pf+As)*	20.48	58.04	56.66	44.09	38.98	86.70	114.75	159.03	402.08	496.67	567.67	535.33	493.33	479.33	249.33	515.67	900.67	1030.67
T ₈ (FYM+Az+V+Pf+As)**	14.08	50.84	42.51	39.29	33.84	73.95	100.98	131.65	377.92	476.33	546.65	517.33	473.67	430.33	238.33	471.33	802.33	968.67
SEm (±)	0.71	2.46	2.81	2.03	2.32	2.35	3.30	1.93	3.10	3.63	2.58	2.82	2.52	2.24	2.05	3.03	3.42	3.67
CD (P=0.05)	2.16	7.47	8.52	6.17	7.02	7.12	10.00	5.86	9.40	11.02	7.83	8.55	7.65	6.79	6.21	9.20	10.36	11.13

VC- vermicompost; *Az+P+Pf+As -*Azotobacter* + PSB + *Pseudomonas fluorescens* + *Azospirillum*;

**Az+V+Pf+As - *Azotobacter*+ VAM + *Pseudomonas fluorescens* + *Azospirillum*; FYM- farm yard manure

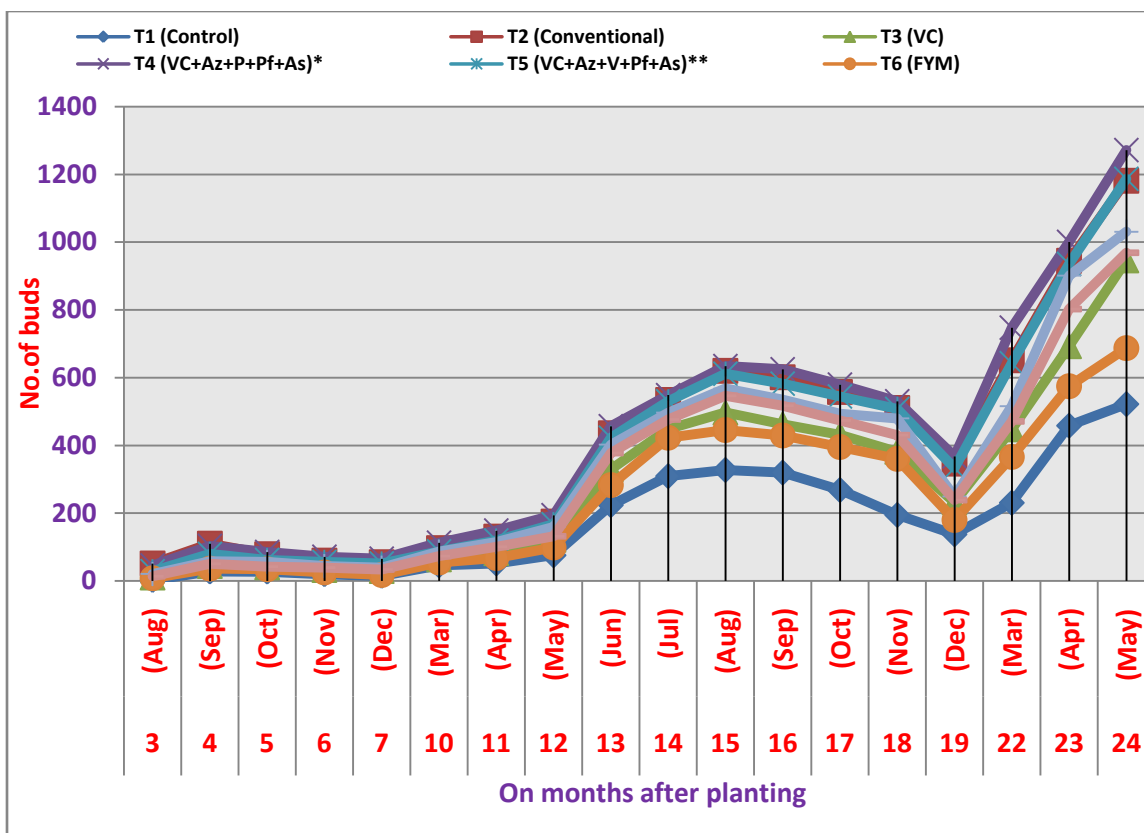


Fig. 4.02.01: Effect of organic cultivation on number of two leaves and a bud harvested per plot month wise up to 24 months after planting

onset of plucking season in march to August/September and then after, decreased in winter season from September / October, T4 (VC+Az+P+Pf+As) showed maximum fresh weight of two leaf and a bud in all months from on 5 MAP to 24 MAP followed by T₂ (conventional), while minimum in T₁ (control). on 3 MAP (Aug' 15) and 4 MAP (Sept' 15) significantly, maximum of 12.84 g, 28.02 g of two leaf and a bud were harvested per plot, respectively in T₂ (conventional) followed by T₄ (VC+Az+P+Pf+As) with 11.65 g and 26.54 g, respectively but they were at par with each other. Minimum of 0.67 g and 6.89 g of two leaf and a bud were harvested per plot, respectively in T₁ (control) during the same period. On 5th MAP *i.e.* in Oct' 15 the plants under Treatment T₄ (VC+Az+P+Pf+As) produced maximum 23.85 g two leaf and a bud per plot, which was comparatively less than the weight two leaf and a bud produced 26.54 g during Sept' 15 and minimum of 6.27 g leaves were produced by the plants under by T₁ (control). During 6th (Nov' 15) and 7th (Dec' 15) MAP, the amount of two leaf and a bud produced were

still less compared to previous months. Maximum T₄ (VC+Az+P+Pf+As) leaves harvested per plot during the 6 MAP and 7 MAP were 21.12 g and 20.28 g while minimum were 5.30 g and 5.11 g respectively in T₁ (control) (Table.4.02.02). From Dec' 15 to Feb' 16 the bushes were under dormancy so no leaves were harvested.

On 10 MAP, *i.e.* Mar'16 to 15 MAP fresh weight of two leaf and a bud per plot increased, T₄ (VC+Az+P+Pf+As) recorded highest fresh weight of two leaf and a bud harvested per plot 35.35 g to 176.58 g followed by T₂ (conventional) 32.24 g to 169.25 g while, T₁ (control) had recorded lowest fresh weight of two leaf and a bud per plot ranging from 15.36 g to 85.41 g. From on 16 MAP *i.e.* Sept' 16 to 19 MAP (Dec' 16) similar trend as observed in previous year 2015 was followed fresh weight of two leaf and a bud per plot decreased. The plants under T₄ (VC+Az+P+Pf+As) recorded highest fresh weight of two leaf and a bud harvested per plot ranging from 175.91 g to 102.02 g followed by T₂ (conventional) ranging from 168.47 g to 95.78 g while, lowest fresh weight of two leaf and a bud harvested per plot ranging from 82.48 g to 40.28 g under T₁ (control).

On 22 MAP, *i.e.* Mar' 17 and 23 MAP T₄ (VC+Az+P+Pf+As) recorded highest fresh weight of two leaf and a bud 210.68 g and 283.70 g per plot, respectively followed by T₂ (conventional) with 187.21 g and 267.29 g, respectively while, T₁ (control) was recorded with lowest 63.66 g and 128.41 g of two leaf and a bud harvested per plot, respectively. Finally on 24 MAP (Table 4.02.02) revealed that T₄ (VC+Az+P+Pf+As) recorded highest 345.03 g of two leaf and a bud harvested per plot followed by T₅ (VC+Az+V+Pf+As) with 319.54 g while, T₁ (control) recorded lowest 140.08 g of two leaf and a bud harvested per plot.

4.02.03. Dry weight of two leaf and a buds per plot

Month wise observations on dry weight of two leaf and a bud harvested per plot have been presented in Table 4.02.03 and illustrated in Fig 4.02.03. The data on dry weight of two leaf and a bud harvested per plot differed significantly among the treatments up to 24 MAP. On 3 MAP and 4 MAP *i.e.* during the month of August and September, 2015 significantly maximum of 3.15 g and 6.46 g of two leaf and a buds were

harvested in T₂ (conventional) per plot, respectively followed by T₄ (VC+Az+P+Pf+As) with 2.75 g and 5.53 g, respectively were they were observed at par with each other. While, minimum 0.16 g and 1.64 g of two leaf and a buds harvested per plot, respectively in T₁ (control). From 5th (Oct '15) to 7th MAP (Dec '15) dry weight of two leaf and a bud per plot for all the treatments decreased; T₄ (VC+Az+P+Pf+As) recorded highest dry weight of two leaf and a buds harvested per plot ranging from 5.31 g to 5.19 g followed by T₂ (conventional) ranging from 4.82 g to 4.29 g but they were at par with each other on 5 MAP and 6 MAP. While, T₁ (control) was recorded lowest dry weight of two leaf and a bud harvested per plot with the ranging from 1.57 g to 1.35 g.

On 10 MAP to 15 MAP, dry weight of two leaf and a bud per plot increased in all the treatments, T₄ (VC+Az+P+Pf+As) recorded highest dry weight of two leaf and a bud harvested per plot ranging from 9.04 g to 39.36 g followed by T₂ (conventional) with 8.06 g to 37.82 g while, (3.84 g to 16.81 g), T₁ (control) has recorded lowest dry weight of two leaf and a bud harvested per plot. On 16 MAP to 19 MAP *i.e.* from Sept '16 to Dec '16 dry weight of two leaf and a bud per plot decreased, in all the plots and T₄ (VC+Az+P+Pf+As) recorded highest dry weight ranging from 39.38 g to 28.27 g followed by T₂ (conventional) ranging from 37.45 g to 26.32 g while, T₁ (control) recorded lowest dry weight of two leaf and a bud harvested per plot with the ranging from 16.53 g to 10.71 g. On 22 MAP and 23MAP, T₄ (VC+Az+P+Pf+As) recorded highest 63.01 g and 73.54 g of two leaf and a bud harvested per plot, respectively followed by T₂ (conventional) with 56.55 g and 67.81 g, respectively while, T₁ (control) has recorded lowest 17.09 g and 31.95 g of two leaf and a bud harvested per plot, respectively. Finally, on 24 MAP (Table 4.02.02) revealed that T₄ (VC+Az+P+Pf+As) recorded highest 86.26 g of two leaf and a bud harvested per plot followed by T₅ (VC+Az+V+Pf+As) with 79.22 g while, T₁ (control) has recorded lowest 33.35 g of two leaf and a bud harvested per plot.

Table 4.02.02: Effect of organic cultivation of tea (TV 26) on fresh weight of two leaves and a bud harvested per plot month wise up to 24 months after planting

Treatments	Fresh weight (g) of two leaves and a bud on months after planting																	
	2015					2016										2017		
	3 (Aug)	4 (Sep)	5 (Oct)	6 (Nov)	7 (Dec)	10 (Mar)	11 (Apr)	12 (May)	13 (Jun)	14 (Jul)	15 (Aug)	16 (Sep)	17 (Oct)	18 (Nov)	19 (Dec)	22 (Mar)	23 (Apr)	24 (May)
T ₁ (Control)	0.67	6.89	6.27	5.30	5.11	15.36	22.78	30.31	58.41	82.60	85.41	82.48	75.30	52.63	40.28	63.66	128.41	140.08
T ₂ (Conventional)	12.84	28.02	22.17	19.02	17.89	32.24	48.38	70.07	109.01	146.29	169.25	168.47	156.30	144.38	95.78	187.21	267.29	315.96
T ₃ (VC)	2.67	11.07	10.28	10.01	9.95	21.32	30.35	46.74	80.68	122.42	132.34	120.67	108.63	102.52	59.60	129.25	195.06	261.40
T ₄ (VC+Az+P+Pf+As)*	11.65	26.54	23.85	21.12	20.28	35.35	52.57	77.78	114.04	151.36	176.58	175.91	162.61	149.75	102.02	210.68	283.70	345.03
T ₅ (VC+Az+V+Pf+As)**	7.12	19.85	17.07	16.52	15.67	29.15	44.11	66.97	105.63	145.37	166.25	162.59	152.58	143.71	94.02	180.80	264.20	319.54
T ₆ (FYM)	2.21	9.31	8.17	7.37	6.33	18.31	25.26	39.81	70.86	114.66	118.20	110.22	103.96	97.79	49.77	102.82	161.47	198.81
T ₇ (FYM+Az+P+Pf+As)*	5.12	14.50	13.38	12.33	11.44	28.90	42.50	63.67	100.52	135.87	153.22	148.46	138.21	135.46	68.57	143.66	254.42	299.42
T ₈ (FYM+Az+V+Pf+As)**	3.62	13.46	11.04	10.55	10.07	24.65	37.4	52.66	94.48	130.50	147.24	135.69	124.43	114.14	62.30	134.86	226.41	270.75
SEm (±)	0.42	0.52	0.57	0.65	0.55	0.81	0.94	0.62	1.32	1.09	2.16	2.07	2.03	1.37	1.71	3.66	3.29	2.97
CD (P=0.05)	1.28	1.57	1.72	1.96	1.67	2.46	2.86	1.87	4.01	3.31	6.55	6.28	6.17	4.15	5.19	11.09	9.99	8.99

VC- vermicompost; *Az+P+Pf+As -Azotobacter + PSB + *Pseudomonas fluorescens* + *Azospirillum*;

**Az+V+Pf+As - Azotobacter+ VAM + *Pseudomonas fluorescens* + *Azospirillum*; FYM- farm yard manure

Table 4.02.03: Effect of organic cultivation of tea (TV 26) on dry weight of two leaves and a bud harvested per plot month wise up to 24 months after planting

Treatments	Dry weight (g) of two leaves and a bud on months after planting																	
	2015					2016										2017		
	3 (Aug)	4 (Sep)	5 (Oct)	6 (Nov)	7 (Dec)	10 (Mar)	11 (Apr)	12 (May)	13 (Jun)	14 (Jul)	15 (Aug)	16 (Sep)	17 (Oct)	18 (Nov)	19 (Dec)	22 (Mar)	23 (Apr)	24 (May)
T ₁ (Control)	0.16	1.64	1.57	1.45	1.35	3.84	5.56	7.22	13.28	16.14	16.81	16.53	16.48	13.35	10.71	17.09	31.95	33.35
T ₂ (Conventional)	3.15	6.46	4.82	4.55	4.29	8.06	11.8	15.98	24.78	31.32	37.82	37.45	36.77	35.22	26.32	56.55	67.81	76.99
T ₃ (VC)	0.53	2.64	2.62	2.53	2.34	5.33	7.40	11.73	18.84	26.27	29.75	26.13	24.84	22.51	16.05	38.75	49.12	64.02
T ₄ (VC+Az+P+Pf+As)*	2.75	5.53	5.31	5.23	5.19	9.04	13.22	18.52	25.92	33.77	39.36	39.38	38.10	36.40	28.27	63.01	73.54	86.26
T ₅ (VC+Az+V+Pf+As)**	1.59	4.73	4.37	4.15	4.02	7.29	10.76	15.90	24.10	30.84	37.35	37.03	36.58	35.13	24.82	56.36	68.69	79.22
T ₆ (FYM)	0.50	2.22	2.18	2.02	1.94	4.58	6.16	9.48	16.10	23.58	24.38	23.89	22.82	21.81	13.03	28.79	40.69	48.03
T ₇ (FYM+Az+P+Pf+As)*	1.22	3.45	3.25	3.10	2.63	7.06	10.37	15.14	22.85	28.74	33.3	32.67	30.52	30.16	18.63	50.33	65.02	72.86
T ₈ (FYM+Az+V+Pf+As)**	0.89	3.2	2.94	2.66	2.39	6.19	9.12	12.54	21.47	27.29	31.8	30.56	28.52	27.33	16.73	40.64	56.18	66.19
SEm (±)	0.15	0.14	0.28	0.27	0.20	0.29	0.32	0.32	0.35	0.48	0.45	0.32	0.46	0.17	0.29	0.46	0.37	0.85
CD (P=0.05)	0.46	0.43	0.84	0.81	0.61	0.88	0.97	0.96	1.05	1.46	1.36	0.96	1.38	0.52	0.88	1.41	1.12	2.57

VC- vermicompost; *Az+P+Pf+As -*Azotobacter* + PSB + *Pseudomonas fluorescens* + *Azospirillum*;

**Az+V+Pf+As - *Azotobacter*+ VAM + *Pseudomonas fluorescens* + *Azospirillum*; FYM- farm yard manure

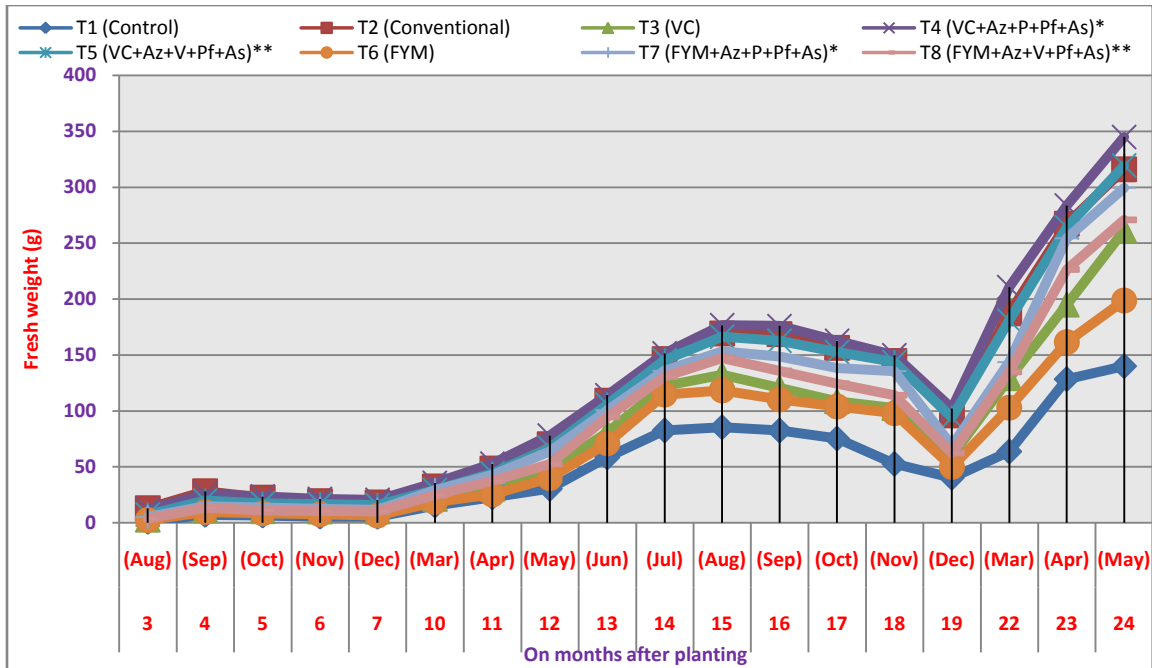


Fig. 4.02.02: Effect of organic cultivation on fresh weight of two leaves and a bud harvested per plot month wise up to 24 months after planting

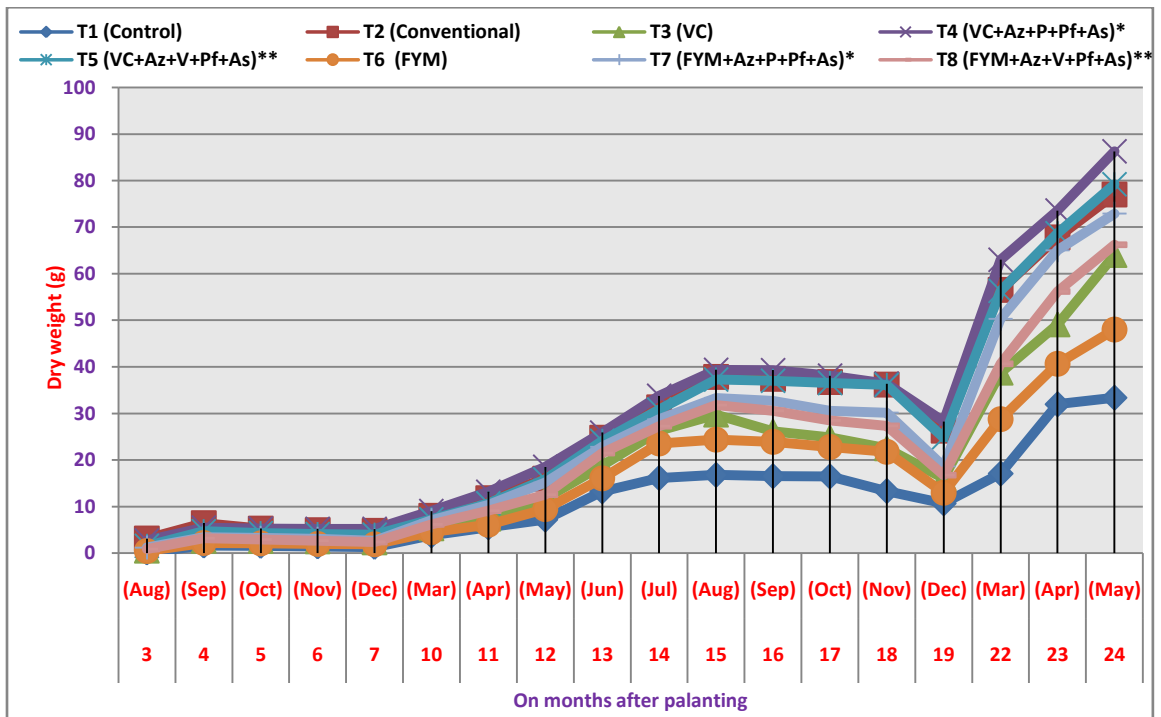


Fig. 4.02.03: Effect of organic cultivation on dry weight of two leaves and a bud harvested per plot month wise up to 24 months after planting

4.02.04. Percentage of growing buds

Month wise observations on percentage of growing buds harvested per plot have been depicted in Table 4.02.04 and illustrated in Fig 4.02.04. It is evident that the percentage of growing buds differed significantly among all the treatments throughout the period of experimentation, *i.e.* from 3 MAP up to 24 months. Overall, percentage of growing buds decreased in winter season compared to rainy and summer season and T₄ (VC+Az+P+Pf+As) showed maximum percentage of growing buds in all months from on 3 MAP to 24 MAP followed by T₂ (conventional), while minimum in T₁ (control). Maximum Percentage of growing buds harvested per plot on 3 MAP and 4 MAP, with 98.92 % and 99.16 %, respectively in T₄ (VC+Az+P+Pf+As) followed by in T₂ (conventional) with 98.97 % and 98.94 %, respectively but they were at par with each other. While, minimum 89.27 % and 89.55 % of growing buds harvested per plot, respectively was noticed in T₁ (control). On 5 MAP (Oct' 15) to 7 MAP (Dec' 15) percentage of growing buds decreased significantly T₄ (VC+Az+P+Pf+As) recorded highest percentage of growing buds harvested per plot ranging from 95.14 % to 79.44 % followed by T₂ (conventional) ranging from 94.12 % to 78.37 % while, T₁ (control) has significantly recorded lowest percentage of growing buds harvested per plot with the ranging from 79.67 % to 60.02 %.

Mar' 16 to Sep' 16 on 10 MAP to 16 MAP percentage of growing buds increased, T₄ (VC+Az+P+Pf+As) significantly showed maximum percentage of growing buds harvested per plot ranging from 96.40 % to 98.12 % followed by T₂ (conventional) with 95.87 % to 97.90 %, but they were at par with each other on 11 MAP, 14 MAP, 15 MAP and 16 MAP. While, T₁ (control) has significantly recorded lowest percentage of growing buds harvested per plot with the ranged from 75.82 to 88.51 per cent. On 17 MAP (Oct'16) to 19 MAP (Dec' 16) decreased percentage of growing buds, T₄ (VC+Az+P+Pf+As) significantly recorded highest percentage of growing buds harvested per plot ranging from 94.45 % to 78.87 % followed by T₂ (conventional) ranging from 93.10 % to 77.47 %. While, T₁ (control) has significantly recorded lowest percentage of growing buds harvested per plot with the ranged from 78.65 % to 61.12 %. On 22 MAP to 24 MAP percentage of growing buds increased, T₄ (VC+Az+P+Pf+As) significantly showed maximum percentage of growing buds harvested per plot ranged from 94.88 % to

Table 4.02.04: Effect of organic cultivation of tea (TV 26) on percentage of growing buds per plot month wise up to 24 months after planting

Treatments	Growing buds (%) on months after planting																	
	2015					2016										2017		
	3 (Aug)	4 (Sep)	5 (Oct)	6 (Nov)	7 (Dec)	10 (Mar)	11 (Apr)	12 (May)	13 (Jun)	14 (Jul)	15 (Aug)	16 (Sep)	17 (Oct)	18 (Nov)	19 (Dec)	22 (Mar)	23 (Apr)	24 (May)
T ₁ (Control)	89.27	89.55	79.67	73.09	60.02	75.82	80.43	83.03	84.82	85.07	88.48	88.51	78.65	72.13	61.12	75.04	86.85	90.73
T ₂ (Conventional)	98.87	98.94	94.12	92.47	78.37	95.87	96.39	96.79	97.34	97.63	97.82	97.90	93.10	91.81	77.47	94.35	96.62	97.55
T ₃ (VC)	96.36	96.48	91.10	88.20	71.61	90.71	93.28	94.23	94.83	95.27	95.31	95.44	90.08	87.24	70.71	89.19	94.29	95.77
T ₄ (VC+Az+P+Pf+As)*	98.92	99.16	95.14	93.07	79.44	96.40	96.73	97.78	98.04	98.07	98.10	98.12	94.45	92.44	78.87	94.88	97.25	98.27
T ₅ (VC+Az+V+Pf+As)**	97.41	98.04	93.21	89.96	73.27	93.02	94.82	95.64	96.25	96.26	96.36	97.05	92.19	89.05	72.37	91.50	95.43	97.53
T ₆ (FYM)	94.14	95.11	90.15	86.20	65.62	84.16	88.81	90.04	91.02	91.32	92.09	93.07	89.13	85.24	62.72	78.64	93.05	93.74
T ₇ (FYM+Az+P+Pf+As)*	97.40	97.83	92.77	89.66	74.68	91.47	94.34	94.81	95.03	95.65	96.35	96.79	91.75	88.70	71.78	90.15	95.25	96.99
T ₈ (FYM+Az+V+Pf+As)**	96.35	96.22	91.83	88.56	72.37	90.74	92.53	94.51	94.98	95.32	95.42	95.48	90.81	87.60	70.47	89.22	95.01	95.78
SEm (±)	0.30	0.15	0.22	0.18	0.26	0.15	0.24	0.17	0.18	0.16	0.18	0.15	0.17	0.19	0.18	0.18	0.17	0.15
CD (P=0.05)	0.92	0.47	0.67	0.55	0.79	0.47	0.72	0.52	0.54	0.48	0.54	0.47	0.52	0.58	0.55	0.54	0.52	0.47

VC- vermicompost; *Az+P+Pf+As -*Azotobacter* + PSB + *Pseudomonas fluorescens* + *Azospirillum*;

**Az+V+Pf+As - *Azotobacter*+ VAM + *Pseudomonas fluorescens* + *Azospirillum*; FYM- farm yard manure

98.27 % followed by T₂ (conventional) ranging from 94.35 % to 97.55 %, but they were at par with each other on 22 MAP. While, lowest percentage of growing buds T₁ (control) recorded with the ranging from 75.04% to 90.73 %.

4.02.05. Percentage of dormant buds

Month wise observations on percentage of dormant buds harvested per plot have been depicted in Table 4.02.05; it was found to be significant among the all treatments up to 24 MAP and illustrated in Fig 4.02.05. Overall, percentage of dormant buds increased in winter season compared to rainy and summer season and T₄ (VC+Az+P+Pf+As) showed minimum percentage of dormant buds in all months from on 3 MAP to 24 MAP followed by T₂ (conventional), while maximum in T₁ (control). On 3 MAP and 4 MAP, significantly minimum with 1.08 % and 0.84 % of dormant buds harvested per plot, respectively was noticed in T₄ (VC+Az+P+Pf+As) followed by in T₂ (conventional) with 1.13 % and 1.06 %, respectively, but they were at par with each other. While, maximum 10.73% and 10.45 % of dormant buds harvested per plot, respectively was noticed in T₁ (control). On 5 MAP to 7 MAP percentage of dormant buds increased, T₄ (VC+Az+P+Pf+As) significantly recorded lowest percentage of dormant buds harvested per plot ranged from 4.53 % to 20.56 % followed by T₂ (conventional) ranged from 5.88 % to 21.63 %. While, T₁ (control) has significantly recorded highest percentage of dormant buds harvested per plot with the ranged from 20.33 % to 39.98 %. On 10 MAP to 16 MAP percentage of dormant buds decreased, T₄ (VC+Az+P+Pf+As) significantly showed minimum percentage of dormant buds harvested per plot ranged from 3.60 % to 1.88 % followed by T₂ (conventional) ranged from 4.13 % to 2.10 %, but they were at par with each other on 11 MAP, 14 MAP, 15 MAP and 16 MAP. While, T₁ (control) has significantly recorded maximum percentage of dormant buds harvested per plot with the ranged from 24.18 % to 11.49 %.

On 17 MAP to 19 MAP increased dormant buds percentage, T₄ (VC+Az+P+Pf+As) significantly observed lower percentage of dormant buds harvested per plot ranged from 5.55 % to 21.46 % followed by T₂ (conventional) ranged from 6.90 % to 22.53 % while, T₁ (control) has significantly observed higher percentage of dormant buds harvested per plot with the ranged from 21.35 % to 38.88 %. Further perusal of data

Table 4.02.05: Effect of organic cultivation of tea (TV 26) on percentage of dormant buds per plot month wise up to 24 months after planting

Treatments	Dormant buds (%) on months after planting																	
	2015					2016										2017		
	3 (Aug)	4 (Sep)	5 (Oct)	6 (Nov)	7 (Dec)	10 (Mar)	11 (Apr)	12 (May)	13 (Jun)	14 (Jul)	15 (Aug)	16 (Sep)	17 (Oct)	18 (Nov)	19 (Dec)	22 (Mar)	23 (Apr)	24 (May)
T ₁ (Control)	10.73	10.45	20.33	26.91	39.98	24.18	19.57	16.97	15.18	14.93	11.52	11.49	21.35	27.87	38.88	24.96	13.15	9.27
T ₂ (Conventional)	1.13	1.06	5.88	7.53	21.63	4.13	3.61	3.21	2.66	2.37	2.18	2.10	6.90	8.19	22.53	5.65	3.38	2.45
T ₃ (VC)	3.64	3.52	8.90	11.80	28.39	9.29	6.72	5.77	5.17	4.73	4.69	4.56	9.92	13.76	29.29	10.81	5.71	4.23
T ₄ (VC+Az+P+Pf+As)*	1.08	0.84	4.53	6.60	20.56	3.60	3.27	2.22	1.96	1.93	1.90	1.88	5.55	7.56	21.46	5.12	2.75	1.73
T ₅ (VC+Az+V+Pf+As)**	2.59	1.96	6.79	10.04	26.73	6.98	5.18	4.36	3.75	3.74	3.64	3.05	7.81	11.05	27.63	8.50	4.57	2.47
T ₆ (FYM)	5.86	4.89	9.85	13.80	34.38	15.84	11.19	9.96	8.98	8.68	7.91	6.93	10.87	14.73	37.28	21.36	6.92	6.26
T ₇ (FYM+Az+P+Pf+As)*	2.60	2.17	7.23	10.34	25.32	8.53	5.06	5.19	4.97	4.35	3.65	3.21	8.25	11.30	28.22	9.85	4.75	3.01
T ₈ (FYM+Az+V+Pf+As)**	3.93	3.78	8.17	11.44	27.63	9.26	7.47	5.49	5.02	4.68	4.58	4.52	9.19	12.4	29.53	10.78	4.99	4.22
SEm (±)	0.03	0.08	0.31	0.28	0.21	0.10	0.12	0.12	0.14	0.15	0.13	0.08	0.16	0.11	0.04	0.18	0.05	0.12
CD (P=0.05)	0.10	0.23	0.95	0.84	0.65	0.31	0.36	0.36	0.43	0.47	0.39	0.24	0.50	0.34	0.12	0.54	0.16	0.36

VC- vermicompost; *Az+P+Pf+As -*Azotobacter* + PSB + *Pseudomonas fluorescens* + *Azospirillum*;

**Az+V+Pf+As - *Azotobacter*+ VAM + *Pseudomonas fluorescens* + *Azospirillum*; FYM- farm yard manure

on 22 MAP to 24 MAP percentage of dormant buds decreased, from 5.12 % to 1.73 % in T₄ (VC+Az+P+Pf+As) followed by T₂ (conventional) with 5.65 % to 2.45 %, but they were at par with each other on 22 MAP While, T₁ (control) has significantly recorded maximum percentage of dormant buds harvested per plot with the ranged from 24.96 % to 9.27 %.

4.02.06. Volume of 20 numbers of two leaves and a bud per plot

Observations on volume of 20 numbers of two leaf and a bud per plot at three months interval of young tea plants from on 10 MAP to 22 MAP have been depicted in Table 4.02.06 and Fig 4.2.6. It is evident from data that the volume of 20 numbers of two leaf and a bud per plot differed significantly among all the treatments. On 10 MAP highest 12.05 cc volume of 20 numbers of two leaf and a bud was observed in T₄ (VC+Az+V+Pf+As) followed by T₂ (conventional) with 11.71 cc. Significantly lowest 10.87cc volume of 20 numbers of two leaf and a bud was observed in T₁ (control). on 13 MAP maximum volume of 20 numbers of two leaf and a bud 11.70 cc was observed in T₄ (VC+Az+V+Pf+As) followed by T₂ (conventional) with 11.34 cc. Significantly lowest volume of 20 numbers of two leaf and a bud 10.32cc was observed in T₁ (control).

A similar trend was observed (Table 4.02.06) during 16 MAP to 22 MAP, where T₄ (VC+Az+V+Pf+As) recorded higher volume of 20 numbers of two leaf and a bud per plot ranging from 11.90 cc to 12.43 cc followed by T₂ (conventional) ranging from 11.61 cc to 12.12 cc, while lower volume of 20 numbers of two leaf and a bud per plot with ranging from 10.58 cc to 11.24 cc in T₁ (control)

4.02.07. Leaf period

Month wise observations on leaf period per plant of young tea plants from on 11 MAP to 19 MAP *i.e.* Apr' 16 to Dec' 16 have been presented in Table 4.02.007; it is evident from data the leaf period per plant differed significantly among the all treatments and illustrated in Fig 4.02.07. Overall leaf period per plant increased in winter season compared to rainy and summer season and T₄ (VC+Az+P+Pf+As) showed minimum leaf period per plant in all months from on 11 MAP to 19 MAP followed by T₂ (conventional), while maximum in T₁ (control).

Table 4.02.06: Effect of organic cultivation of tea (TV 26) on volume of 20 numbers of two leaves and a bud per plot at three months interval

Treatments	Volume (cc) on months after planting				
	10 (Mar'16)	13 (Jun'16)	16 (Sep'16)	19 (Dec'16)	22 (Mar'17)
T ₁ (Control)	10.87	10.32	10.58	10.88	11.24
T ₂ (Conventional)	11.71	11.34	11.61	11.84	12.12
T ₃ (VC)	11.31	11.02	11.12	11.42	11.68
T ₄ (VC+Az+P+Pf+As)*	12.05	11.70	11.90	12.15	12.43
T ₅ (VC+Az+V+Pf+As)**	11.61	11.27	11.51	11.73	11.95
T ₆ (FYM)	11.01	10.74	10.92	11.08	11.34
T ₇ (FYM+Az+P+Pf+As)*	11.40	11.12	11.35	11.50	11.69
T ₈ (FYM+Az+V+Pf+As)**	11.25	10.95	11.22	11.37	11.58
SEm (±)	0.07	0.07	0.06	0.05	0.08
CD (P=0.05)	0.21	0.22	0.19	0.14	0.25

VC- vermicompost

*Az+P+Pf+As -Azotobacter + PSB + *Pseudomonas fluorescens* + *Azospirillum*

**Az+V+Pf+As - Azotobacter+ VAM + *Pseudomonas fluorescens* + *Azospirillum*

FYM- farm yard manure

Observations on leaf period per plant (Table 4.02.07) on 11 MAP, significantly minimum (4.28 days) leaf period per plant was noticed in T₄ (VC+Az+P+Pf+As) followed by in T₂ (conventional) with 4.32 days, but they were at par with each other. While, maximum (4.67 days) leaf period per plant was noticed in T₁ (control). From 12 MAP to 14 MAP leaf period per plant decreased, T₄ (VC+Az+P+Pf+As) significantly showed minimum leaf period per plant ranging from 4.06 days to 3.11days followed by T₂ (conventional) ranging from 4.09 days to 3.14 days, but they were at par with each other from on 12 MAP to 14 MAP while, T₁ (control) has recorded maximum leaf period per plant with the ranged from 4.38 days to 3.39 days.

On 15 MAP, T₄ (VC+Az+P+Pf+As) significantly showed lower (3.33 days) leaf period per plant followed by T₂ (conventional) with 3.37 days but they were at par with each other while, T₁ (control) has significantly observed higher leaf period per plant with 3.52 days. From 16 MAP to 19 MAP leaf period per plant increased, T₄ (VC+Az+P+Pf+As) recorded lowest leaf period per plant ranging from 3.64 days to 6.47 days followed by T₂ (conventional) ranging from 3.66 days to 6.50 days but they were at par with each other from on 16 MAP to 19 MAP. While, T₁ (control) has recorded highest leaf period per plant with the ranging from 3.84 days to 6.72 days.

Table 4.02.07: Effect of organic cultivation on leaf period of TV 26 in from Apr'16 to Dec'16

Treatments	leaf period(days) on months after planting								
	2016								
	11 (Apr)	12 (May)	13 (Jun)	14 (Jul)	15 (Aug)	16 (Sep)	17 (Oct)	18 (Nov)	19 (Dec)
T ₁ (Control)	4.67	4.38	3.91	3.39	3.52	3.84	4.24	5.62	6.72
T ₂ (Conventional)	4.32	4.09	3.67	3.14	3.37	3.66	4.05	5.44	6.50
T ₃ (VC)	4.48	4.24	3.80	3.25	3.48	3.75	4.16	5.51	6.61
T ₄ (VC+Az+P+Pf+As)*	4.28	4.06	3.61	3.11	3.33	3.64	4.01	5.40	6.47
T ₅ (VC+Az+V+Pf+As)**	4.36	4.11	3.70	3.16	3.39	3.70	4.07	5.46	6.53
T ₆ (FYM)	4.53	4.30	3.81	3.30	3.49	3.78	4.19	5.55	6.64
T ₇ (FYM+Az+P+Pf+As)*	4.40	4.18	3.74	3.2	3.44	3.72	4.10	5.48	6.57
T ₈ (FYM+Az+V+Pf+As)**	4.43	4.22	3.77	3.22	3.46	3.74	4.12	5.5	6.59
SEm (±)	0.02	0.01	0.02	0.01	0.02	0.01	0.02	0.02	0.02
CD (P=0.05)	0.05	0.04	0.07	0.04	0.05	0.03	0.06	0.05	0.05

VC- vermicompost

*Az+P+Pf+As -*Azotobacter* + PSB + *Pseudomonas fluorescens* + *Azospirillum*

**Az+V+Pf+As – *Azotobacter* + VAM + *Pseudomonas fluorescens* + *Azospirillum*

FYM- farm yard manure

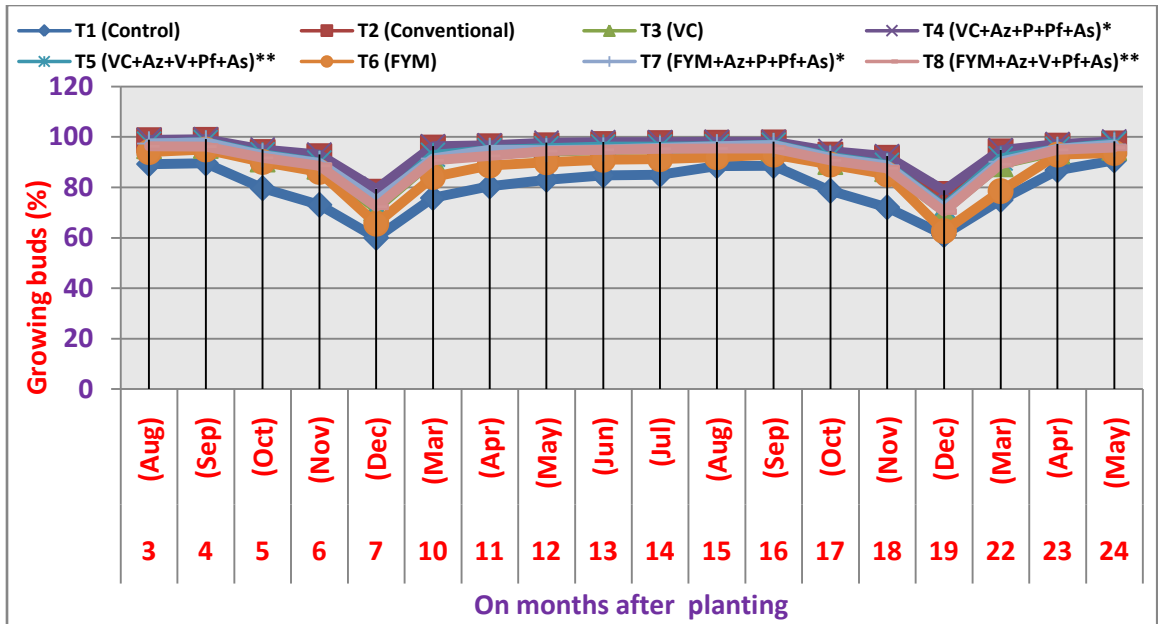


Fig. 4.02.4: Effect of organic cultivation on percentage of growing buds per plot month wise up to 24 months after planting

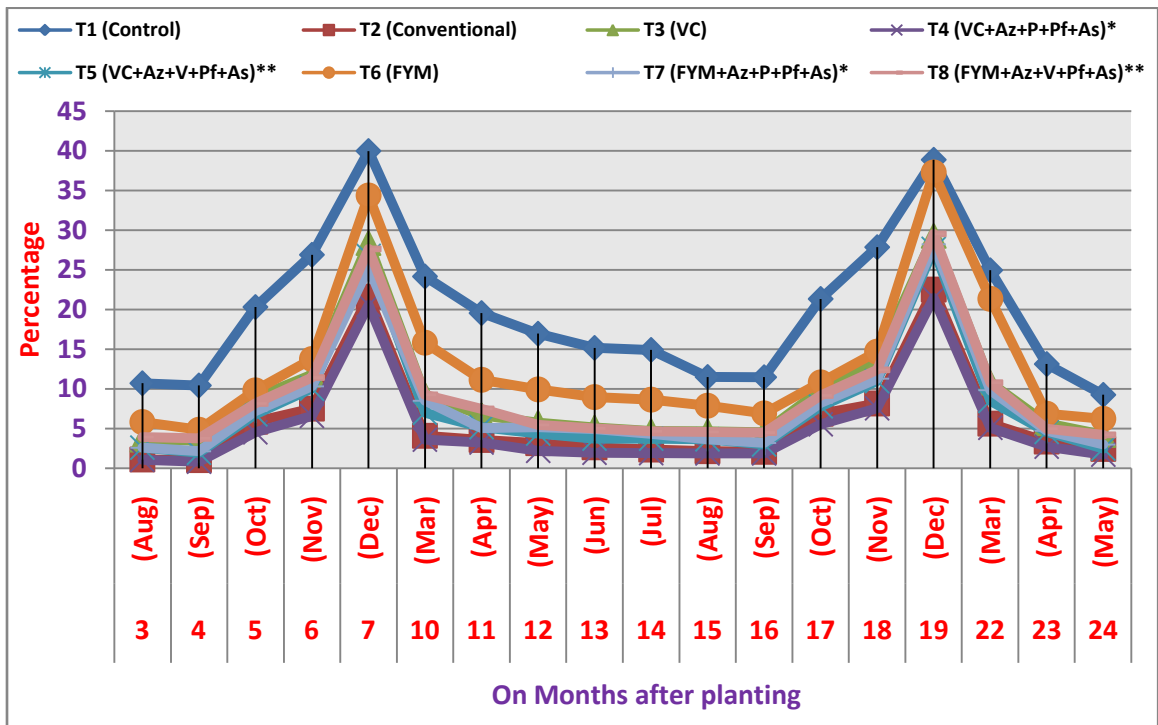


Fig. 4.02.05: Effect of organic cultivation on percentage of dormant buds per plot month wise up to 24 months after planting

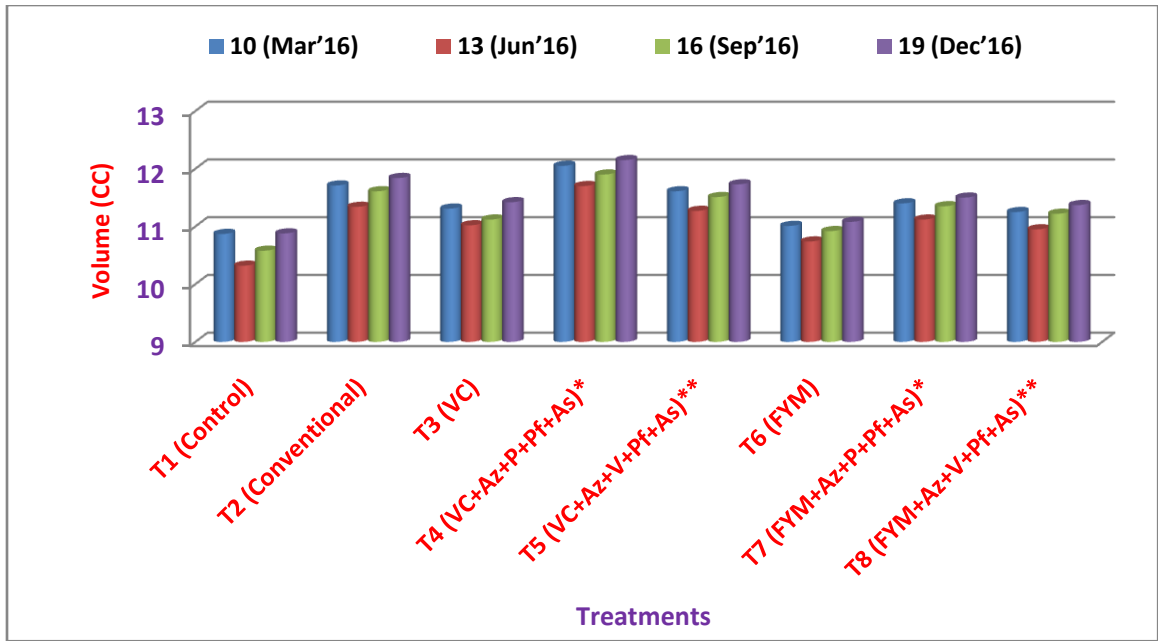


Fig. 4.02.06: Effect of organic cultivation on volume of two leaf and a bud per plot at three months interval

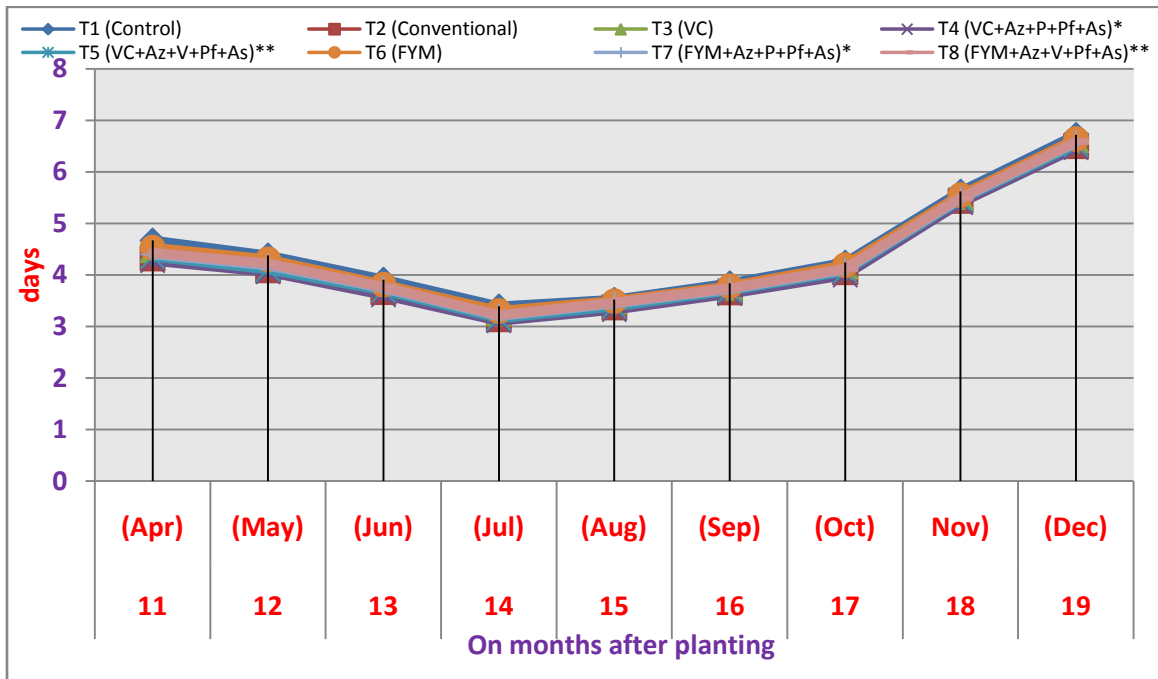


Fig. 4.02.07: Effect of organic cultivation on leaf period of TV 26 from Apr' 16 to Dec'16

4.02.08. Number of plucking points

Observations on number of plucking points of young tea plants at six months interval upto 24 MAP are presented in Table 4.02.08 and illustrated Fig. 4.02.08. On 6 MAP, the significantly maximum 3.76 of plucking points were observed in T₄ (VC+Az+P+Pf+As) followed by T₂ (conventional) with 3.08 of plucking points while lower 1.08 of plucking points were observed in T₁ (control). Both on 12 MAP and 18 MAP similar trend was followed, T₄ (VC+Az+P+Pf+As) significantly maximum 18.02 and 25.79 of plucking points, respectively were noticed followed by T₂ (conventional) with 16.87 and 23.51 of plucking points, respectively. While lower number of plucking points were recorded in T₁ (control) with 9.21 and 13.05, respectively.

Finally, on 24 MAP significantly maximum 30.78 of plucking points were observed in T₄ (VC+Az+P+Pf+As) followed by T₅ (VC+Az+V+Pf+As) with 28.76 of plucking points, while lower 15.17 plucking points were observed in T₁ (control).

Table 4.02.08: Effect of organic cultivation of tea (TV 26) on number of plucking points per quadrat of 25cmX 25 cm upto 24 months after planting at six months interval

Treatments	Number of plucking points per plant on months after planting			
	6 (Nov'15)	12 (May'16)	18 (Nov'16)	24 (May'17)
T ₁ (Control)	1.08	9.21	13.05	15.17
T ₂ (Conventional)	3.08	16.87	23.51	28.37
T ₃ (VC)	2.10	14.18	19.02	22.09
T ₄ (VC+Az+P+Pf+As)*	3.76	18.02	25.79	30.78
T ₅ (VC+Az+V+Pf+As)**	2.92	16.05	23.17	28.76
T ₆ (FYM)	1.96	12.19	18.36	20.48
T ₇ (FYM+Az+P+Pf+As)*	2.66	15.41	21.14	26.97
T ₈ (FYM+Az+V+Pf+As)**	2.47	14.44	20.09	23.58
SEm (±)	0.09	0.14	0.22	0.27
CD (P=0.05)	0.26	0.43	0.66	0.81

VC- vermicompost

*Az+P+Pf+As -Azotobacter + PSB + *Pseudomonas fluorescens* + *Azospirillum*

**Az+V+Pf+As - Azotobacter+ VAM + *Pseudomonas fluorescens* + *Azospirillum*

FYM- farm yard manure

4.02.09. Green leaf yield

Observations on total average yield of green leaf harvested per plot at every end of plucking season *i.e* Aug'15 -Dec'15; Mar'16 -Dec'16; Mar'17-May'17 have been presented in Table 4.02.09 and Fig 4.02.09. The data on total yield of green leaf harvested per plot differed significantly among the treatments at three plucking seasons.

Total green leaf yield harvested per plot on first end of plucking season, significantly maximum with 0.103 kg of green leaf harvested per plot in T₄ (VC+Az+P+Pf+As) followed by in T₂ (conventional) with 0.100 kg, but they were at par with each other. While, lower 0.024 kg of green leaf harvested per plot in T₁ (control). On second and third end of plucking seasons similar trend was followed, T₄ (VC+Az+P+Pf+As) significantly recorded highest 1.20 kg and 0.84 kg, of green leaf harvested per plot, respectively followed by T₂ (conventional) with 1.14 kg and 0.77 kg, green leaf harvested per plot, respectively. While, T₁ (control) has significantly recorded lowest green leaf harvested per plot with 0.55 kg and 0.33 kg, respectively.

Table 4.02.09: Effect of organic cultivation of tea (TV 26) on average yield of green leaf per plot (15.77 m²) #

Treatments	Green leaf yield(kg) per plot#		
	Aug'15 -Dec'15	Mar'16 -Dec'16	Mar'17-May'17
T ₁ (Control)	0.024 (15.37)	0.55(345.95)	0.33 (210.26)
T ₂ (Conventional)	0.100 (63.37)	1.14 (723.09)	0.77 (488.27)
T ₃ (VC)	0.044 (27.89)	0.83 (523.63)	0.59 (371.13)
T ₄ (VC+Az+P+Pf+As)*	0.103 (65.59)	1.20 (759.94)	0.84 (532.66)
T ₅ (VC+Az+V+Pf+As)**	0.076 (48.34)	1.11 (704.11)	0.76 (484.93)
T ₆ (FYM)	0.033 (21.17)	0.75 (474.90)	0.46 (293.69)
T ₇ (FYM+Az+P+Pf+As)*	0.057 (36.01)	1.02 (643.87)	0.70 (442.88)
T ₈ (FYM+Az+V+Pf+As)**	0.049 (30.91)	0.92 (585.60)	0.62 (400.77)
SEm (±)	0.007	0.01	0.01
CD (P=0.05)	0.02	0.03	0.02

VC- vermicompost, *Az+P+Pf+As -*Azotobacter* + PSB + *Pseudomonas fluorescens* + *Azospirillum*

**Az+V+Pf+As - *Azotobacter*+ VAM + *Pseudomonas fluorescens* + *Azospirillum*,

FYM- farm yard manure

#- figures in parentheses indicate yield per hectare

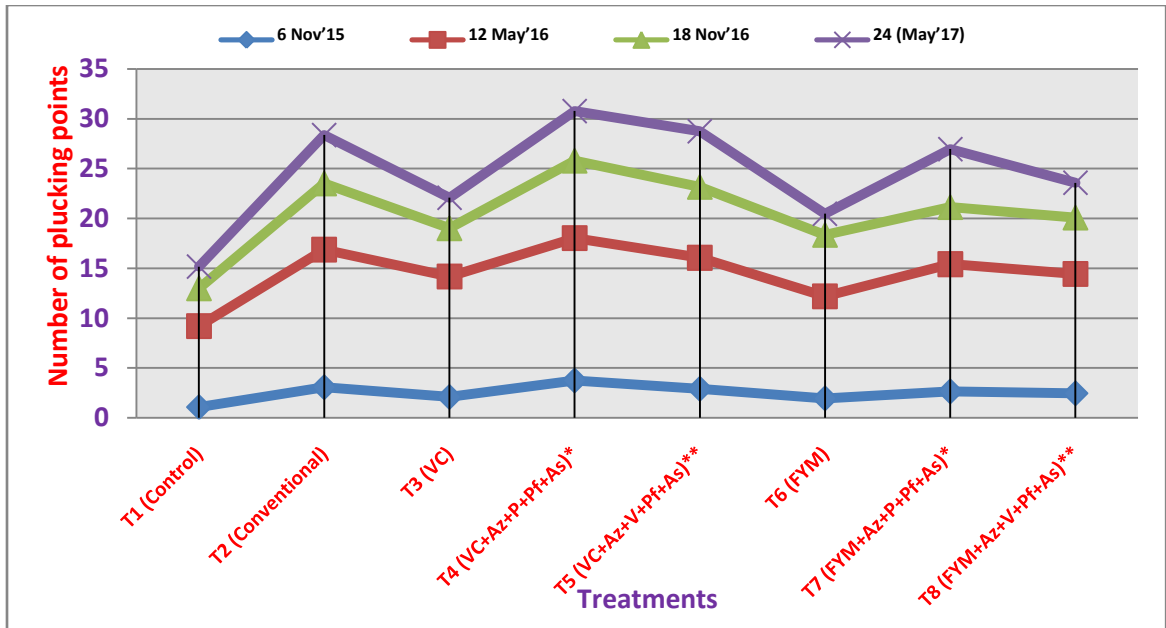


Fig. 4.02.08: Effect of organic cultivation on number of plucking points per quadrat of 25cm X 25 cm upto 24 months after planting at six months interval.

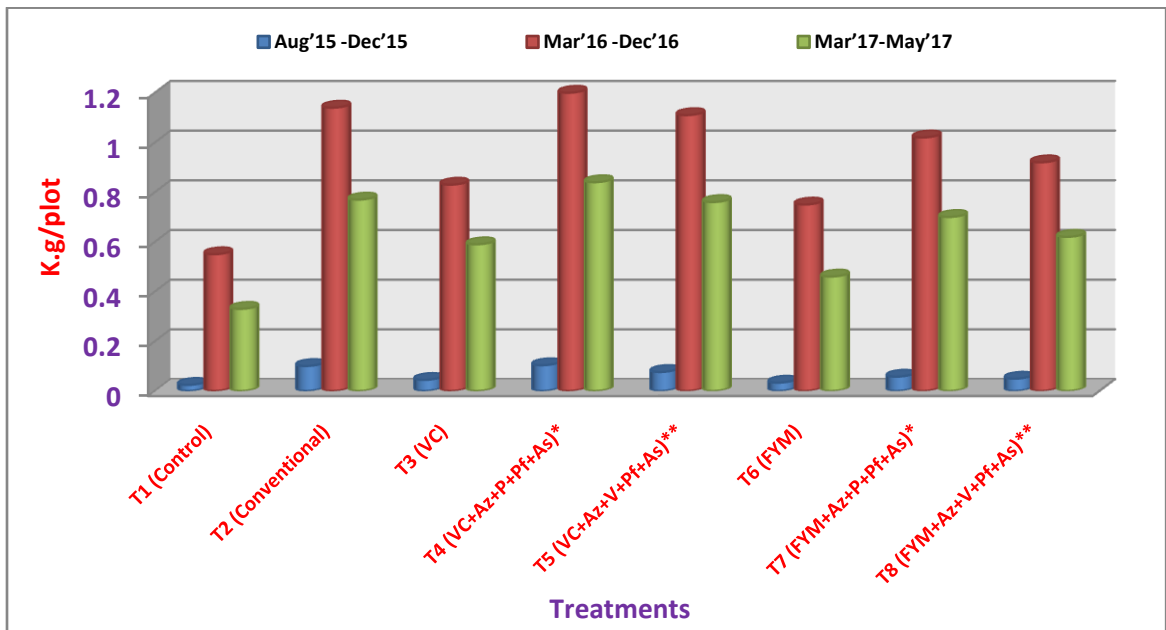


Fig. 4.02.09: Effect of organic cultivation of tea (TV 26) on average yield of green leaf per plot

4.03. Quality parameters of young tea plants under organic cultivation

4.03.01. Total chlorophyll content

Observations on total chlorophyll content per plant at three months interval of young tea plants from on 13 MAP (Jun'16) to 22 MAP (Mar '17) have been depicted in Table 4.03 and illustrated in Fig 4.03.01 It is evident from data, the total chlorophyll content per plant differed significantly among the all treatments and total chlorophyll content was increased from on 13 MAP to 22 MAP.

On 13 MAP, highest chlorophyll content of 44.96 SPAD units was observed in T₄ (VC+Az+V+Pf+As) followed by T₂ (conventional) with 43.21 SPAD units of chlorophyll content. Significantly, lowest 30.03 chlorophyll content was recorded in T₁ (control). a similar trend was observed from on 16 MAP (Sep' 16) to 22 MAP , T₄ (VC+Az+P+Pf+As) significantly showed maximum total chlorophyll content per plant ranged from 51.46 to 57.66 followed by T₅ (VC+Az+V+Pf+As) ranged from 49.20 to 56.61 chlorophyll content. While, T₁ (control) has significantly recorded minimum total chlorophyll content per plant with the ranged from 38.73 to 45.95.

4.03.02. Polyphenol oxidase content

Observations on PPO content in two leaf and a bud at three months interval of young tea plants from on 13 MAP (Jun '16) to 22 MAP (Mar'17) have been depicted in Table 4.03. It is evident from data, the PPO content per plant differed significantly among all treatments and PPO content was decreased from on 13 MAP to 16 MAP and increased upto 22 MAP. On 13 MAP, T₄ (VC+Az+P+Pf+As) recorded higher 13.46 PPO content in two leaf and a bud compared to rest of the treatments which was followed by T₅ (VC+Az+V+Pf+As) with 12.97 PPO content, but they were at par with each other. While lower PPO content in two leaf and a bud was recorded in T₁ control with 8.68 PPO content.

On 16 MAP, T₄ (VC+Az+P+Pf+As) recorded significantly maximum 12.41 PPO content in two leaf and a bud which was followed by T₅ (VC+Az+V+Pf+As) with 12.13, but they were at par with each other while minimum 7.81 PPO content in two leaf and a

bud was recorded in T₁ (control). Similar results were observed on 19 MAP and 22 MAP (Table 4.03). T₄ (VC+Az+P+Pf+As) showed highest 15.60 and 16.60 PPO content in two leaf and a bud, respectively followed by T₅ (VC+Az+V+Pf+As) with 14.37 and 15.37 PPO content, respectively. While T₁ (control) has significantly recorded lowest 9.87 and 10.78 PPO content in two leaf and a bud, respectively on 19 MAP and 22 MAP.

4.03.03. Caffeine content

Observations on caffeine content in two leaf and a bud at three months interval of young tea plants from on 13 MAP (jun' 16) to 22 MAP (Mar'17) have been depicted in Table 4.03 and illustrated Fig 4.03.02 It is evident from data, the caffeine content per plant differed significantly among all the treatments and caffeine content was low in winter season compared to other seasons. On 13 MAP, T₄ (VC+Az+P+Pf+As) recorded higher 3.94 % caffeine content in two leaf and a bud compared to rest of the treatments which was followed by T₅ (VC+Az+V+Pf+As) with 3.93 % caffeine and T₇ (FYM+Az+P+Pf+As) with 3.92 % caffeine, but T₄ at par with T₅ and T₇. While lower caffeine content in two leaf and a bud was recorded in T₁ control with 3.86 %.

On 16 MAP, T₄ (VC+Az+P+Pf+As) recorded maximum 3.95 % caffeine content in two leaf and a bud which was followed by T₅ (VC+Az+V+Pf+As) with 3.94 % caffeine and T₇ (FYM+Az+P+Pf+As) with 3.93 % caffeine, but T₄ at par with T₅ and T₇. While lower caffeine content in two leaf and a bud was recorded in T₁ control with 3.86 %. Similar results were observed on 19 MAP and 22 MAP (Table 4.03). T₄ (VC+Az+P+Pf+As) showed highest 3.79 % and 3.86 % caffeine content respectively in two leaf and a bud followed by T₅ (VC+Az+V+Pf+As) with 3.78% and 3.85% caffeine content respectively and T₇ (FYM+Az+P+Pf+As) with 3.77 % and 3.84% caffeine content respectively but T₄ at par with T₅ and T₇. While T₁ (control) has significantly recorded lowest 3.73% and 3.79% caffeine content respectively in two leaf and a bud on 19 MAP and 22 MAP.

4.03.04. Tannin content

Observations on tannin content in two leaf and a bud at three months interval of young tea plants from on 13 MAP (jun' 16) to 22 MAP (Mar'17) have been depicted in

Table 4.03 and illustrated Fig 4.03.02 It is evident from data, the tannin content per plant differed significantly among the all treatments and Tannin content was low in winter season compared to other seasons. On 13 MAP, T₄ (VC+Az+P+Pf+As) recorded higher 2.98 % tannin content in two leaf and a bud compared to rest of the treatments which was followed by T₅ (VC+Az+V+Pf+As) with 2.97 % tannin content, but they were at par with each other. While lower 2.85 % tannin content in two leaf and a bud was recorded in T₁ (control).

On 16 MAP, T₄ (VC+Az+P+Pf+As) recorded significantly maximum 3.06 % tannin content in two leaf and a bud which was followed by T₅ (VC+Az+V+Pf+As) with 3.05 % tannin content, but they were at par with each other. While lower 2.93 % tannin content in two leaf and a bud was recorded in T₁ (control). Similar results were observed on 19 MAP and 22 MAP (Table 4.03). T₄ (VC+Az+P+Pf+As) showed highest 2.91 % and 2.95 % tannin content in two leaf and a bud, respectively followed by T₅ (VC+Az+V+Pf+As) with 2.90 % and 2.94 % tannin content, respectively but they were at par with each other. While T₁ (control) has significantly recorded lowest 2.83 % and 2.84 % tannin content in two leaf and a bud respectively on 19 MAP and 22 MAP.

4.04. Observations on physical and chemical status of soil in young tea under organic cultivation

4.04.01. pH

Observations on soil pH at six months interval in young tea have been depicted in Table 4.04.01. It is evident from data the soil pH differed significantly among all the treatments throughout the period of experimentation, *i.e.* from 6 MAP upto 24 months.

On 6 MAP, highest soil pH 5.72 was observed in T₆ (FYM) followed by T₈ (FYM+Az+V+Pf+As) with 5.67 pH but they were at par with each other. Significantly lowest 5.54 soil pH was recorded in T₂ (conventional). On 12 MAP, T₆ (FYM) showed maximum soil pH with 5.75 followed by T₈ (FYM+Az+V+Pf+As) with 5.69 pH

4.03: Effect of organic cultivation on biochemical parameters of two leaves and a bud harvested for young tea plants (TV 26)

Treatments	Biochemicals and pigments on months after planting															
	Total chlorophyll content (SPAD units)				PPO ($\Delta 490/\text{min}/\text{gram fresh weight}$)				Caffeine (% Dry weight)				Tannin (% Dry weight)			
	13 (Jun'16)	16 (Sep'16)	19 (Dec'16)	22 (Mar'17)	13 (Jun'16)	16 (Sep'16)	19 (Dec'16)	22 (Mar'17)	13 (Jun'16)	16 (Sep'16)	19 (Dec'16)	22 (Mar'17)	13 (Jun'16)	16 (Sep'16)	19 (Dec'16)	22 (Mar'17)
T ₁ (Control)	30.03	38.73	44.05	45.95	8.68	7.81	9.87	10.78	3.86	3.86	3.73	3.79	2.85	2.93	2.83	2.84
T ₂ (Conventional)	43.21	49.08	52.85	54.56	10.04	9.93	11.19	11.58	3.89	3.90	3.75	3.82	2.89	2.99	2.85	2.87
T ₃ (VC)	38.38	45.28	49.39	51.92	11.45	10.68	12.23	13.51	3.91	3.92	3.76	3.83	2.94	3.03	2.88	2.91
T ₄ (VC+Az+P+Pf+As)*	44.96	51.46	55.14	57.66	13.46	12.41	15.60	16.60	3.94	3.95	3.79	3.86	2.98	3.06	2.91	2.95
T ₅ (VC+Az+V+Pf+As)**	42.94	49.20	54.24	56.61	12.97	12.13	14.37	15.37	3.93	3.94	3.78	3.85	2.97	3.05	2.90	2.94
T ₆ (FYM)	34.92	42.95	47.95	49.28	10.11	9.76	11.16	11.79	3.90	3.90	3.75	3.82	2.89	3.01	2.87	2.90
T ₇ (FYM+Az+P+Pf+As)*	41.68	47.55	51.08	53.08	12.11	11.32	13.33	14.33	3.92	3.93	3.77	3.84	2.95	3.04	2.89	2.92
T ₈ (FYM+Az+V+Pf+As)**	40.89	47.14	50.29	52.82	11.95	11.08	12.89	14.04	3.91	3.92	3.76	3.83	2.93	3.03	2.88	2.92
SEm (\pm)	0.32	0.23	0.26	0.30	0.17	0.23	0.21	0.20	0.01	0.01	0.01	0.01	0.01	0.003	0.003	0.01
CD (P=0.05)	0.96	0.71	0.78	0.91	0.52	0.69	0.63	0.6	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.02

VC- Vermicompost; *Az+P+Pf+As -Azotobacter + PSB + Pseudomonas fluorescens + Azospirillum;

**Az+V+Pf+As - Azotobacter+ VAM + Pseudomonas fluorescens + Azospirillum; FYM- Farm yard manure

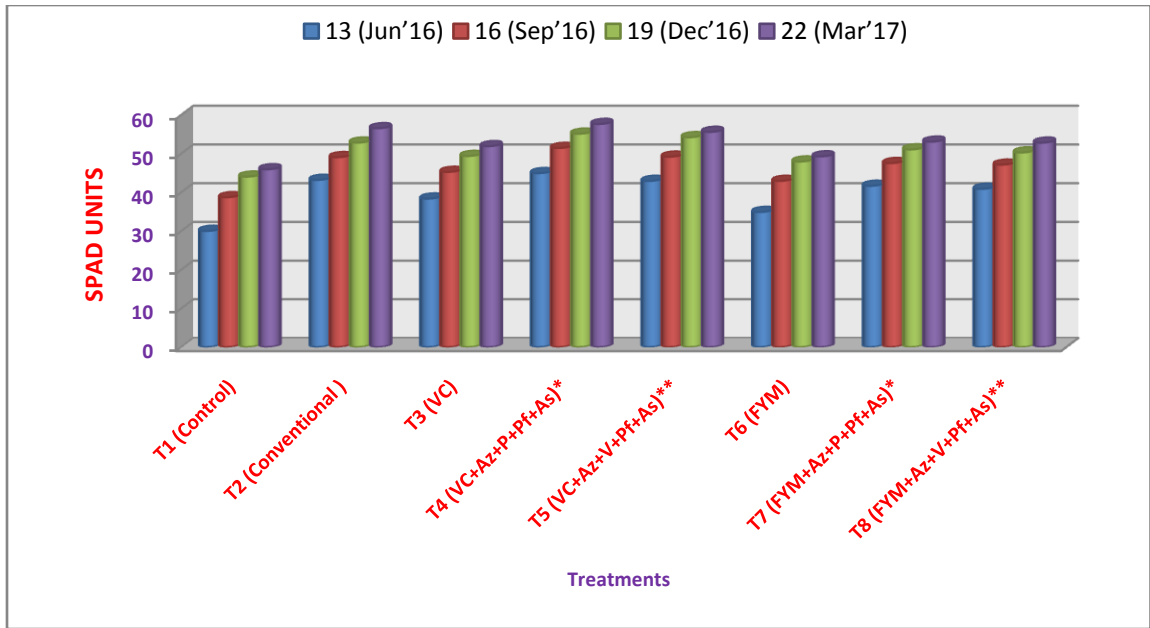


Fig. 4.03.01: Effect of organic cultivation on total chlorophyll content of two leaves and a bud harvested from young tea plants (TV 26)

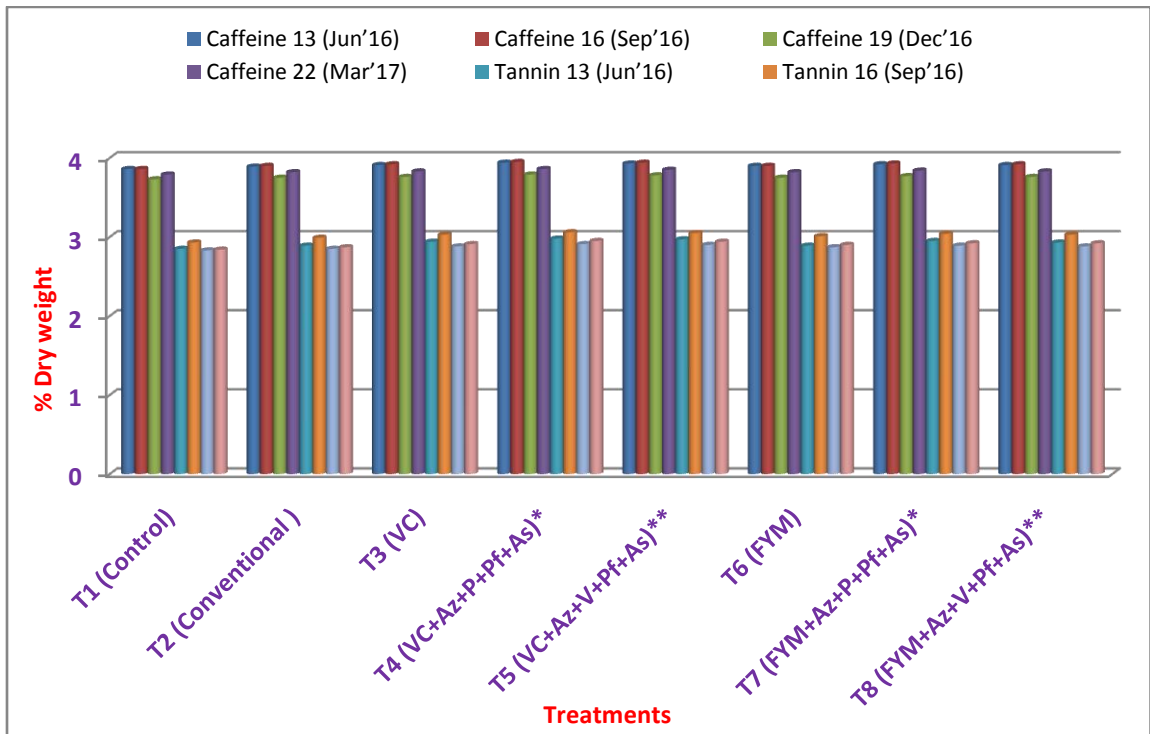


Fig. 4.03.02: Effect of organic cultivation on caffeine and tannin content in tender shoots of young tea plants (TV 26)

while minimum 5.54 soil pH was recorded in T₁ (control). On 18 MAP, higher soil pH of 5.79 was recorded in T₆ (FYM) followed by T₈ (FYM+Az+V+Pf+As) with 5.73 pH while, lower soil pH was recorded in T₁ (control) with 5.53 pH. Finally, on 24 MAP, higher 5.82 soil pH was noticed in T₆ (FYM) followed by T₂ (conventional) with 5.76 pH. While lower 5.54 soil pH was noticed in T₁ (control).

4.04.02. Organic carbon

Observations on soil organic carbon at six months interval in young tea have been depicted in Table 4.04.01 and Fig 4.04.01. It is evident from data, the soil organic carbon differed significantly among all the treatments throughout the period of experimentation, *i.e.* from 6 MAP upto 24 months. Throughout the period of experimentation, *i.e.* from 6 MAP upto 24 months, in all treatments soil organic carbon increased, except T₂ (conventional) and T₁ (control), were soil organic carbon decreased. On 6 MAP revealed that highest 0.69 % organic carbon was observed in T₅ (VC+Az+V+Pf+As) followed by T₄ (VC+Az+P+Pf+As) with 0.68 % organic carbon, T₃ (VC) with 0.68 % and T₇ (VC+Az+P+Pf+As) with 0.68 % organic carbon however, T₅ was at par with T₄, T₃ and T₇; while lowest 0.62 % organic carbon was recorded in T₁ (control). On 12 MAP, highest 0.71 % organic carbon was observed in T₅ (VC+Az+V+Pf+As) followed by T₃ (VC) with 0.70 % organic carbon, T₇ (VC+Az+P+Pf+As) with 0.70 % organic carbon, T₄ (VC+Az+P+Pf+As) with 0.69 % organic carbon and T₆ (FYM) with 0.68 % organic carbon but T₅ at par with T₃, T₇, T₄ and T₆ while lowest 0.61 % organic carbon was recorded in T₁ (control).

Perusal of data on soil organic carbon (Table 4.04.01), on 18 MAP revealed that highest 0.72 % organic carbon was observed in T₃ (VC) followed by T₅ (VC+Az+V+Pf+As) with 0.71 % organic carbon, T₇ (VC+Az+P+Pf+As) with 0.71% organic carbon, T₄ (VC+Az+P+Pf+As) with 0.70 % organic carbon and T₆ (FYM) with 0.70 % organic carbon but T₃ at par with T₅, T₇, T₄ and T₆ while lowest 0.60 % organic carbon was recorded in T₁ (control). On 24 MAP revealed that highest 0.74 % organic carbon was observed in T₃ (VC) followed by T₅ (VC+Az+V+Pf+As) with 0.73 % organic carbon, T₄ (VC+Az+P+Pf+As) with 0.73 % organic carbon, T₇ (VC+Az+P+Pf+As) with 0.72% organic carbon and T₆ (FYM) with 0.72 % organic

carbon but T₃ at par with T₅, T₄, T₇ and T₆ while lowest 0.59 % organic carbon was recorded in T₁ (control).

4.04.03. Total carbon

Observations on total soil carbon at six months interval in young tea have been presented in Table 4.04.01 and illustrated in Fig 4.04.01. It is evident from data, the total soil carbon differed significantly among all the treatments throughout the period of experimentation, *i.e.* from 12 MAP upto 24 months. On 6 MAP revealed that there is no significant difference among treatments, however maximum 1.20 % total soil carbon was observed in T₄ (VC+Az+P+Pf+As) followed by T₇ (VC+Az+P+Pf+As) with 1.19 % total soil carbon while lowest 1.14 % total soil carbon was recorded in T₂ (conventional).

Perusal of data in Table 4.04.01 indicated that on 12 MAP, T₄ (VC+Az+P+Pf+As) significantly showed maximum 1.22 % total soil carbon which was at par with all organic plots, *i.e.* T₇, T₅, T₃, T₄ and T₆; while lowest 1.15 % total soil carbon was recorded in T₁ (control). On 18 MAP, T₅ (VC+Az+V+Pf+As) significantly showed maximum of 1.24 % total soil carbon which was closely followed by T₄, T₇, and T₃; while lowest 1.14 % total soil carbon was recorded in T₁ (control). On 24 MAP, T₅ (VC+Az+V+Pf+As) significantly showed maximum 1.25 % total soil carbon but T₅ at par with T₄, T₇ and T₃. While lowest 1.13 % total soil carbon was recorded in T₁ (control).

4.04.04. Bulk density

Observations on bulk density of soil at the end of the experiment in young tea 24 MAP *i.e.*, have been presented in Table 4.04.01 and illustrated Fig 4.04.02. Throughout the period of experimentation, *i.e.* from 0 MAP upto 24 months, in organic treatments soil bulk density decreased. T₂ (conventional) and T₁ (control) soil bulk density increased. on 24 MAP revealed that minimum bulk density of soil 1.17 g/cc was observed in T₅ (VC+Az+V+Pf+As), T₃ (VC) and T₇ (FYM+Az+P+Pf+As) but at par with all organic plots *i.e.* T₄, T₈, and T₆. While highest 1.24 g/cc bulk density of soil was recorded in T₂ (conventional).

Table 4.04.01: Effect of organic cultivation of tea (TV 26) on physico- chemical properties of soil plots at six months interval

Treatments	Physico- chemical properties of soil on months after planting												
	pH				Organic C (%)				Total C (%)				Bulk density# (g/cc)
	6 (Nov'15)	12 (May'16)	18 (Nov'16)	24 (May'17)	6 (Nov'15)	12 (May'16)	18 (Nov'16)	24 (May'17)	6 (Nov'15)	12 (May'16)	18 (Nov'16)	24 (May'17)	24 (May'17)
T ₁ (Control)	5.54	5.54	5.53	5.54	0.62	0.61	0.60	0.59	1.16	1.15	1.14	1.13	1.23
T ₂ (Conventional)	5.43	5.56	5.67	5.76	0.65	0.64	0.62	0.61	1.14	1.13	1.12	1.11	1.24
T ₃ (VC)	5.51	5.57	5.65	5.69	0.68	0.70	0.72	0.74	1.19	1.20	1.22	1.23	1.17
T ₄ (VC+Az+P+Pf+As)*	5.64	5.66	5.68	5.70	0.68	0.69	0.70	0.73	1.20	1.22	1.23	1.24	1.18
T ₅ (VC+Az+V+Pf+As)**	5.64	5.66	5.69	5.72	0.69	0.71	0.71	0.73	1.18	1.20	1.24	1.25	1.17
T ₆ (FYM)	5.72	5.75	5.79	5.82	0.66	0.68	0.70	0.72	1.17	1.19	1.21	1.22	1.19
T ₇ (FYM +Az+P+Pf+As)*	5.63	5.65	5.69	5.71	0.68	0.70	0.71	0.72	1.19	1.21	1.23	1.24	1.17
T ₈ (FYM+Az+V+Pf+As)**	5.67	5.69	5.73	5.75	0.64	0.66	0.69	0.70	1.17	1.19	1.20	1.21	1.18
SEm (±)	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD (P=0.05)	0.07	0.05	0.03	0.02	0.02	0.03	0.02	0.02	N.S	0.03	0.02	0.02	0.02

VC- Vermicompost; *Az+P+Pf+As -*Azotobacter* + PSB + *Pseudomonas fluorescens* + *Azospirillum*;

**Az+V+Pf+As - *Azotobacter*+ VAM +*Pseudomonas fluorescens* + *Azospirillum*; FYM- Farm yard manure

- observed only on 24 MAP

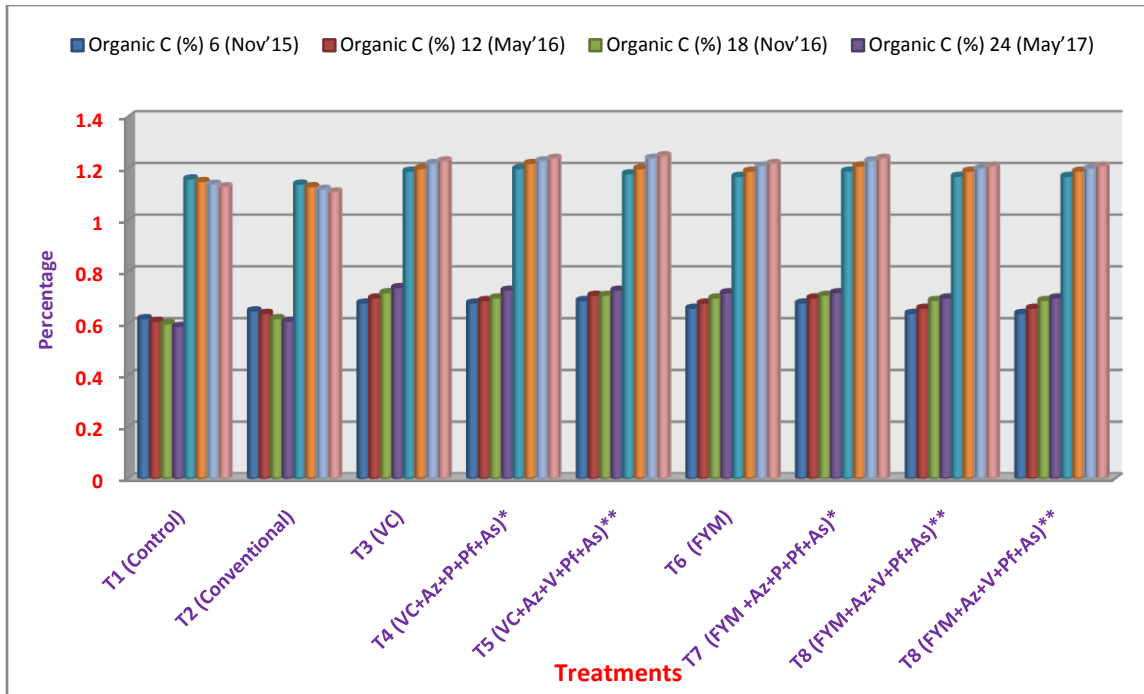


Fig. 4.04.01: Effect of organic cultivation on organic c % and total c % of soil in young tea (TV 26) at six months interval.

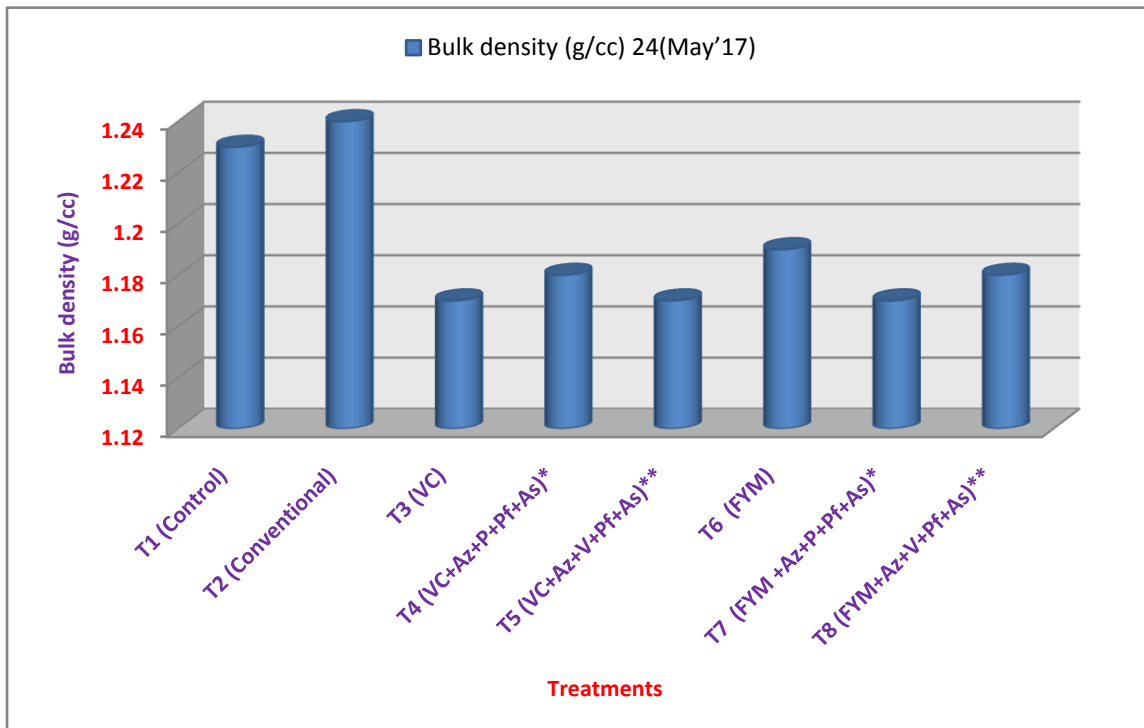


Fig. 4.04.02: Effect of organic cultivation on bulk density of soil in young tea (TV 26) at 24 MAP

4.04.05. Available nitrogen

Observations on available nitrogen of soil at six months interval in young tea have been shown in Table 4.04.02 (a) and illustrated in Fig 4.04.03. It is evident from data; the available nitrogen of soil differed significantly among the all treatments throughout the period of experimentation, *i.e.* from 6 MAP upto 24 months. On 6 MAP, significantly higher 208.08 kg/ha of available nitrogen was noticed in T₄ (VC+Az+P+Pf+As) followed by in T₂ (conventional) with 206.88 kg/ha but they were at par with each other while, lower 147.12 kg/ha of available nitrogen was noticed in T₁ (control).

Observations on available nitrogen of soil (Table 4.04.02) revealed that on 12 MAP, significantly higher 221.20 kg/ha of available nitrogen was noticed in T₄ (VC+Az+P+Pf+As) followed by in T₂ (conventional) with 217.27 kg/ha while; lower 143.34 kg/ha of available nitrogen was noticed in T₁ (control). Similar trend was followed both on 18 MAP and 24 MAP, T₄ (VC+Az+P+Pf+As) recorded the highest with 249.42 kg/ha and 258.23 kg/ha available nitrogen respectively, followed by T₅ (VC+Az+V+Pf+As) with 241.61 kg/ha and 253.64 kg/ha available nitrogen respectively, while in T₁ (control) lowest available nitrogen 136.17 kg/ha and 133.14 kg/ha on 18 MAP and 24 MAP respectively.

4.04.06. Total nitrogen

Observations on total nitrogen of soil at six months interval in young tea have been shown in Table 4.04.02 (a) and illustrated in Fig 4.04.03. It is evident from data the total nitrogen of soil differed significantly among the all treatments throughout the period of experimentation *i.e* from 6 MAP upto 24 months. On 6 MAP revealed that, maximum 619.88 kg/ha total nitrogen was observed in T₅ (VC+Az+V+Pf+As) followed by T₈ (FYM+Az+V+Pf+As) with 618.95 kg/ha total nitrogen, but they were at par with each other while lowest 604.97 kg/ha total nitrogen was recorded in T₁ (control).

On 12 MAP, maximum 628.94 kg/ha total nitrogen was observed in T₈ (FYM+Az+V+Pf+As) followed by T₅ (VC+Az+V+Pf+As) with 625.28 kg/ha total nitrogen, while lowest 590.09 kg/ha total nitrogen was recorded in T₁ (control). On 18

Table 4.04.02(a): Effect of organic cultivation of tea (TV 26) on available and total N of soil at six months interval

Treatments	Available N (kg/ha) on months after planting				Total N (kg/ha) on months after planting			
	6 (Nov'15)	12 (May'16)	18 (Nov'16)	24 (May'17)	6 (Nov'15)	12 (May'16)	18 (Nov'16)	24 (May'17)
T ₁ (Control)	147.12	143.34	136.17	133.14	604.97	590.09	586.43	584.10
T ₂ (Conventional)	206.88	217.27	236.74	245.70	616.52	623.44	632.21	638.11
T ₃ (VC)	189.02	195.33	218.63	229.07	613.57	621.30	628.96	633.63
T ₄ (VC+Az+P+Pf+As)*	208.08	221.20	249.42	258.23	618.20	623.27	637.74	640.47
T ₅ (VC+Az+V+Pf+As)**	204.95	215.66	241.61	253.64	619.88	625.28	635.22	642.12
T ₆ (FYM)	180.94	187.97	205.76	214.27	618.25	620.87	623.91	633.93
T ₇ (FYM+Az+P+Pf+As)*	198.22	210.38	232.23	243.42	617.92	625.23	631.52	639.27
T ₈ (FYM+Az+V+Pf+As)**	195.88	206.46	227.74	238.14	618.95	628.94	636.22	642.74
SEm (±)	0.71	0.98	0.98	0.82	0.39	0.62	0.65	0.59
CD (P=0.05)	2.14	2.98	2.96	2.49	1.17	1.88	1.97	1.80

VC- Vermicompost; *Az+P+Pf+As -*Azotobacter* + PSB + *Pseudomonas fluorescens* + *Azospirillum*;

**Az+V+Pf+As - *Azotobacter*+ VAM +*Pseudomonas fluorescens* + *Azospirillum*; FYM- Farm yard manure

MAP revealed that, maximum 637.74 kg/ha total nitrogen was observed in T₄ (VC+Az+P+Pf+As) followed by T₈ (FYM+Az+V+Pf+As) with 636.22 kg/ha total nitrogen, but they were at par with each other while lowest 586.43 kg/ha total nitrogen was recorded in T₁ (control). On 24 MAP, maximum 642.74 kg/ha total nitrogen was observed in T₈ (FYM+Az+V+Pf+As) followed by T₅ (VC+Az+V+Pf+As) with 642.12 kg/ha total nitrogen, but they were at par with each other while lowest 584.10 kg/ha total nitrogen was recorded in T₁ (control).

4.04.07. Available phosphorus

Observations on available P of soil at six months interval in young tea have been shown in Table 4.04.02(b) and illustrated in Fig 4.04.04. It is evident from data the available P of soil differed significantly among all the treatments throughout the period of experimentation, *i.e.* from 6 MAP upto 24 months. On 6 MAP, highest 21.19 kg/ha available P was observed in T₄ (VC+Az+P+Pf+As) followed by T₇ (FYM+Az+P+Pf+As) with 20.78 kg/ha significantly, lowest 18.52 kg/ha available P was observed in T₁ (control).

The data on available P of soil (4.4.2(b)) revealed that, a similar trend was observed from on 12 MAP to 24 MAP, T₄ (VC+Az+P+Pf+As) significantly showed maximum available P ranged from 23.82 kg/ha to 28.23 kg/ha, but on 24 MAP T₄ at par with T₅ and T₃. T₁ (control) has significantly recorded minimum available P with the ranged from 18.13 kg/ha to 16.78 kg/ha.

4.04.08. Available potassium

Observations on available K of soil at six months interval in young tea have been shown in Table 4.04.02(b) and illustrated in Fig 4.04.04. It is evident from data, the available K of soil differed significantly among all the treatments throughout the period of experimentation *i.e.* from 6 MAP upto 24 months. On 6 MAP, highest 130.17 kg/ha available K was observed in T₂ (conventional) followed by T₄ (VC+Az+P+Pf+As) with 126.46 kg/ha, while lowest 119.16 kg/ha available K was observed in T₁ (control).

Table 4.04.02(b): Effect of organic cultivation of tea (TV 26) on available P and K of soil at six months interval.

Treatments	Available 'P' (kg/ha) on months after planting				Available 'K' (kg/ha) on months after planting			
	6 (Nov'15)	12 (May'16)	18 (Nov'16)	24 (May'17)	6 (Nov'15)	12 (May'16)	18 (Nov'16)	24 (May'17)
T ₁ (Control)	18.52	18.13	17.47	16.78	119.16	117.56	114.33	110.83
T ₂ (Conventional)	20.46	22.18	24.88	25.39	130.17	133.82	136.67	141.81
T ₃ (VC)	20.32	22.92	25.24	27.87	124.28	128.24	129.21	131.04
T ₄ (VC+Az+P+Pf+As)*	21.19	23.82	25.83	28.23	126.46	128.35	131.42	133.15
T ₅ (VC+Az+V+Pf+As)**	20.57	22.73	25.23	28.12	126.31	130.04	132.25	135.17
T ₆ (FYM)	19.41	20.79	22.12	24.17	122.61	123.81	126.88	130.13
T ₇ (FYM+Az+P+Pf+As)*	20.78	22.81	23.72	25.19	122.13	126.03	131.58	135.51
T ₈ (FYM+Az+V+Pf+As)**	20.62	21.71	23.76	24.68	122.23	128.27	131.10	135.24
SEm (±)	0.18	0.28	0.18	0.26	0.66	0.86	0.64	0.59
CD (P=0.05)	0.54	0.85	0.54	0.80	1.99	2.60	1.94	1.78

VC- Vermicompost; ***Az+P+Pf+As** -*Azotobacter* + PSB + *Pseudomonas fluorescens* + *Azospirillum*;

****Az+V+Pf+As** - *Azotobacter*+ VAM +*Pseudomonas fluorescens* + *Azospirillum*; **FYM-** Farm yard manure

Perusal of data in Table 4.04.02(b) indicated that on 12 MAP, significantly higher 145.35 kg/ha available K was recorded in T₂ (conventional) followed by T₅ (VC+Az+V+Pf+As) with 130.04 kg/ha. While lower 117.56 kg/ha available K was recorded in T₁ (control). On 18 MAP, significantly higher 136.67 kg/ha available K was recorded in T₂ (conventional) followed by T₅ (VC+Az+V+Pf+As) with 132.25 kg/ha. While lower 114.33 kg/ha available K was recorded in T₁ (control). On 24 MAP maximum 161.81 kg/ha of available K was observed in T₂ (conventional) followed by T₇ (FYM+Az+P+Pf+As) with 135.51 kg/ha available K, while lower 110.83 kg/ha available K was observed in T₁ (control).

4.05. Observations on nutrient content of leaf in young tea (TV 26) under organic cultivation

4.05.01. Leaf nitrogen content

Observations on nitrogen content of leaf at six months interval in young tea have been shown in Table 4.05 and illustrated in Fig 4.05. It is evident from data the nitrogen content of leaf differed significantly among the all treatments throughout the period of experimentation, *i.e.* from 6 MAP upto 24 months. Throughout the period of experimentation, *i.e.* from 6 MAP upto 24 months, nitrogen content of leaf all treatments in November months *i.e.* 6 MAP and 18 MAP more compared to May months *i.e.* 12 MAP and 24 MAP. On 6 MAP, significantly higher 3.96 % of nitrogen was noticed in T₄ (VC+Az+P+Pf+As) followed by T₂ (conventional) with 3.92 % and T₅ (VC+Az+V+Pf+As) with 3.89 %, but T₄ at par with T₂ and T₅. While lower 3.13 % of nitrogen content of leaf was noticed in T₁ (control). On 12 MAP, T₄ (VC+Az+P+Pf+As) recorded highest 3.92 % of nitrogen content of leaf followed by T₂ (conventional) with 3.88 % nitrogen content of leaf but they were at par with each other. While T₁ (control) has recorded lowest 2.97 % nitrogen content of leaf.

Observations on nitrogen content of leaf (Table 4.05.) on 18 MAP, highest 3.99 % nitrogen content of leaf was observed in T₄ (VC+Az+P+Pf+As) followed by T₅ (VC+Az+V+Pf+As) with 3.91 % nitrogen content of leaf. Significantly lowest 3.10 % nitrogen content of leaf was observed in T₁ (control). On 24 MAP, significantly

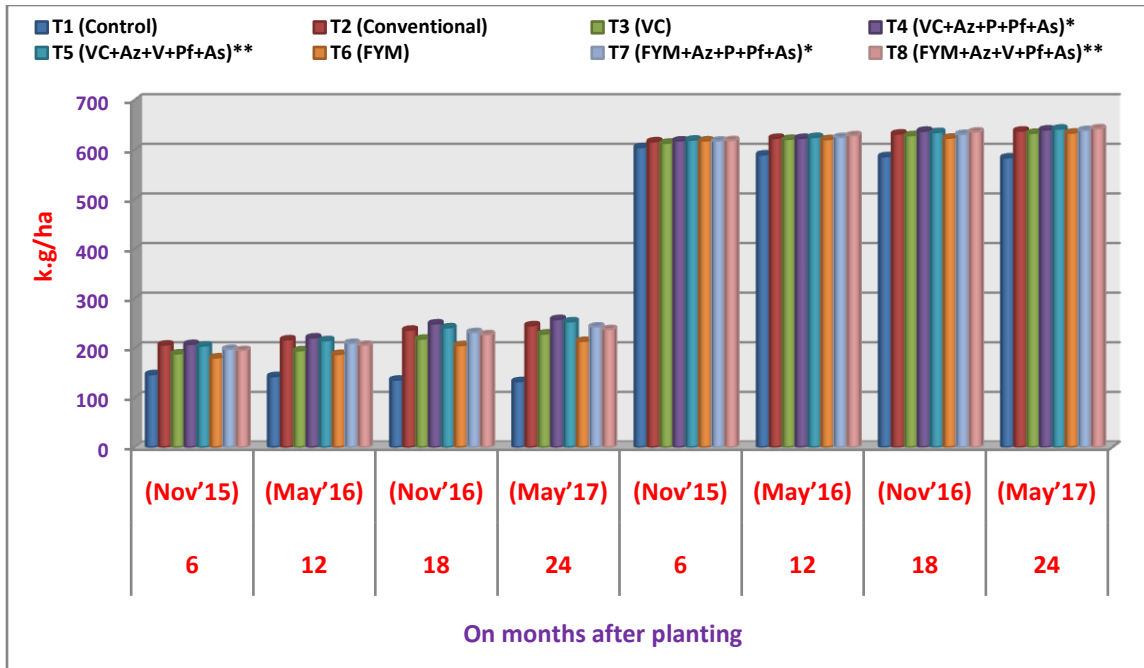


Fig. 4.04.03: Effect of organic cultivation on available and total N of soil in young tea (TV 26) at six months interval

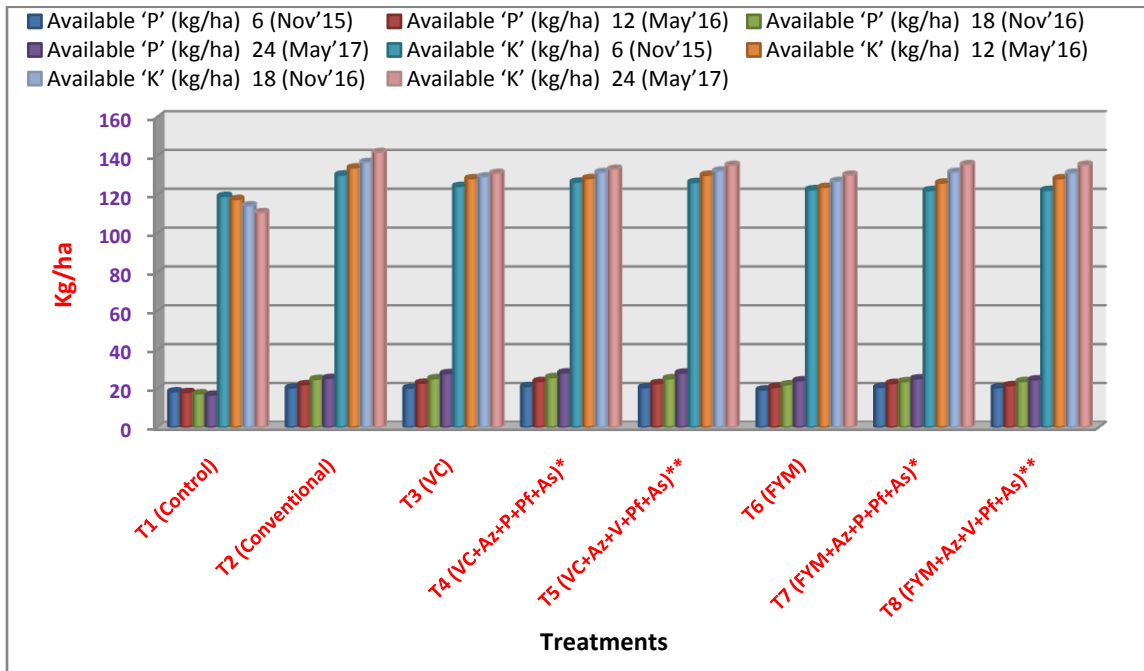


Fig. 4.04.04: Effect of organic cultivation on available P and available K of soil in young tea (TV 26) at six months interval

maximum 3.93 % nitrogen content of leaf was observed in T₄ (VC+Az+P+Pf+As) followed by T₅ (VC+Az+V+Pf+As) with 3.83 %, while lower 2.94 % nitrogen content of leaf was observed in T₁ (control).

4.05.02. Leaf phosphorus content

Observations on phosphorus content of leaf at six months interval in young tea have been shown in Table 4.05. and illustrated in Fig 4.05. It is evident from data the phosphorus content of leaf differed significantly among all the treatments throughout the period of experimentation, *i.e* from 6 MAP upto 24 months. Throughout the period of experimentation, *i.e* from 6 MAP upto 24 months, phosphorus content of leaf in all treatments in November months, *i.e.* 6 MAP and 18 MAP was more compared to May months, *i.e.* 12 MAP and 24 MAP. On 6 MAP, highest 0.34 % phosphorus content of leaf was observed in T₄ (VC+Az+P+Pf+As) followed by T₂ (conventional) with 0.32 % but they were at par with each other. Significantly lowest 0.16 % phosphorus content of leaf was observed in T₁ (control).

Perusal of data in Table 4.05. indicated that on 12 MAP, significantly higher 0.33 % phosphorus content of leaf was recorded in T₄ (VC+Az+P+Pf+As) followed by T₂ (conventional) with 0.30 % while, lower phosphorus content of leaf was recorded in T₁ (control) with 0.14 %. On 18 MAP, significantly higher 0.34 % of phosphorus content of leaf was noticed in T₄ (VC+Az+P+Pf+As) followed by in T₂ (conventional) with 0.31 % while, lower 0.15 % of phosphorus content of leaf was noticed in T₁ (control). On 24 MAP significantly maximum 0.32 % of phosphorus content of leaf was observed in T₄ (VC+Az+P+Pf+As) followed by T₅ (VC+Az+V+Pf+As) with 0.29 % of phosphorus content of leaf, but they were at par with each other while, lower phosphorus content of leaf was observed in T₁ (control) with 0.13%.

4.05.03. Leaf potassium content

Observations on potassium content of leaf at six months interval in young tea have been shown in Table 4.05. and illustrated in Fig 4.05. It is evident from data the potassium content of leaf differed significantly among the all treatments throughout the period of experimentation, *i.e.* from 6 MAP upto 24 months. Throughout the period of experimentation, *i.e.* from 6 MAP upto 24 months, potassium content of leaf in all

Table 4.05.: Effect of organic cultivation on nutrient content (%) in leaf of young tea (TV 26) at six months interval

Treatments	Leaf N (%)				Leaf P (%)				Leaf K (%)			
	6 (Nov'15)	12 (May'16)	18 (Nov'16)	24 (May'17)	6 (Nov'15)	12 (May'16)	18 (Nov'16)	24 (May'17)	6 (Nov'15)	12 (May'16)	18 (Nov'16)	24 (May'17)
T ₁ (Control)	3.13	2.97	3.10	2.94	0.16	0.14	0.15	0.13	1.01	0.89	0.96	0.86
T ₂ (Conventional)	3.92	3.88	3.90	3.78	0.32	0.30	0.31	0.28	1.72	1.62	1.89	1.57
T ₃ (VC)	3.76	3.73	3.78	3.13	0.26	0.25	0.27	0.25	1.32	1.29	1.43	1.25
T ₄ (VC+Az+P+Pf+As)*	3.96	3.92	3.99	3.93	0.34	0.33	0.34	0.32	1.73	1.66	1.98	1.91
T ₅ (VC+Az+V+Pf+As)**	3.89	3.85	3.91	3.83	0.29	0.28	0.3	0.29	1.67	1.60	1.86	1.69
T ₆ (FYM)	3.46	3.43	3.47	3.44	0.17	0.16	0.19	0.18	1.04	1.01	1.12	1.03
T ₇ (FYM+Az+P+Pf+As)*	3.80	3.76	3.81	3.75	0.28	0.27	0.29	0.27	1.31	1.22	1.43	1.31
T ₈ (FYM+Az+V+Pf+As)**	3.70	3.68	3.71	3.68	0.24	0.22	0.25	0.23	1.13	1.06	1.25	1.22
SEm (±)	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD (P=0.05)	0.09	0.05	0.07	0.05	0.04	0.02	0.02	0.03	0.03	0.04	0.03	0.02

VC- vermicompost; *Az+P+Pf+As -*Azotobacter* + PSB + *Pseudomonas fluorescens* + *Azospirillum*;

**Az+V+Pf+As - *Azotobacter*+ VAM +*Pseudomonas fluorescens* + *Azospirillum*; FYM- farm yard manure

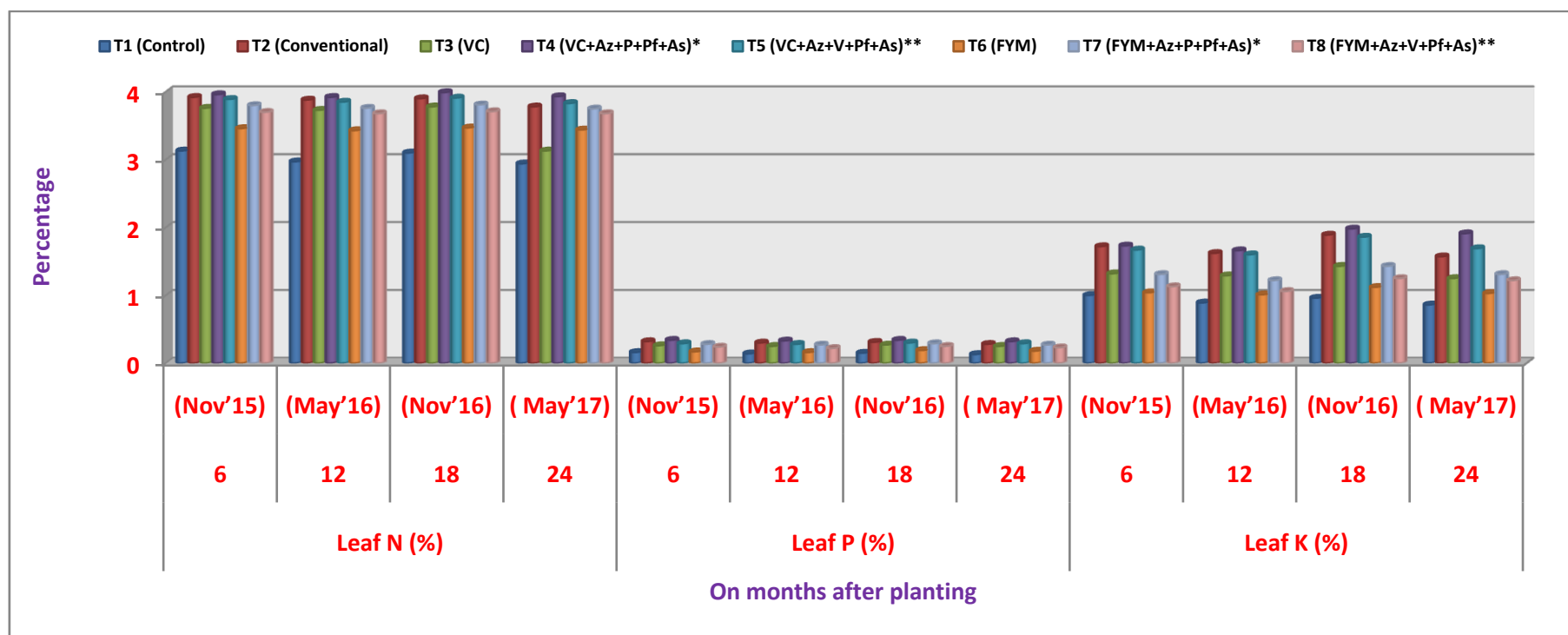


Fig.4.05: Effect of organic cultivation on nutrient content (%) in leaf of young tea (TV 26) at six months interval

treatments in November months, *i.e.* 6 MAP and 18 MAP was more compared to May months *i.e.* 12 MAP and 24 MAP. On 6 MAP, highest 1.73 % potassium content of leaf was observed in T₄ (VC+Az+P+Pf+As) followed by T₂ (conventional) with 1.72 % but they were at par with each other significantly, lowest 1.08 % potassium content of leaf was observed in T₁ (control).

Perusal of data in Table 4.05. indicated that on 12 MAP, significantly higher 1.66 % potassium content of leaf was recorded in T₄ (VC+Az+P+Pf+As) followed by T₂ (conventional) with 1.62 % potassium content of leaf but they were at par with each other. While lower 0.89 % potassium content of leaf was recorded in T₁ (control). On 18 MAP, significantly higher 1.98 % of potassium content of leaf was noticed in T₄ (VC+Az+P+Pf+As) followed by in T₂ (conventional) with 1.89 % potassium content of leaf while, lower 0.96 % of potassium content of leaf was noticed in T₁ (control). On 24 MAP, significantly maximum 1.91 % of potassium content of leaf was observed in T₄ (VC+Az+P+Pf+As) followed by T₅ (VC+Az+V+Pf+As) with 1.69 % potassium content of leaf, while lower 0.86 % potassium content of leaf was observed in T₁ (control).

4.06. Economics of growing young tea under organic cultivation

Various operations done from field preparation to harvesting have been listed in Table 4.06.01 under two broad groups – fixed costs and variable costs. Treatment wise costs involved, yield of green leaf and income could have generated at the prevalent market price have been presented in Table 4.06.02.

It is evident from Table 4.06.02 that minimum cost per plot of Rs. 814.31 was involved in T₁ (control), while maximum cost of Rs. 978.31 was incurred in T₄, T₅, T₇, and T₈. When converted to per ha, there was an involvement of a minimum of Rs. 5,16,366.51 in T₁ (control) to a maximum of Rs. 6,20,361.44 in T₄, T₅, T₇, and T₈. Green leaf yield per plot during the whole period of experimentation, *i.e.* up to two years ranged from 0.91 kg (T₁) to 2.15 kg (T₄), which were equivalent to 571.94 kg/ha and 1,357.52 kg/ha respectively. Considering the price of organic green leaf @ Rs. 50.00 per kg and conventional leaf @ Rs. 20.00 per kg, income generated could have been minimum Rs. 40.40 per plot in T₂, and maximum Rs. 107.50 in (T₄).

Corresponding income per ha for two years were calculated to be from Rs. 25,498.60 in T₂ to Rs. 67,876.00 in T₄ respectively.

Table 4.06.01. Various costs involved of growing tea organically in the initial years.

Fixed Costs
1. Land preparation
a. Tractor ploughing
b. Power tiller ploughing
c. Cleaning of weeds and stubbles
d. Layout of the field
2. Planting materials
3. Digging drains
4. Digging pits and planting
5. Intercultural operations
a. Bringing up of young tea
b. Weeding
c. Mulching
d. Application of organic manures, biofertilizers and fertilizers
e. Pests and disease management
f. Irrigation
g. Harvesting
Variable costs
1. Organic manures
a. FYM
b. Vermi compost
2. Biofertilizers
3. Fertilizers
Urea, SSP, MOP
4. Plant protection

Table No. 4.06.02. Evaluation of costs involved and income generated from organic cultivation of tea for two initial years.

Treatments	Cost of cultivation/plot (Rs.)	Cost of cultivation/ha (Rs.)	Green leaf yield (kg/plot)	Green leaf yield (kg/ ha)	Income per plot * (Rs.) @50/kg	Income per ha* (Rs.) @50/kg
T ₁ (Control)	814.31	5,16,366.51	0.91	571.94	45.50	28,597.00
T ₂ (Conventional)	817.22	5,18,211.79	2.02	1274.93	40.40	25,498.60
T ₃ (VC)	914.31	5,79,778.06	1.46	922.61	73.00	46,130.50
T ₄ (VC+Az+P+Pf+As)*	978.31	6,20,361.44	2.15	1357.52	107.50	67,876.00
T ₅ (VC+Az+V+Pf+As)**	978.31	6,20,361.44	1.96	1237.25	98.00	61,862.50
T ₆ (FYM)	914.31	5,79,778.06	1.25	789.68	62.50	39,484.00
T ₇ (FYM+Az+P+Pf+As)*	978.31	6,20,361.44	1.77	1122.16	88.50	56,108.00
T ₈ (FYM+Az+V+Pf+As)**	978.31	6,20,361.44	1.61	1017.27	80.50	50,863.50

*Sell price of green leaf organic tea cost Rs.50 and conventional cost Rs. 20 per kg

Table No. 4.06.03. Total cost of cultivation, income generated and profit/loss earned from organic cultivation of tea during initial years

Treatments	Total Cost of cultivation (Rs /ha)	Green leaf yield (kg/ ha)	Total income (Rs) (@50/kg)	Profit/Loss
T ₁ (Control)	5,16,366.51	571.94	28,597.00	(-)4,87,769.51
T ₂ (Conventional)	5,18,211.79	1274.93	25,498.60	(-)4,92,713.19
T ₃ (VC)	5,79,778.06	922.61	46,130.50	(-)5,33,647.56
T ₄ (VC+Az+P+Pf+As)*	6,20,361.44	1357.52	67,876.00	(-)5,52,485.44
T ₅ (VC+Az+V+Pf+As)**	6,20,361.44	1237.25	61,862.50	(-)5,58,498.94
T ₆ (FYM)	5,79,778.06	789.68	39,484.00	(-)5,40,294.06
T ₇ (FYM+Az+P+Pf+As)*	6,20,361.44	1122.16	56,108.00	(-)5,64,253.44
T ₈ (FYM+Az+V+Pf+As)**	6,20,361.44	1017.27	50,863.50	(-)5,69,497.94

Over all, in T₁ (control) total cost of cultivation Rs. 5,16,366.51 per ha, income Rs. 28,597.00 per ha, loss of Rs. 4,87,769.51 per ha. Among the organic plots T₃ and T₆ involved a total cost of cultivation Rs. 5,79,778.06 per ha, income generated Rs. 46,130.50 and Rs. 39,484.00 per ha respectively. T₄, T₅, T₇ and T₈ total cost of cultivation Rs. 6,20,361.44 per ha, however T₄ produced an maximum income of Rs. 67,876.00 per ha with a loss of Rs. 5,52,485.44 per ha. Minimum loss of Rs. 5,33,647.56 per ha was estimated in T₃ and maximum loss of Rs. 5,69,497.94 per ha was estimated in T₈ (Table 4.06.03). However, after due consideration of the trend in production of green leaf in T₄, after expending an amount of Rs. 6,20,361.44 per ha maximum income of Rs. 67,876.00 per ha could be generated, which was closely followed by T₅ (Table 4.06.03).

So, from the preceding results it could be observed that except T₁ (control) and T₂ (conventional) other treatments using organic fertilizers for commercial cultivation of organic tea in *terai* zone, T₄ (VC+Az+P+Pf+As) was the most remunerative treatment combination, followed by T₅ (VC+Az+V+Pf+As).

Chapter-V

Discussion

Chapter V

DISCUSSION

During last fifty years considerable progress has been achieved throughout the tea growing countries in the world with respect to increasing production, productivity and quality of tea by INM, IPM and other biotic and abiotic stresses by various inputs like fertilizer, insecticides, pesticides, acaricides, fungicides chemicals of synthetic origin. As the harvestable produce of tea is the young succulent tender leaves and apical buds containing 3-5 % N, 1% P₂O₅ and 2% K₂O and responses well to higher doses of N,P,K and to be kept free from pests. These practices degraded the product quality, soil health and environment. Organic farming is the production supplements, which avoids or largely excludes the use of synthetically compounded fertilizer, pesticides, growth regulators and live stock feed additives. Organic farming system rely upon crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes and aspects of biological pest control to maintain soil productivity to supply plant nutrients and to control insects, weeds and other pests (Sharma, 2002). Organic fertilizers are eco-management for long term sustainability of soil fertility and overall productivity of the agro-eco system for optimum yield of a quality product. In organic tea culture, nutrition is provided through organic manures like FYM, vermicompost, vermin wash, shade trees dropping, recycled pruning litter, mulching using biological wastes and various insecticides of plant origin like neem oil, neem cake and bio-fertilizers. So the product is free from hazardous chemicals and their residues maintain the soil microbial diversity, are better in quality with longer shelf life, higher antioxidant activity which make a perfect health drink (Parmar, 2008). Because of these reasons, there is growing awareness, all over the world and demand for organic tea. So in recent times, many tea plantations are converting from traditional (inorganic) system to organic system of culture. However, converting to organic estate is a complex operation for a long time involving technical and economical problems. For a plantation to be truly organic, it has to be ensured that the land and planting materials should be free from the residues of any chemicals from before initiation of planting and during culture process. Supply of proper nutrition for maintenance of health and vigour of plants, development of good frame, protection from pest and diseases by maintaining proper soil health are of utmost necessary (Barthakur, 2004,

Phukan *et al.*, 2011). However, there is no recommended package of practices for organic cultivation of young tea for *Terai* zone of West Bengal.

Considering these aspects the present investigation was undertaken to observe various growth parameters, yield and yield components of young tea plants using various organic inputs like FYM, vermicompost either alone or combined with bio-fertilizer treatments combinations for finding out the most remunerative treatment combination of organics for *Terai* zone of West Bengal in the initial years.

For the present investigation, an uncultivated piece of land was cleared, ploughed and plots were laid and plantable plants of clone TV 26 were planted maintaining a spacing of 105 cm X 70 cm as per treatment details and observations were taken on various growth and developmental parameters; yield and yield components; biochemical parameters reflecting the quality of harvested leaves; nutrients contents in soil and harvested leaves and finally the economics of organic tea production up to two years from planting for finding out the most remunerative treatment combinations

5.01. Growth parameters of young tea plants under organic cultivation

5.01.01. Days taken to attain tipping: Among all the treatments, 75% of the plants (Table 4.01.01) under treatment T₂ (Conventional) reached tipping height of 55 cm within a minimum of 79.41 days, closely followed by 81.33 days in T₄ (VC+Az+P+Pf+As) and maximum number of days (136.67) taken in T₁ (control). However, all the treatments showed significant differences in attaining tipping height, which could be explained by enhanced vegetative growth of young tea plant with increased nitrogen fertilization as N and P play significant role in promoting the vegetative growth of plants by enhancing increased cell division and elongation and availability is faster from inorganic sources (Owuor *et al.*, 2008, 2010; Qamar-uz-Zaman *et al.*, 2011). Enhanced growth of young tea plants fertilized with organic and inorganic based fertilization in Nigeria (Ipinmoroti *et al.*, 2001 and Sarwar *et al.*, 2007). The present findings were in conformity with Tennakoon *et al.*, (2007) in tea who also reported application of *Azotobacter* and *Azospirillum* produced maximum plant height in tea and Kaur, 2014 in rose.

5.01.02. Weight of pruning litter per plant: The pruning litter per plant was observed after centering or lung pruning about one month after planting. Weight of pruning litter per plant

ranged from 14.59 g (T₂) to 20.05 g (T₅), there was no significant difference among the treatments (Table 4.01.02). At the initiation of the experiment the planting materials were chosen basing on uniformity of their vegetative growth so that treatment variation could be neglected.

5.01.03. Total number of branches per plant: Total number of branches per plant consistently increased in all the treatments from 3 MAP to 24 MAP (Table 4.01.03), significantly among all the treatments, T₄ (VC+Az+P+Pf+As) showed maximum of 41.73 branches per plant and minimum of 17.70 branches per plant in T₁ (control) on 24 MAP.

This may be attributed to the fact that vermicompost with its richness in both macro and micro nutrients besides having humus forming microbes, sustained availability of nutrients throughout the crop growth period. *Azospirillum* also enhanced the uptake of nitrogen along with carbohydrates synthesised by the leaves which ultimately led to the formation of nitrogenous substances such as amides, proteins, enzymes etc., would have helped to build up new tissues (Ramanandan *et al.*, 2008). Number of branches per plant increased to 62 in tea clone TV 26 in the field six months after application of *Serratia marcescens* (TRS-1) PSB (Chakraborty *et al.*, 2010). In the second year after planting, Ipinmoroti *et al.*, (2011) recorded 48 branches in only FYM applied tea plants. Debere *et al.*, (2014) also observed 11.60 branches per plant in one year old tea seedlings by application of 150 kg/ha N as urea and P @ 30 kg/ha as organophosphorus in Ethiopia. Radhakrishnan and Mahendran (2010) reported 4.67 primary branches and 9.67 secondary branches in tea nursery plants using vermicompost and vermiwash.

5.01.04. Total number of leaves per plant: Total number of leaves per plant significantly increased in all the treatments from 3 MAP to 24 MAP (Table 4.01.04) however maximum 243.78 leaves per plant observed in T₄ (VC+Az+P+Pf+As) and minimum 130.74 of leaves per plant observed in T₁ (control) on 24 MAP.

Significant increase in number of leaves might be due to increased absorption of nutrients and increased activity of hormones produced by *Azospirillum* and phosphate solubilizing bacteria (PSB). The PSB applied might have increased phosphate availability in the soils which in turn helped better proliferation of root growth and uptake of other nutrients to a greater extent. The enlargement in cell size and cell division might have

helped in increasing number of leaves per plant. Number of leaves per plant increased to 180 in tea clone TV 26 in the field six months after application of *Serratia marcescens* (TRS-1) PSB (Chakraborty *et al.*, 2010). Ipinmoroti *et al.*, (2011) recorded 909 leaves in only FYM applied tea plants. Debere *et al.*, (2014) also observed 73.60 leaves per plant in one year old tea seedlings by application of 150 kg/ha N as urea and P @ 30 kg/ha as organophosphorus in Ethiopia. Radhakrishnan and Mahendran (2010) reported 71.00 number of leaves in tea nursery plants using vermicompost and vermiwash.

5.01.05. Leaf area: Generally the third leaf area decreased in winter season compared to rainy and summer season. In the present investigation maximum area of third leaf (21.50 cm²) was observed under T₄ (VC+Az+P+Pf+As) and minimum of 11.82 cm² leaf area was observed in T₁ (control) on 24 MAP.

These results corroborate with the finding of Chin *et al.*, (2010) in organic farming system of tea with maximum leaf length of 15.14 cm and leaf width of 7.33 cm recorded, Debere *et al.*, (2014) also observed leaf length-8.3 cm in one year old tea seedlings by application of 150 kg/ha N as urea and P @ 30 kg/ha as organophosphorus in Ethiopia.

5.01.06. Girth at collar: Girth at collar per plant differed significantly among the all the treatments throughout the period of experimentation. On 24 MAP maximum girth at collar of 4.14 cm was observed in plants under T₄ (VC+Az+P+Pf+As) while minimum girth of 2.66 cm was observed under T₁ (control).

Our observations were in conformity with Ipinmoroti *et al.*, (2011), who observed 5.36 cm girth in only FYM applied tea plants, Radhakrishnan and Mahendran (2010) reported 3.20 cm girth in tea nursery plants using vermicompost and vermiwash. Ipinmoroti *et al.*, (2008) reported that poultry droppings and tea fluff enriched organic manures enhanced girth up to 4.5cm in tea plants

5.01.07. Spreading: In the present investigation it was observed that spreading of branches increased continuously and significantly with the advancement of age up to 24 MAP significantly among all the treatments. On 24 MAP (Table 4.01.07), maximum 1961.44 cm² plant spreading was observed in T₄ (VC+Az+P+Pf+As) and minimum 1011.33 cm² plant spreading was observed in T₁ (control).

Nyasulu, (1995) observed a bush area of 3440 cm² in young tea plants applied with dead mulch and Bagyalakshmi *et al.*, (2012) reported plucking surface of 7935.7 cm² with N₁₀₀ P₁₀₀ K₁₀₀ + KSB + VC and 6954.0 cm² with N₅₀ P₅₀ K₅₀ + KSB + VC respectively in mature tea bushes.

5.02. Yield and yield attributes of young tea plants under organic cultivation

5.02.01. Number of two leaves and a bud harvested per plot

Total number of two leaves and a bud harvested per plot differed significantly among the treatments up to 24 months. Initially (Table 4.02.01) up to 4 MAP, T₂ (conventional) showed maximum number of two leaves and a bud, however from 5 MAP to 24 MAP, T₄ (VC+Az+P+Pf+As) showed maximum total number of two leaves and a bud. On 24 MAP, 1271.33 number of two leaves and a bud were harvested per plot and on 4 MAP, minimum total number of two leaves and a bud 521.67 was recorded in T₁ (control).

Vermicompost contains plant growth regulators, *viz.*, cytokinins and auxins and other microbial produced plant growth compounds including humates and beneficial microorganisms (biofertilisers) that produces positive effect on yield of tea (Grappelli *et al.*, 1987; Krishnamoorthy and Vajrabhiah, 1986; Vessey, 2003).

The highest yield was obtained in rains and photosynthesis was also observed to be high. There is a positive correlation observed between photosynthesis and yield. The temperature, relative humidity and soil moisture were high during June to August. Relative air humidity of 80–90 % is favorable for growth of tea plant but shoot growth is inhibited and adversely affected if it is below 50 % and 40 % respectively (Huang, 1989)

5.02.02. Fresh weight of two leaf and a bud per plot

Fresh weight of two leaf and a bud harvested per plot differed significantly among the treatments up to 24 months. Up to 4 MAP, T₂ (conventional) maximum fresh weight of two leaf and a bud recorded. From on 5 MAP to 24 MAP, T₄ (VC+Az+P+Pf+As) showed maximum fresh weight of two leaf and a bud harvested per plot on 24 MAP 345.03 g of two leaf and a bud harvested per plot recorded. From 3 MAP to 24 MAP, minimum fresh weight

of two leaf and a bud harvested per plot was observed in T₁ (control) where as, on 24 MAP, 140.08 g of two leaf and a bud harvested per plot.

5.02.03. Dry weight of two leaf and a buds per plot

Dry weight of two leaf and a bud harvested per plot differed significantly among the treatments up to 24 months. Up to 4 MAP, tea plants under T₂ (conventional) produced maximum dry weight of two leaf and a bud. From 5 MAP to 24 MAP, the plants under T₄ (VC+Az+P+Pf+As) showed consistently increasing in dry weight of two leaf and a bud, harvested per plot on 24 MAP maximum 86.26 g of two leaf and a bud harvested per plot. From 3 MAP to 24 MAP, minimum dry weight of two leaf and a bud harvested per plot in T₁ (control); on 24 MAP, as 33.35 g of two leaf and a bud harvested per plot. Chakraborty *et al.*, (2010), reported dry mass of leaves 120 g in tea clone TV 26 in the field six months after application of *Serratia marcescens* (TRS-1) PSB and Tennakoon *et al.*, (2007) also reported *Azospirillum* inoculated plots enhanced dry matter accumulation in shoot. The increased harvestable fresh and dry weight could be attributed to enhanced soil fertility following optimum application of urea as nitrogenous fertilizer. Fertilizers increase leaf yields of tea plant through increased growth rate and density of harvested shoots (Kamau *et al.*, 2008; Owuor *et al.*, 2008). According to Othieno (1983), the leaf yield of young tea plant increased with phosphatic fertilizer application.

5.02.04. Percentage of growing and dormnt buds

Numbers of growing buds increased with the onset of monsoon and maximum number of growing buds were observed up to 99.16 % during Aug/Sept. Thereafter, the percentage of growing bud decreased and dormant bud increased with the winter season crept in. As is this part of the country from October onwards, day length shortens, temperature start fall in down, soil had moisture stress. So overall environmental factors did not favour for luxuriant growth of tea. In the winter months i.e, during December maximum number of buds observed to be under dormant phase (up to 38.88) and thereafter during late December to early March, they remain dormant. (Barua, 1969; Tanton 1982 a; 1982 b).

Kumar *et al.*, (2015) reported, there were differences in the distribution of seasonal yield. Highest yield and photosynthesis were recorded in rains. 50 % of the annual crop is produced in the wet season (June to August). A proportion of the carbon fixed by

photosynthesis is used in maintenance respiration, and the remainder is then available for partitioning into shoot or root growth or into storage reserves. Smith *et al.*, (1993). No yield was recorded in Darjelling during winter and moisture-stress period from second week of November until end of March. The day length was observed below 11 h during November and December and then gradually increased till August (13 h). The seasonal yield distribution varies primarily as a result of seasonal changes in temperature and the development of soil moisture stress during the dry season. The temperature, relative humidity and soil moisture were high during June to August. Relative air humidity of 80–90 % is favorable for growth of tea plant but shoot growth is inhibited and adversely affected if it is below 50 % and 40 % respectively (Huang, 1989).

5.02.05. Volume of two leaves and a bud

Observations recorded on volume of 20 numbers of two leaf and a bud per plot from 10 MAP to 22 MAP at three months interval in young tea plants differed significantly among all the treatments. On 22 MAP, maximum volume of 12.15 cc two leaf and a bud was observed in T₄ (VC+Az+V+Pf+As) and minimum volume of 11.24 cc two leaf and a bud was observed in T₁ (control)

5.02.06. Leaf period

Leaf period per plant increased in winter season compared to rainy and summer season and T₄ (VC+Az+P+Pf+As) showed minimum leaf period per plant in all months from on 11 MAP to 19 MAP followed by T₂ (conventional), while maximum in T₁ (control).

Nitrogen is probably the key element that promotes vegetative growth, improves shoot succulence, shoot size and leaf size and also reduces flowering and fruit setting (Sarwar *et al.*, 2007; Han *et al.*, 2008). Govindan and Purushothaman (1984) opined that the increase in growth characters was due to *Azospirillum* to its N-fixing role and the production of phyto-hormones. Ramanandan *et al.*, (2008) reported that synergistic interaction between organics and bio-fertilizers resulted in maximum dry matter production in stem, leaf at harvest in cassava.

In the present investigation, it was observed that during both the years, the production of total number of leaves and branches were comparatively more in T₂

(conventional) for the initial months and thereafter in T₄ than other treatments, which might be due to the double advantage of quick release of nutrients from the inorganic sources and the slow but gradual release of nutrients from the mineralization of the organic materials. With the advancement of age, the organic matters undergone sufficient decomposition and mineralization to release nutrients and were available to tea plants. Similar observation was also reported by Ipinmoroti *et al.*, (2011) in young tea in Nigeria.

5.02.07. Number of plucking points

From 6 MAP to 24 MAP, number and density of plucking points increased significantly in all the bushes under all the treatments. On 24 MAP, maximum number of plucking points (30.78) was observed in T₄ (VC+Az+P+Pf+As) and minimum (15.17) plucking points was observed in T₁ (control). Bagyalakshmi *et al.*, (2012) observed 116.0 plucking points (per sq. ft.) under N₁₀₀ P₁₀₀ K₁₀₀ + KSB + VC and 111.8 plucking points under N₅₀ P₅₀ K₅₀ + KSB + VC treatments. The application of potassium soluble bacteria in soils showed improvement in tea plant growth and also reduced banji content. Similarly, the increasing level of nutrients in soil had increased the yield by improving the yield components like plucking points; plucking surface was reported by Balasubramanian *et al.*, (2010).

5.02.08. Green leaf yield

In the present investigation, during all the three plucking seasons, *i.e.* Aug'15 to Dec'15; Mar'16 to Dec'16 and Mar'17-May'17 green leaf yield per plot varied significantly with the treatments. Maximum total green leaf of 2.143 kg per plot, equivalent to 1358.19 kg/ha was recorded in T₄ (VC+Az+P+Pf+As); while minimum of 0.904 kg two leaf and a bud per plot, equivalent to 571.58 kg/ha was recorded in T₁ (control).

Fertilizers increase leaf yields of tea plant through increased growth rate and density of harvested shoots (Kamau *et al.*, 2008; Owuor *et al.*, 2008). According to Othieno (1983), the green leaf yield of young tea plant increased with phosphatic fertilizer application. Fertilizer is one of the major agricultural inputs contributing to increase productivity in tea plantation (Bonheure and Willson, 1992). For proper maintenance of the health of tea bushes and subsequent high yield, a well-balanced fertilization is necessary throughout the

year (Othieno, 1992; Bonheure and Willson, 1992). Owuor and Wanyoko, 1996 and Ipinmoroti *et al.*, (2001) also highlighted that nitrogen, potassium and phosphorous are three major nutrients required for tea cultivation and should be used in proper proportion.

Saikia *et al.*, (2011) reported yield of 339.00 kg made tea per hectare in young tea plants under bio-fertilizers treatment. Balamurugan *et al.*, (2015) observed a yield of 2626 kg made tea per hectare under organic manure + biofertilizers (N₂ fixer, *Pseudomonas* and AMF). Yield of organic plots maintain by application of various organic matters as observed by Kumar *et al.*, (2015) where vermicompost plots 610.57 kg made tea per hectare and through only farm yard manure plots 480 kg made tea per hectare. Verma (1997) indicated that production of 1000 kg tea leaf (dry weight) removes 40-50 kg nitrogen, 7-8 kg phosphorus and 20-25 kg potash. However, the response of nitrogen at any level is dependent on adequate availability of other nutrients in the soil pool (Owuor *et al.*, 2001). Organic fertilizers, besides their role as nutrient store and soil fertility enhancer, improve soil structure, stimulate soil biological activity and enhances the solubility of phosphorus applied as fertilizer in the soil and contribute greatly to soil health (Hailu *et al.*, 2008; Ipinmoroti *et al.*, 2001). A good correlation was observed obtained between arbuscular mycorrhiza fungi population and growth of tea varieties. Three year old tea (TV-26) plants showed only 35% root colonization and very poor growth, while, six-year old plot had 100% root colonization and good growth (Roy *et al.*, 2002). Application of biofertilizers can not only decrease the use of chemical fertilizer by 20 to 50%, but can also simultaneously increase the yield of crop by 10 to 20%. Among the different beneficial soil microbes, *Azospirillum* strains were effective in nitrogen fixing and they could also produce growth promoting substances (Tyagi *et al.*, 1999).

Kumar *et al.*, (2015) revealed that OM treatment showed much greater increase in tea yields, more effective improvement in soil chemical fertility, and higher diversity of bacterial community, compared to the other fertilizer treatments. Therefore, OM treatment could be considered and recommended as better fertilization practices in tea soil in southeastern China. Amount of N in the soil had positive correlation with the tea leaf growth and unshaded tea the increase in crop yield is directly proportional to the amount of N applied (Wilson and Clifford (1992). Tea is a fertilizer dependent crop, and its response to N, P, and K has been well documented (Rahman, 1977). Among the organic treatments,

vermicompost @ 5t/ha, cattle manure @ 3t/ha + vermicompost 2t/ha and vermicompost @ 2t/ha + mixed bio-fertilizers, maintained significantly higher yield over others. It was reported that the photosynthetic basis for increasing harvested yield involves light interception and conversion by foliage into photosynthetic products and then the partitioning of photo assimilates to the harvested economic sinks (Gifford *et al.*, 1984).

Continued use of organic fertilizers results in increased soil organic matter, reduced erosion, better water infiltration and aeration, higher soil biological activity as the materials decompose in soil, and increased yields after the year of application (residual effects). Proper handling of organic fertilizers enhances their quality and effectiveness. The best response to fertilizer use is obtained if the soil has a high inherent organic matter level. Building inherent fertility requires practices such as retaining crop residues on the field (Kumar *et al.*, 2015). Incorporation of *Azospirillum* strains and bacterial strains (diazotrophs) like *Azospirillum brasilense*, *Bacillus megaterium* and *Klebsiella pneumoniae* produced many phytohormones like auxins, cytokinins, gibberellins (GA₃) and abscisic acid or their derivatives produced by microorganisms and play big role in biological activities which markedly enhanced by microbial interactions in the rhizosphere of plants (Tensingh Baliah *et al.*, 2003).

5.03. Quality parameters: All the quality parameters viz., total chlorophyll content, PPO, caffeine and tannin content of young tea plants under organic cultivation were observed from 13 MAP to 22 MAP at 3 months interval.

5.03.01. Total chlorophyll content

Total chlorophyll content was increased from on 13 MAP to 22 MAP, on 22 MAP highest 57.66 SPAD units of total chlorophyll content was observed in T₄ (VC+Az+V+Pf+As) minimum 45.95 SPAD units of total chlorophyll content in T₁ (control) which was significantly among the all treatments.

Kumar *et al.*, (2015) observed in summer, total chlorophyll content in fym application 1.2 mg/g and in vermicompost application 1.5 mg/g; in rainy season total chlorophyll content in fym application 2 mg/g and in vermicompost application 2.9 mg/g; in winter season, total chlorophyll content in fym application 1.9 mg/g and in vermicompost

application 2.7 mg/g. Kaur, (2014) observed (Azotobacter + Azospirillum) high chlorophyll in rose plants.

5.03.02. Polyphenol content and its activity

Tea leaves contain a large range of enzymes, though many have not been studied closely, most of which play important role and influence tea quality during processing. Tea leaf poly phenol oxidase (o-di phenol : O₂ oxidoreductase 1.10.3.1) is of crucial importance (Banerjee, 1993). Polyphenol oxidase activity varies seasonally between mature and young tea leaves, possibly due to variation in the relative amounts of the individual isoenzymes and during different stages of tea processing (Takeo and Baker, 1973).

Generally, it was observed that PPO activity was decreased from *i.e.*, June'16 (13 MAP) to Sept'16 (16 MAP) and increased upto 22 MAP (*i.e.*, Mar'17), T₄ (VC+Az+P+Pf+As) recorded maximum PPO activity of 16.60 min/g. Fresh weight in two leaf and a bud significantly among all the treatments and minimum 10.78 PPO content was in T₁ (control) on 22 MAP. Wood *et al.* (1964) observed that ppo activity ranged from 12.8 to 22.8 in the plucked leaves

5.03.03. Caffeine content

Caffeine content differed significantly among all the treatments and caffeine content was low in winter season compared to other seasons. Among the treatments T₄ (VC+Az+P+Pf+As) recorded maximum 3.95 % caffeine content in two leaf and a bud and minimum 3.86 % caffeine content in two leaf and a bud was recorded in T₁ (control) on 16 MAP. Chin *et al.*, (2010) observed in organic farming system plants higher caffeine- 65.23 mg/g in young shoots of tea plants, Bagyalakshmi *et al.*, (2012) also reported 2.5% caffeine under N₁₀₀ P₁₀₀ K₁₀₀ + KSB + VC and 3.6% caffeine under N₅₀ P₅₀ K₅₀ + KSB + VC treatments.

5.03.04. Tannin content

Tannin content per plant differed significantly among all the treatments and tannin content was low in winter season compared to other seasons. T₄ (VC+Az+P+Pf+As)

recorded higher (3.06 %) tannin content in two leaf and a bud and lower tannin content of 2.84% in two leaf and a bud was recorded in T₁ (control) on 16 MAP. The findings of the present investigation were corroborate with Kumar *et al.*, (2012) also observed tannin in organic plots ranging from 3.4 to 4.0% and inorganic plots ranging from 3.2 % to 4.2 %.

5.04. Physical and chemical characteristics of soil: Physical and chemical status of soil in young tea under organic cultivation were observed from 6 MAP to 24 MAP at six months interval.

5.04.01. Soil pH

Soil pH differed significantly among all the treatments throughout the period of experimentation, *i.e* from 6 MAP upto 24 months. On 24 MAP, higher soil pH 5.82 was noticed in T₆ (FYM) followed by 5.76 pH in T₂ (conventional), while lower 5.54 soil pH was noticed in T₁ (control).

This might be due to the buffering action of the soil (Santhy *et al.*, 1999). Similar effects on pH under organic tea experiments were also reported by Stamatoados *et al.*, (1999). Chin *et al.*, (2010) reported in organic farming system higher soil pH (4.14), Dolui *et al.*, (2014) observed in vermicompost treated plots soil pH increased from 4.57 to 4.60. In FYM 5t/ha application treatments pH increased from 4.65 to 4.84 and in Vermi compost 2t/ha + *Azospirillum* (2 kg/ha) + *Azotobacter* (2 kg/ha) + PSB (2 kg/ha) + KSB (2 kg/ha) application treatments, pH increased from 4.65 to 4.78 (Baruah *et al.*, 2011). Louis Mary *et al.*, (2015) concluded that application of vermicompost + biofertilizers enhanced the soil pH 6.89 in mulberry.

Nitrogenous fertilizers used in conventional tea cultivation such as ammonium sulphate, ammonium nitrate, ammonium sulphate nitrate, urea, calcium ammonium nitrate and ammonium chloride lead to increased acidity (Tee *et al.*, 1987; Ma *et al.*, 1990).

5.04.02. Organic carbon

Soil organic carbon differed significantly among all the treatments throughout the period of experimentation, *i.e.* from 6 MAP upto 24 months, in all treatments soil organic carbon increased, except T₂ (conventional) and T₁ (control) soil organic carbon decreased.

On 24 MAP revealed that highest 0.74 % organic carbon was observed in T₃ (VC) but T₃ at par with T₅, T₄, T₇ and T₆ while lowest 0.59 % organic carbon was recorded in T₁ (control). Dolui *et al.*, (2014) observed in vermicompost treated plots organic carbon increased from 1.00% to 1.07% in young tea plants. Sarmah *et al.*, (2011) observed that the positive effect of vermicompost on carbon sequestration in tea soil at Tocklai was also observed building up of soil organic carbon increased from 0.71% to 0.80% as well as humus carbon from 0.31 to 0.39%. In vermicompost @ 2t/ha + *Azospirillum* (2 kg/ha)+*Azotobacter* (2 kg/ha) + PSB (2 kg/ha)+ KSB (2 kg/ha) application treatments, organic carbon increased from 0.95 to 1.06% (Baruah *et al.*, 2011).

Higher build-up of organic carbon was observed in the treatments where organic manure was applied alone followed by combined application of organic and inorganic fertilizers. In general, the status of organic carbon in soil after two years of experimentation was higher. The increased in organic carbon content of soil in the plots receiving organic manure might be due to direct incorporation of organic matter through organic manure in the soil (Singh *et al.*, 2011).

5.04.03. Total carbon

The total soil carbon differed significantly among all the treatments throughout the period of experimentation, *i.e.* from 12 MAP upto 24 months. On 24 MAP, T₅ (VC+Az+V+Pf+As) significantly showed maximum 1.25 % total soil carbon but T₅ at par with T₄, T₇ and T₃, while lowest 1.13 % total soil carbon was recorded in T₁ (control).

All the organically managed plots maintained higher build-up of carbon over conventional plots, which could be due to the addition of various forms of organic manure (More, 1992, Nambiar *et al.*, 1992). Addition of organic manures added considerably to the organic matter status of soil and maintained the satisfactory level of organic carbon (Anon, 1996). Kumar *et al.*, (2015) continued use of organic fertilizers results in increased soil organic matter, reduced erosion, better water infiltration and aeration, higher soil biological activity as the materials decompose in soil, and increased yields after the year of application (residual effects). Proper handling of organic fertilizers enhances their quality and effectiveness. The best response to fertilizer use is obtained if the soil has a high inherent

fertility level (high organic matter status). Building inherent fertility requires practices such as retaining crop residues on the field.

5.04.04. Bulk density

In organic treatments soil bulk density decreased. T₂ (conventional) and T₁ (control) soil bulk density increased. On 24 MAP revealed that minimum bulk density of soil 1.17 g/cc was observed in T₅ (VC+Az+V+Pf+As), T₃ (VC) and T₇ (FYM+Az+P+Pf+As) but at par with all organic plots *i.e* T₄, T₈, and T₆. While highest 1.24 g/cc bulk density of soil was recorded in T₂ (conventional).

Singh *et al.*, (2011) observed soil bulk density decreased in vermicompost treatment to 1.02 to 0.84 mg/m³, Ping *et al.*, (2014) bulk density is low in organic treatments 1.20 g/cm³ compared to inorganic treatment 1.33 g/cm³

5.04.05. Available nitrogen

Available nitrogen of soil differed significantly among all the treatments throughout the period of experimentation *i.e.* from 6 MAP up to 24 months. On 24 MAP, T₄ (VC+Az+P+Pf+As) recorded highest 258.23 kg/ha available nitrogen and T₁ (control) has recorded lowest 133.14 kg/ha available nitrogen.

Singh *et al.*, (2011) increased to available nitrogen from 305.25 to 317.79 kg/ha in vermicompost treatment. Dolui *et al.*, (2014) also observed in vermicompost treated plots in young tea plants available N increased from 401.8 to 405.1 kg/ha.

5.04.06. Total nitrogen

The total nitrogen of soil differed significantly among all the treatments throughout the period of experimentation, *i.e.* from 6 MAP up to 24 months. On 24 MAP, maximum 642.74 kg/ha total nitrogen was observed in T₈ (FYM+Az+V+Pf+As) and lowest 584.10 kg/ha total nitrogen was recorded in T₁ (control).

Balamurugan *et al.*, (2015) observed in tea, application of organic manure with biofertilizers (N₂ fixer, *Pseudomonas* and AMF) increased total N increased from 60 to 66%, Dasl *et al.*, (2011) also observed in newly planted tea soil total N increased from 1000 ppm to 1055 ppm. Nutrient requirements of commercial tea crops, like any crop,

requires many nutrients for its growth. Nutrient requirements for commercial tea production are particularly high because the harvestable portions of tea are succulent shoots, which contain the largest percentage of nutrients in the plant. According to Ranganathan and Natesan (1985), N is the most important nutrient element for tea cultivation because it is required in large quantities, accounting for approximately 4 to 5% of the dry weight of the harvested shoots. Potassium and P are possibly the next most important nutrients after N, accounting for 2% and 0.5% respectively, of the dry weight of the tea harvest.

Low N content in conventional plot where chemical fertilizers were used might be due to leaching and denitrification as nitrate is known to be very mobile in soil and moves largely with the soil water particularly during excessive rain, it will leach out from the upper horizons of the soil into deeper layers (Tisdale and Nelson, 1975). Diepeningen *et al.*, (2006) also reported similar results in their study comparing the effects of organic and conventional management on chemical and biological parameters in agricultural soil. They suggest that soil type (clay or sandy soil) has a stronger effect on the soil characteristics rather than management type.

5.04.07. Available phosphorus

Available P of soil differed significantly among the all treatments throughout the period of experimentation, *i.e.* from 6 MAP up to 24 months. On 24 MAP, T₄ (VC+Az+P+Pf+As) showed maximum 28.23 kg/ha available P, T₄ at par with T₅ and T₃. T₁ (control) has recorded minimum 16.78 kg/ha available P.

Baruah *et al.*, (2011) observed available P increased from 19 ppm to 22 ppm in vermi compost 2t/ha + *Azospirillum* (2 kg/ha) + *Azotobacter* (2 kg/ha) + PSB (2 kg/ha)+ KSB (2 kg/ha) application treatments at Tocklai Tea Estate-T3E3 mature tea plants. Das *et al.*, (2011) also observed in newly planted tea soil available P-increased from 14 ppm to 16 ppm (vermicompost 300 g/pit + *Azospirillum* (3g/pit) + *Azotobacter* (3 g/p it) + PSB (3 g/pit)). Available P increased to 16.4 ug/g in tea clone TV 26 in the field six months after application of *Serratia marcescens* (TRS-1) PSB (Chakraborty *et al.*, 2010).

The optimum pH for good growth and optimum nutrient utilization, especially N, is between 4 and 5 (Ranganathan and Natesan, 1985). Soil pH is considered a critical factor for tea plant growth. Nitrification activity was positively correlated with soil pH, in which

the lowest limit of pH was approximately 2 (Hayatsu, 1993). Over 70% of tea soils are P deficient (Lin *et al.*, 1991). Inorganic P is the major constituent of phosphate in soil. Most of this is occluded P in aluminum- and iron-bound forms. Adjusting the soil pH and adding organic matter (OM) are the most common methods of decreasing P deficiencies in tea soils (Zhang *et al.*, 1997).

5.04.08. Available potassium

Available K of soil differed significantly among the all treatments throughout the period of experimentation, *i.e.* from 6 MAP upto 24 months. On 24 MAP, maximum 161.81 kg/ha of available K was observed in T₂ (conventional) followed by T₇ (FYM+Az+P+Pf+As) with 135.51 kg/ha available K, while lower 110.83 kg/ha available K was observed in T₁ (control).

Balamurugan *et al.*, (2015) observed in tea application of organic manure with biofertilizers (N₂ fixer, *Pseudomonas* and AMF) increased available K from 236 to 325 mg/kg. Dolui *et al.*, (2014) reported in young tea plants soil increased available K from 176.5 to 177.3 kg/ha in vermicompost treated plots. Study in India by Verma (1997) has indicated that production of 1000 kg tea-leaf (dry weight) removes 40-50 kg nitrogen, 7-8 kg phosphorus and 20-25 kg potash. However, the response of nitrogen at any level is dependent on adequate availability of other nutrients in the soil pool (Owuor *et al.*, 2001). Organic fertilizers, besides their role as nutrient store and soil fertility enhancer, improve soil structure, stimulate soil biological activity and enhances the solubility of phosphorus applied as fertilizer in the soil and contribute greatly to soil health (Hailu *et al.*, 2008; Ipinmoroti *et al.*, 2001).

In tea, excessive amounts of fertilizers are usually applied, particularly to ensure the availability of N as frequent harvests of tender young shoots containing high N content and regular pruning, removing large amounts of biomass for maintaining a vigorous vegetative growth (Vorgelegt, 2005). Nutrient availability to plants from organic matters depend on many environmental factors such as aeration, moisture, pH and temperature of soil, as well as the C: N ratio of the organic materials before decomposition and mineralization can take place (Zech *et al.*, 1997). In other words, organic fertilizers require more time before

nutrients become available for plant use as compared to chemical fertilizers (Tisdale and Nelson, 1975).

However, Mohotti *et al.*, (2008) concluded that organic cultivation did not change the soil nutrient content, but improved the organic carbon content in soil and during dry periods organically managed soils held more moisture. Soil organic matter contents varied from 9.00% to 30.03%, and the highest value occurred in OM treatment. Similarly, the contents of TN, TP, AN, AP, and AK were the highest in OM treatment. Obviously, the OM-treatment showed much greater increase in soil chemical fertility, which could be attributed to the regular and greater addition of organic manure for 5 yr, this was consistent with the findings at Xinhua and Ningxiang in Hunan, China (Hao *et al.*, 2008).

5.05. Leaf nutrient content

5.05.01. Leaf nitrogen content

The nitrogen content of leaf differed significantly among all the treatments throughout the period of experimentation, *i.e.* from 6 MAP upto 24 months. On 18 MAP, highest 3.99 % nitrogen content of leaf was observed in T₄ (VC+Az+P+Pf+As) and lowest 3.10 % nitrogen content of leaf was observed in T₁ (control).

Increase in leaf nitrogen status observed was partially attributed to the stimulating influence of biofertilizers on organic manure which, in turn, increases nutrient-absorption rate and translocation in the plant system. It could also be due to increased dry-matter production, and nitrogen fixation or nitrogen assimilation by *Azotobacter* and *Azospirillum* (Singh and Singh, 2004).

Baruah *et al.*, (2011) reported that tea leaf nitrogen content increased from 4.49% to 4.52% in vermi compost 2t/ha + *Azospirillum* (2 kg/ha) + *Azotobacter* (2 kg/ha) + PSB (2 kg/ha)+ KSB (2 kg/ha), Tennakoon *et al.*, (2007) observed the potential of *Azospirillum* and enhanced the nitrogen nutrient content in shoot to 2.46% of tea plants.

5.05.02. Leaf phosphorus content

The phosphorus content of leaf differed significantly among all the treatments throughout the period of experimentation, *i.e.* from 6 MAP up to 24 months. On 18 MAP,

higher 0.34 % of phosphorus content of leaf was noticed in T₄ (VC+Az+P+Pf+As) and lower 0.15 % of phosphorus content of leaf was noticed in T₁ (control).

This was perhaps due to production of enzyme complexes by the biofertilizers applied, which may have solubilized the unavailable form of phosphorus and made it available to the plant (Singh *et al.*, 2003).

Tennakoon *et al.*, (2007) observed the potential of *Azospirillum* and enhanced the phosphorus nutrient content in shoot to 0.18 % of tea plants. Akash Sharma *et al.*, 2011 also reported leaf phosphorus increased to 0.24 % in poultry manure+ *Azotobacter* and *Azospirillum* in guava.

5.05.03. Leaf potassium content

The potassium content of leaf differed significantly among all the treatments throughout the period of experimentation, *i.e.* from 6 MAP up to 24 months. On 18 MAP, significantly higher 1.98 % of potassium content of leaf was noticed in T₄ (VC+Az+P+Pf+As) and lower 0.96 % of potassium content of leaf was noticed in T₁ (control).

This increase in leaf potassium in guava was probably due to the combined use of organic manure and biofertilizers which may have contributed to improving soil physical-properties. In turn the results in better rooting, and therefore, better uptake of potassium from native sources. Increase in potassium content in the present study is also in conformity with findings of Akash Sharma *et al.*, 2011 where leaf potassium increased to 1.23 % in poultry manure+ *Azotobacter* and *Azospirillum* in guava. Balamurugan *et al.*, (2013) reported biofertilizer application increased k content 1.25% in tea shoot.

5.06. ECONOMICS

Various fixed costs and variable costs evaluated. Treatment wise costs involved, yield of green leaf, income generated and profit or loss per ha, during two years were estimated (Table 4.06.03) So, from the preceding results it could be observed that except T₁ (control) and T₂ (conventional), using inorganic fertilizers for commercial cultivation of

organic tea in *terai* zone, T₄ (VC+Az+P+Pf+As) was the most remunerative treatment combination followed by T₅ (VC+Az+V+Pf+As).

Ipinmoroti *et al.*, 2011 reported that in new planted garden, the readily availability of the organic fertilizer materials compared to NPK (25:5:5), their relatively cheaper procurement cost when used either sole or in combination with urea as organominerals and their better growth enhancement effects on tea plants suggests their inevitability for optimum tea production in Nigeria.

Chapter-VI

Summary and Conclusions

CHAPTER VI

SUMMARY AND CONCLUSION

All over the world, about 4 billion cups of tea is drunk a day than any other drink, just next to water. The world annual tea production reaches 2.5 million tonnes and it used to be achieved by following conventional inorganic sources of fertilizers most probably, indiscriminate use of chemical inputs degraded the environment, soil health and product quality. In this scenario, a novel method of nourishment without losing yield and quality of tea, to establishing a fundamental organic and sustainable farming system for tea growers by using low cost, readily available and easily adaptable techniques. The practice of organic cultivation at young growth stages could be very much helpful to the tea plantation to bring the ideal combination of organic fertilizers to meet nutrient requirements of tea plants. Therefore, a study was undertaken at the Instructional Plots of the Department of Plantation Crops and Processing, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India from March, 2015 to May, 2017 to “Studies on growth, development and yield of young tea plants (*Camellia sinensis* (L.) O. Kuntze) under organic cultivation”. The study attempts to evaluate the effect of different organic manures (vermicompost and FYM) singly or in combination with biofertilizers (*Azotobacter*, PSB, *Fl. pseudomonas*, *Azospirillum* and VAM) on young tea plants growth, yield, and leaf and soil quality.

From the present investigation following could be summarized and conclusion drawn as follows:

- 1) The young tea plants of clone TV 26 took only 79.41 days (75 % plants in a plot) to reach the tipping height of 55 cm after centering in T₂ (conventional). The pruning litter was observed after centering or lung pruning about one month after planting there was no significant difference among the treatments.
- 2) Result showed that the total number of branches, leaves and spreading of young tea plants up to 3 months after planting in treatment T2 (conventional) *i.e.* inorganic treated plot, performed better than the organically treated plots. From 6 months after planting up to the total period of experimentation, *i.e.* 24 MAP, T4 [vermi compost @ 1.0 kg + (*Azotobacter* + PSB + *Fl. pseudomonas* + *Azospirillum*) @ 5.0 g each] the plants exhibited better with respect to all growth parameters like total number of

branches (41.73) per plant, total number of leaves (243.78) per plant, leaf area (21.50 cm²), girth at collar (4.14 cm) and canopy spreading (1961.44 cm²) at 24 MAP. Maximum number of days (62.67) taken to reach tipping height and from 3 months after planting up to the total period of experimentation, *i.e.* 24 MAP, minimum growth parameters total number of branches (17.70) per plant, total number of leaves (130.74) per plant, leaf area (11.82 cm²) girth at collar (2.66 cm) and canopy spreading (1011.33 cm²) at 24 MAP was recorded in T₁ (Control- no manure and fertilizer).

- 3) The yield parameters observed included total number, fresh and dry weight of two leaf and a bud harvested per plot observed maximum in T₂ (conventional) on 3 MAP and 4 MAP. From 6 MAP up to 24 MAP T₄ [vermicompost @ 1.0 kg + (*Azotobacter* + PSB + *Fl. pseudomonas* + *Azospirillum*) @ 5.0 g each] maximum 1271.33 number of two and a bud harvested, 345.03 g fresh weight of green leaves and corresponding dry weight was 86.26 g on 24 MAP.
- 4) Maximum Percentage of growing and minimum dormant buds were 98.27% and 1.73% respectively, 1271.33 number of plucking points with a density per 625 cm² was 30.78 at 24 MAP; volume of two leaf and a bud with 12.43cc on 22 MAP, and a yield of 0.269 kg/plot during first year and 1.871 kg /plot during second year recorded in T₄. Minimum yield parameters were observed in T₁ (Control- no manure and fertilizer).
- 5) Result showed that quality parameters in organic plots more compared to inorganic plot. Quality parameters include maximum leaf total chlorophyll was 57.66 SPAD units, PPO content 16.60 per min/g, caffeine 3.86% and tannin contents 2.95% on 22 MAP in T₄ closely followed by T₅ [Vermicompost @ 1.0kg + (*Azotobacter* + VAM + *Fl. pseudomonas*+ *Azospirillum*) each @ 5.0 g/plant]. Minimum quality parameters observed in T₁ (Control- no manure and fertilizer).
- 6) Evaluation of economics including fixed costs and variable costs among the organic treatments, T₄ was observed to be the best with an income per ha for two years was Rs. 67,876 followed by T₅ with Rs. 61,862 per ha.

So, from the investigation, by observing the young tea plants only for two years, though it is premature to conclude, it was observed that T₄ [vermicompost @ 1.0 kg +

(*Azotobacter* + PSB + *Fl. pseudomonas* + *Azospirillum*) @ 5.0 g each] was the most remunerative treatment of organics for Terai zone of West Bengal.

Chapter-VII

Future scope of research

CHAPTER VII

FUTURE SCOPE OF RESEARCH

Based on the results obtained in the present study, it is evident that there is lot of scope in future for research on the following aspects for increasing production and improving quality of tea.

- ✓ Sustainable organic farming is gaining importance and hence studies on the possibilities of using green manure crops and other locally available organics (litter, karanj cake, castor cake, compost, urban waste and poultry manure) may be initiated.
- ✓ There is an urgent need to screen large number of organics and biofertilizers on different tea clones which have profound influence on yield and quality.
- ✓ It is necessary to identify suitable organics and biofertilizers for improving physiological and biochemical parameters in tea.
- ✓ Studies on different doses and time of application of organic manures need to be taken up for further investigation.
- ✓ Long term studies on organic manures along with other sources of organic nutrients need to be initiated to develop integrated nutrient management schedule for higher leaf yield and leaf quality in tea and take long term microbial observations in different locations under different sources of organic nutrients.
- ✓ Long term storability studies with application of organic manures on tea may be initiated.
- ✓ Research may be taken up to study the exact physiology of tea growth and development with the application of organic manures with and without bio-fertilizers.

- ✓ Research may be taken up to reduce the cost of producing organics there by reducing the cost of cultivation.
- ✓ To develop nutrients dynamics including micro-nutrients for *terai* and other agro-ecological situations.
- ✓ Pest, disease and weed management in using organic cultivation of tea insect and pests repellants, biopesticides from organic origin.

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ANNEXURE-I

Month wise meteorological parameters during the period of experimentation (March 2015 to May 2017)

Month	Temperature ($^{\circ}\text{C}$)		Relative humidity (%)		Rainfall (cm)
	Max.	Min.	Max.	Min.	
March, 2015	30.11	16.75	73.72	55.93	0.00
April, 2015	29.83	19.73	78.62	69.27	4.41
May, 2015	31.73	22.33	84.9	77.2	12.59
June, 2015	31.2	23.9	91.4	82.87	20.73
July, 2015	33.43	25.12	84.44	74.7	8.64
August, 2015	31.83	25.16	89.32	81.11	26.58
September, 2015	32.88	24.92	78.53	71.63	9.99
October, 2015	32.51	22.27	72.81	67.77	0
November, 2015	29.28	22.66	81.67	74.87	0
December, 2015	25.14	18.05	83.27	79.2	0
January, 2016	23.73	9.47	91.4	82.03	0.18
February, 2016	27.92	12.55	81.38	67.6	0.01
March, 2016	30.66	17.29	70.47	59.7	0.03
April, 2016	31.52	21.78	80.57	73.8	4.59
May, 2016	31.02	21.72	83.61	76.42	11.77
June, 2016	32.77	23.61	88.97	79.43	29.54
July, 2016	31.48	25.35	93.26	85.65	27.3
August, 2016	34.16	25.99	85.9	78.42	13.32
September, 2016	32.22	24.83	90.9	85.85	16.5
October, 2016	32.85	21.81	82	74.32	4.76
November, 2016	31.13	16.52	74.83	69.1	0
December, 2016	28.32	12.32	80.32	69.97	0
January, 2017	26.08	9.06	97.29	46.76	0
February, 2017	27.7	16.6	79	43	0
March, 2017	27.1	21	83	64	0
April, 2017	31.31	19.82	89.19	62.9	7.37
May, 2017	31.39	21.91	90.43	70.48	10.82

