STANDARDIZATION OF SINGLE WINDOW ORGANIC TECHNOLOGY FOR SAFE PRODUCTION OF GINGER

A Thesis Submitted

To

Sikkim University

In Partial Fulfilment of the Requirement for the
Degree of Doctor of Philosophy

By

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December 2019

Date: 24/12/2019

DECLARATION

I, **Miss Deeki Lama Tamang**, hereby declare that the research work embodied in the thesis titled "**Standardization of Single Window Organic Technology for Safe Production of Ginger**" submitted to Sikkim University for the award of the degree of Doctor of Philosophy, is my original work. The thesis has not been submitted for any other degree of this university or any other university.

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CERTIFICATE

This is to certify that the Ph.D. thesis entitled "**Standardization of Single Window Organic Technology For Safe Production of Ginger**" submitted to the Sikkim University, in partial fulfillment of the requirements of the award of the degree of **Doctor of Philosophy** in **Department of Horticulture**, embodies the result of *bonafide* research work carried out by **Ms. Decki Lama Tamang** under the guidance and supervision of **Dr. S. Manivannan** and co-supervision of **Dr. Niladri Bag.**

This work is an original contribution of the candidate unless otherwise stated, and no part of the thesis has been submitted for any other degree or diploma.

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All the assistance and help received during the course of investigation have been duly acknowledged by her.

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This is to certify that plagiarism check has been carried out for the following Ph.D. thesis with the help of **URKUND SOFTWARE** and the result is 0% tolerance rate, within the permissible limit (below 10% tolerance rate) as per the norms of Sikkim University.

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submitted by **Decki Lama Tamang** under the supervision of **Dr. S. Manivannan, Associate Professor, Department of Horticulture, School of Life Science, Sikkim University.**

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DEDICATED TO MY BELOVED PARENTS

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ABBREVIATIONS

FYM	Farm Yard Manure
VAM	Vesicular Arbuscular Mycorrhiza
AM	Arbuscular Mycorrhiza
PGPR	Plant Growth Promoting Rhizobacteria
PSB	Phosphate Solubilizing Bacteria
PDI	Percent Disease Index
DAP	Days After Planting
DAS	Days After Spraying
GCMS	Gas Chromatography-Mass Spectrometry
GC	Gas Chromatography
MSL	Mean Sea Level
g	Gram
kg	Kilo gram
t	tonne
µg	Micro gram
mL	Millilitre
mgL^{-1}	Milligram per Litre
cm	Centimeter
m	Meter
ha	Hectare
%	Percentage

min	Minutes
°C	Degree Centrigrade
@	at the rate of
H_2SO_4	Sulfuric Acid
NaOH	Sodium Hydroxide
N	Nitrogen
P	Phosphorus
K	Potassium
Ca	Calcium
Mg	Magnesium
Fe	Iron
Mn	Manganese
S	Sulphur
Zn	Zinc
Na	Sodium
NO_3^-	Nitrate
Cl^-	Chlorine
K	Potassium

CHAPTER - 1

INTRODUCTION

INTRODUCTION

Ginger (*Zingiber officinale* Rosc.) is an important spice crop that supports the livelihood of many farmers in Kerala, Karnataka, Himachal Pradesh, Meghalaya, Sikkim, West Bengal and other North Eastern states of India (Kumar and Sarma, 2004). It was grown on west coast of India from time immemorial and later its cultivation spread to various other parts mainly to Bengal and North Eastern India. It was exported from ancient Malabar Coast of peninsular India. It was the Arabs, Portuguese and Dutch, who took it to western world. It belongs to the family Zingiberaceae, which is a herbaceous perennial, the rhizomes of which are used as a spice. Ginger is a perennial crop and a monocotyledon. It is 30-100cm tall with a robust branched rhizome borne horizontally near the surface of soil, bearing leafy shoots close together. It is called Adraka in Sanskrit, Adrak in Hindi, Sunti in Kannada and Adua in Nepali.

The use of chemical fertilizers and pesticides in the crop and soil has significantly deteriorated the soil fertility and structure, the residual effect in the soil causes the imbalance in the nutrient content and thus reduces the agricultural produce. In the modern era people are more concerned about the well being of oneself so the use of naturally available resources is the best option for reducing the long-term ill effects on the soil as well as the health of organisms that consume them. In organic farming the use of land is less intensive and the use of chemicals is restricted. It focuses mainly on the protection of soil and environment and encourages the use of naturally available resources to maintain the status of the soil structure and fertility (Duruigbo *et al*., 2013). Organic manures are the slow releaser of nutrients and require specific soil microbes for the plant to receive the nutrients and combining different organic amendments can supply the required nutrient by the plant. Ginger also requires a right kind of nutrient to grow and increase its yield. The use of organic manures is one technology that has been exploited overtime and across ages because of its ability to restore soil fertility, supply major plant nutrients, such as N, P, K, Ca, Mg and also stabilizer soil pH (Sanchez and Miller, 1986).

Sikkim, with an area of about 7096 sq. km where farming is done in about 10.20%, is declared as an Organic state. Ginger being one of the major cash crops of Sikkim plays a vital role in the state's economy in terms of direct and indirect income and employment generation since time immemorial. Ginger cultivation in Sikkim is a good source of income for farmers and it is grown up to an elevation of 1500 m above MSL, occupying an area about 8000 ha producing 44,000 tons of ginger (Yadav *et al.,* 2014).

The following points are some of the problem identified in Sikkim:

- The high rainfall received in the region causes heavy infestation with weeds, pests and diseases and leaching of nutrients.
- Disease infestation of Soft rot caused by *Pythium aphanidermatum* is the major disease of ginger prevailing in Sikkim.
- Pest infestation of Shoot Borer *Conogethes punctiferalis* is a serious pest of Sikkim.
- Managing nutrient requirement, pest and diseases organically is a major challenge.
- Application of different organic inputs alone and in combinations as well as in a cumulative manner can supply the nutrient requirement of the plant.

There is an ample scope for further improvement of organic production and productivity of ginger for increasing the incomes of the farming community of the state. Hence, the present study was carried out with the following objectives:

1.1. Objectives

1. To evaluate the effect of the new generation organic inputs in two cultivars namely Bhaise and Majuley for yield, quality and nutrient parameters.
2. To analyze the soil for nutrient content before and after the application of organic inputs.
3. To challenge inoculate and assess the tolerance for the important pest and disease.
4. To understand the organic inputs affected soil nutrients with plant nutrients, yield and quality and soil and plant nutrients with tolerance to major pest and disease.

CHAPTER - 2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

2.1 Organic farming

In India farming is the main occupation for almost two third of the population. They are engaged directly or indirectly in the farming system. During the era of green revolution, India had witnessed a tremendous growth in the agricultural production by the use of high yielding variety seeds, pesticides and fertilizers. Due to high usage of pesticides and fertilizers it had a negative impact like loss of soil fertility, soil erosion, soil toxicity, diminishing and polluting the water resources, salinity of the underground water, increased incidence of human and livestock diseases and environmental pollution. Since, organic farming techniques have the potential to improve soil fertility, soil structure and soil moisture retention capacity. It provides solutions to the problems which are associated with degradation of the land (Ramesh *et al*., 2010).

Organic farming is a system of using less intensive land by doing all the cultivation practices and restricting the use of chemical pesticides and fertilizers. It focuses on environmental protection and the usage of all the available natural resources for the maintenance of soil structure and fertility, water resources and biodiversity (Duruigbo *et al*., 2013). Since, organic farming is gaining popularity worldwide, there is a huge demand for organic products in the market.

Sikkim a small state of India is one of the first declared organic state. It is rich in biodiversity with abundant plant species because of which the soil is rich in organic matter content. The main crops which are being cultivated in Sikkim are maize, rice, buckwheat, black gram, soybean and mustard. The main horticultural crops are orange, pears, ginger, large cardamom, turmeric, cherry pepper, cole crops, peas, bean, tomato and potato.

2.2 Crop

Ginger being one of the major cash crops of Sikkim plays an important role in the states economy. *Zingiber officinale* Roscoe belongs to the family Zingiberacae and is one of the important spice crops. It is also used as a medicinal plant which is naturally found in the various country like India, China, South East Asia, West Indies, Mexico and other parts of the world. From the ancient time it has been consumed worldwide as a spice and flavoring agent (Ghosh *et al.,* 2011).

It is an erect perennial crop which grows up to a height of one to three feet tall. The main economic part of ginger is the thick scaly rhizomes which are found underneath the soil. The rhizomes branch with thick thumb-like structure which is known as the mother rhizome, the buds on the mother rhizome develop and it produces the tillers which inflate into rhizomes and thus becomes the primary fingers.

Ginger is mainly used as a spice in foods to enhance the taste of the dish, not only it is used in flavoring the dishes but also it has a medicinal property which is used way back long. It has been an important ingredient in Chinese, Ayurvedic and Unani herbal medicines. Ginger has been used in treating a number of ailments including arthritis, rheumatism, indigestion, constipation, ulcer, atherosclerosis, hypertension, vomiting, diabetes mellitus, and cancer (Shukla and Singh, 2007). Anti-inflammatory and anti-oxidative properties in ginger help in controlling the process of aging and antimicrobial properties helps in treating infectious diseases (Zheng and Wang, 2001).

2.3 Organic Manures

Organic manures are the materials that are obtained from the plant and animal waste which are decomposed well and are applied in the crops to supply plant nutrients and to improve the soil physical health. Organic manures are divided into bulky and concentrated manures. Bulky manures include well rotten FYM, vermicompost, green manures and concentrated manures include oil cakes. These manures are applied alone or in combination to enrich the soil for proper growth of the plants.

2.3.1 Farm Yard Manure and Vermicompost

Well decomposed FYM provides essential plant nutrients including micronutrients which improve the soil health and it increases the soil organic carbon. The increase in the soil organic carbon increases the crop growth and yield. It also accelerates the respiratory process of the plant which increases the cell permeability and hormonal growth action (Ismail *et al.,* 1998). Vermicompost, which is produced by earthworms helps to convert organic waste into rich humus which is a good source of both micro and macro nutrients, vitamins, growth hormones and enzymes (Bhavalker, 1991 and Anonymous, 1992). The nutrients are readily water soluble which makes easy for the uptake by micro flora.

In growth and yield response of ginger grown in Nigeria, three sources of organic manures which included cow dung manure, poultry manure and pig manure @ 20 t/ha, the poultry manure had the highest plant height of 12.67 cm, number of leaves of 14.87 and leaf area of 231.8 among the other two organic manures. There general conclusion was that organic manures in the forms of cow dung, poultry and pig manures had the tendency to increase the growth characters and yield of ginger in the rainforest zone of Nigeria (Egbuchua and Enujeke, 2013).

A similar kind of study conducted in the seedlings growth of tomato and marigold in a green house was enhanced significantly by the mixture of pig solids vermicompost (Atiyeh *et al.,* 2000). The soil fertility and growth of green gram plants was improved when the sugar mill effluent polluted soil was mixed with vermicompost (Baskaran *et al*., 2009). In mung bean the application of phosphorus and vermicompost helps on development of roots and nodulation and it also plays an important role in growth, development and maturity of crop (Arsalan *et al*., 2016). The amendments of vermicompost and biogas slurry in saline soils improved the net yield, fresh and dry biomass of shoot and rhizome yield of ginger (Ahmad *et al.,* 2009).

The vermicompost enriched with rock phosphate showed its superiority over other treatments for yield and uptake of major nutrients like N, P, K, Ca and Mg in cowpea (Kumari and Ushakumari, 2002). Sharma *et al.,* (2017) conducted an experiment on the effect of vermicompost and nutrients application on yield, soil, uptake and quality of Indian mustard (*Brassica juncea*) where individual application and in combination of vermicompost and nutrients significantly increased the seed and stover yield, oil content, nutrient content and uptake of N, S, Zn and Fe in seed and stover over the treatment where no application was given.

A study on growth, quality and disease resistance on *Thymus vulgaris* was conducted by Amooaghaie and Golmohammadi (2017). The various vermicompost substitutions (0, 25, 50, and 75%) were used where 25% vermicompost substitution promoted the best growth parameters and the highest essential oil content were observed in 50% vermicompost substitution. They also observed that the vermicompost was an effective biocontrol agent against *Fusarium oxysporum* and *Phytophthora infestans*. The result concluded that vermicompost has the potential in promoting plant yield and inducing systemic resistance in *Thymus vulgaris.*

A study conducted by Lepcha *et al*.,(2019) on the effect of organic nutrient sources on productivity, profitability and quality of ginger (*Zingiber officinale)* in acid soils of Eastern Himalayas. The study revealed that the growth and yield of ginger rhizomes are influenced by a combination of different organic manures rather than a single organic soil nutrient.

2.3.2 Biofertilizers

Biofertilizers are the living microbial inoculants of bacteria, algae, fungi which when applied to seeds, plant or soil; they colonize in the rhizosphere and promote growth by supplying the available nutrients to the plants.

Different combinations of organic manures like FYM, vermicompost, neem cake and green leaves along with the biofertilizers like *Trichoderma* and Arbuscular mycorrhiza fungi were evaluated and compared with the package of practices on nutrient status of soil in ginger intercropped in coconut garden. Deficit nutrient balance during the first and the second year for N and P for all organic manure biofertilizer treatment were observed and a positive nutrient balance for K was seen and nutrient deficit was more in control. A buildup of available N, P and K in the status of the soil was noticed after harvest of the crop for treatments that followed organic manure biofertilizer combination. The result concluded that the use of organic manure and biofertilizer combination is sustainable for ginger production (Sreekala, 2015).

In Sikkim well-decomposed FYM or compost @40-50 t/ha, neem cake @2 t/ha, biofertilizer (*Azospirillum*+PSB) @5-6 kg/ha is applied in rows at the time of planting which helps in reduction of incidence of rhizome rot and increases the yield. Vermicompost @ 5t/ha is applied two months after planting of the rhizome (Yadav *et al.,* 2014).

Three types of biofertilizers namely nitrogenous biofertilizer, phosphate solubilizing bacteria and potassic mobilizer with combination of inorganic fertilizer doses (100%, 75% and 50% NPK) and two levels of FYM *i.e.* 15 t and 30 t were applied in the variety Gorubathan of ginger to identify the suitable bio-organic combination. Among different treatments, maximum plant height, number of tillers, number of leaves and plot yield $3m^{-2}$ were recorded, in respect of sole effect of farmyard manure the maximum plant height (83.81), maximum number of tiller (16.96), maximum leaf number (156.0) and maximum plot yield (9.92 kg $3m^{-2}$) were observed with 30t ha^{-1} FYM. In case of inorganic fertilizer and biofertilizer, the maximum plant height of (85.60 cm), maximum number of tiller (16.04), maximum leaf number (157.50), maximum yield 10.57 kg $3m^{-2}$ was observed with NPK 100% + *Azotobacter* + PSB + K mobilize (Chandrashekhar and Hore, 2019).

Highest rhizome yield of ginger was recorded in azospirillum (11.59 t/ha) alone and no significant difference was seen in inorganic fertilizer. The application of azospirillum + phosphorus +wood ash gave the maximum dry matter (17.7%), oil (2.0%) and oleoresin (6.98%) (Rana and Korla, 2010). A similar field experiment was conducted by Shadap *et al.,* 2018 to assess the performance of ginger treated with different combinations of organic and inorganic nutrition. A significant difference in the vegetative growth and rhizome yield was noticed when combinations of organic and inorganic nutrition were tried. The best treatment was observed in Vermicompost+NPK75%+Azospirillum+VAM +PSB (4.09).

Effect of organic source of nutrients and biofertilizers on growth, yield and quality of ginger was conducted by Datta *et al.,* 2018. The treatments were taken for two different levels of FYM, vermicompost, green leaf manure, rock phosphate, wood ash, *Azospirillum* and PSB. There was a significant difference among the different treatments. The results revealed that application of green leaf manure (from *Glyricidia maculata*) @ 12t/ha along with rock phosphate @ 0.2 t/ha, wood ash @ 1 t/ha, *Azospirillum* @ 5kg/ha + PSB @ 5kg/ha gave the significantly highest fresh (20.68 t/ha) and dry yield (4.52 t/ha) followed by vermicompost 5 t/ha along with *Azospirillum* @ 5kg/ha + PSB @ 5kg/ha (18.59 t/ha and 4.06 t/ha, respectively). Maximum dry recovery (22.43%) and oleoresin content (4.37%) was recorded in the treatment of sole application of FYM @ 15 t/ha. Similarly Silva *et al*., 2008 studied the effect of arbuscular mycorrhizal fungal isolates on the development and oleoresin production of micropropagated Z*ingiber officinale*. The result suggested that the screening and inoculation of arbuscular mycorrhizal fungi in ginger plants is a feasible procedure to increase the oleoresin production of *Z. officinale* and increase the ginger rhizome production.

Equal effect in growth and yield parameters were seen by the organic manures. The effect of mycorrhizal treatment with various doses of 5g/plant, 10 g/plant and 15 g/plant increased the growth and yield of ginger but no affect was seen in the fresh and dry weight of the plant (Samanhudi *et al.*, 2014).

A study on the response of ginger and turmeric to organic versus traditional production practices was done by Verma *et al*., 2019 where a field experiment was conducted on plant growth, yield and quality attributes of turmeric cv. Megha Turmeric-1 and ginger cv. Nadia for two consecutive years. Seed rhizomes treated with *Trichoderma harzianum* @ 5g kg^{-1} seed rhizome and soil application of FYM (7.5 t ha^{-1}) + vermicompost (2 t ha^{-1})+ Neemcake (250 kg ha^{-1}) enriched with PSB and *Azospirillum* @ of 10 kg ha^{-1} each was found to be superior over traditional practices.

Lone *et al*., 2015 studied about the effect of Arbuscular Mycorrhizal Fungi on growth and development of potato (*Solanum tuberosum*) plant. Plant infected with higher level in mycorrhiza were found that a net increase in the above and below ground growth of the plant and the chlorophyll content. Kumar *et al*., 2012 conducted an experiment to evolve integrated organic nutrient management practice for high yield of groundnut (*Arachis hypogaea* L.) under rainfed condition. The growth, quality and yield parameters were higher in the application of FYM (7.5 t/ha) +*Rhizobium* + PSB + Panchagavya spray (3% at 30, 60 and 75 DAS).

Studies have been conducted for the growth; yield and quality of various crops as influenced by organic nutrient management. Kumar *et al*., 2017 studied about the growth, yield and quality of snake gourd *Trichosanthes anguina* L. as affected by organic nutrient management practices. Harshavardhan *et al.,* 2016 conducted a test to find out the best integrated nutrient approach for carnation production under polyhouse condition where 75 per cent recommended dose of nitrogen and phosphorus and 100 % potassium + *Azospirillum brasilense* + *Bacillus megaterium* + *Glomus fasciculatum* (VAM Fungi) + *Trichoderma harzianum* + vermicompost + panchagavya + jeevamrutha were found best as compared to 100 per cent check treatment. Bohra and Kumar, 2014 studied the effect of organic manures and bioinoculants on vegetative and floral attributes of chrysanthemum cv. Little Darling. Different combinations along with the control treatments like VAM, *Trichoderma* sp. (each @ 20 g/plant), poultry manure, vermicompost (each @ 300 g/m2) were applied. The result concluded that application of VAM (20 g/plant) + vermicompost (300 g/m2) could be recommended for commercial cultivation of chrysanthemum cv. Little Darling. Meena *et al.,* 2019 studied the effect of phosphorus levels and bio-fertilizers on yield and quality parameters of garlic (*Allium sativum* L.) cv. G -282 where the maximum bulb growth, yield was seen in a combination of phosphorus levels 25, 50, 75 kg/ha and bio-fertilizers PSB, VAM and PSB+VAM inoculation.

2.3.3 PGPR

Plant growth promoting rhizobacteria are a wide range of root colonizing bacteria which has the capacity to enhance seed germination, plant growth and crop yield (Kloepper 1992). To suppress the plant pathogens and to enhance the growth of the crop the application of PGPR in several crops has been used (Glick *et al*., 1995). The spermosphere where the activities of soil microorganisms are huge and the rhizosphere are influenced by the germinating seeds and growing plants (Lynch, 1990).

PGPR species have the ability to act both as biofertilizer and biopesticide. The strains of *Burkholderia cepacia* have the biocontrol characteristics to *Fusarium* spp. and it can also stimulate growth of maize under iron-poor conditions (Bevivino *et al*., 1998). With the host plant the PGPR have the rhizospheric and endophytic relationship. In rhizospheric relationship, the PGPR can colonize the rhizosphere (McCully 2001). In endophytic relationship, PGPR resides within the apoplastic spaces inside the host plants, legume-rhizobia symbiosis (Vessey, 2003). The biological nitrogen in the soil is fixed by PGPR which ultimately increases the available nutrients in rhizosphere, increase in root surface area and enhances the beneficial symbioses of the host. PGPR with non-pathogenic strains have the ability to induce systemic disease resistance in plants (Kloepper *et al*., 2004; Elbadry *et al*., 2006). Induction of systemic disease resistance in faba bean (*Vicia faba* L.) against bean yellow mosaic potyvirus (BYMV) via seed bacterization with *Pseudomonas fluorescens* and *Rhizobium leguminosarum* has been investigated by Elbadry *et al.,* 2006. Similarly, induction of systemic resistance by *Pseudomonas putida* strain 89B-27 and *Serratia marcescens* strain 90–166 against *Fusarium* wilt of cucumber incited by *Fusarium oxysporum* f.sp. *cucumerinum* has been investigated by Liu *et al.,* 1995. Several strains of *Bacillus* like *B. amyloliquefaciens, B. subtilis, B. pasteurii*, *B. cereus, B. pumilus, B. mycoides and B. sphaericus* (Ryu *et al*., 2004) are presently recorded to elicit significant reduction in disease incidence on diversity of hosts. Elicitation of resistance by the strains has been demonstrated both in green house and field trials on tomato, bell pepper, muskmelon, watermelon, sugarbeet, tobacco and cucumber. Inoculation of PGPR species could increase the growth attributes like leaf area, chlorophyll content and consequently, the total biomass of the musa plantlets under nitrogen-free hydroponics (Baset Mia *et al*., 2010) as compared to the uninoculated control. Shaikh *et al.,* 2016 studied on the plant growth promoting rhizobacteria which is an eco-friendly approach for sustainable agroecosystem for soil-borne diseases caused by fungal and bacterial pathogens.

Bacillus amyloliquifaciens (GRB 35) is a good strain of PGPR that is used for growth promotion and disease control. Based on soil test, application of lime/dolomite, rock phosphate and wood ash may be done to get required quantity of phosphorus and potassium supplementation (IISR, 2014). Application of plant growth-promoting rhizobacteria (PGPR) has been shown to increase legume growth and development under optimal temperature conditions, and specifically to increase nodulation and nitrogen fixation of soybean (Zhang *et al.,* 1997).

2.4 Essential oil

Essential oil content of ginger varied from 0.2 to 3%, depending on the origin and state of rhizome (van Beek *et al*., 1987 and Ekundayo *et al*., 1988). Although the essential oil composition of two unique ginger cultivars i.e., Bhaisa and Majulay from Sikkim accounted for sixty constituents for 94.9% and 92.6% of the Bhaisa and Majulay oils. The compounds detected on the essential oil of Bhaisa oil were geranyl acetate (18.8%), zingiberene (16.3%) and geranial (8.2%) and those of Majulay oil were zingiberene (19.8%) and geranial (16.5%). They compared to other ginger cultivar oils and found that the Bhaisa oil had higher content of oxygenated compounds i.e., 43.1% (Sasidharan *et al*., 2012).

In another study of the essential oil and oleoresins (ethanol, methanol, CCl4 and isooctane) of *Zingiber officinale* which were extracted respectively by hydrodistillation and Soxhlet methods and subjected to GC–MS analysis by Singh *et al*., (2008), geranial (25.9%) was the major component in essential oil; eugenol (49.8%) in ethanol oleoresin, while in the other three oleoresins, zingerone was the major component. Kamaliroosta *et al.,* (2013) isolated and extracted the essential oil by the application of Clevenger apparatus and the total phenolic compounds responsible for flavouring, preserving and antioxidant activities were determined. The results indicated that Zingiberene was the major compound present in the oil fraction.

The essential oil from ginger was evaluated for its antimicrobial activity. The essential oil was characterized by high percentage of sesquiterpenes (66.66%), monoterpenes (17.28%) and aliphatic compounds (13.58%). The predominant sesquiterpene was zingiberene (46.71%) followed by valencene (7.61%), β-funebrene (3.09%) and selina-4(14),7(11)-diene (1.03%). The major monoterpenes were characterized as citronellyl *n*-butyrate (19.34%), β-phellandrene (3.70%), camphene (2.59%) and α-pinene (1.09%). The essential oil exhibited significant antimicrobial activity against *Bacillus subtilis, Staphylococcus aureus*, *Escherichia coli, Pseudomonas aeruginosa*, *Candida albicans* and *Aspergillus niger* (Sharma *et al*., 2016). Anti bacterial activity of ginger oil was active against gram-positive bacteria *Bacillus licheniformis, Bacillus spizizenii* and *Staphylococcus aureus*, and the gram-negative bacteria *Escherichia coli, Klebsiella pneumoniae* and *Pseudomonas stutzeri* (Sivasothy *et al.,* 2011).

A similar study was conducted by Sasidharan and Menon in 2010, where the essential oil obtained was analyzed by GC and GC-MS. In this finding zingiberene was the major compound in both ginger oils. Fresh ginger oil contained geranial (8.5%) and it had more oxygenated compounds (29.2%) as compared to dry ginger oil (14.4%). The dry ginger oil also contained ar-curcumene (11%), β-bisabolene (7.2%), sesquiphellandrene (6.6%) and δ-cadinene (3.5%). Fresh ginger oil had a minimum inhibitory concentration value of <1 µg/mL against *Aspergillus niger* and *Candida albicans* and dry ginger oil had less than 1 µg/mL against *Pseudomonas aeruginosa*, *Pencillium* spp and *Candida albicans.* This study concluded that the dry ginger oil and fresh ginger oil could be used against these organisms as alternative to synthetic chemicals. The study shows a wide application of ginger oil in the treatment of many bacterial and fungal diseases.

A comparison between the rhizome oil was made from the three different locations in India, viz. Mizoram, Chennai and two varieties from Sikkim and were analyzed by GC and GC-MS. In all the four oils, zingiberene (10.5% - 16.6%) was the major constituents and although the composition of all the oils was by and large similar, quantitative differences in the concentration of the constituents were observed. The GC and GC-MS analysis of Mizoram, Chennai and Sikkim (Majhauley and Bhaisey varieties) ginger rhizome oils resulted in the identification and quantitation of 29, 29, 28 and 28 constituents representing 84.3%, 86.6%, 88.8% and 86.8% of the total oils, respectively. Among the four oils analyzed the Majhauley variety had an edge over the rest of three oils due to the higher content of zingiberene (16.6%) followed by e-citral (12.0%), z-citral (8.8%), camphene (7.6%) and ocimene (6.5%) (Raina *et al*., 2005).

2.5 Fiber and nutrient analysis

By the experiment conducted by Latona *et al*., 2012 ginger had 34.13% crude protein, 4.07% ether extract, 4.02% crude fibre content, 13.75% moisture content, 7.64% ash content and 1.036% vitamin C. Furthermore, ginger had major minerals like: Zn 64.0 mg/l, Mn 5.90 mg/l, Fe 279.7 mg/l, Cu 8.80 mg/l, Ca 280.0 mg/l and P 8068.0 mg/l. The result obtained confirmed the usefulness of ginger root as a potential functional food and could be explored further in new product and formulation.

The composition profiling of *Zingiber officinale* as conducted by Tanweer *et al*., 2014 indicated moisture, protein, fat, fiber, ash and nitrogen free extract as 75.14±13.9, 8.43±0.32, 5.35±0.17, 3.14±0.13, 2.60±0.09 and 5.37±0.18%, respectively. Moreover, *Zingiber officinale* contained appreciable amount of minerals especially potassium 410.91±13.97, magnesium 45.02±1.80, phosphorus 32.56±1.24, calcium 15.76±0.57, manganese 0.70±0.04, copper 0.58±0.02, iron 0.54±0.03 and zinc 0.33±0.01 mg/100g, respectively. However, potassium, magnesium, phosphorous, calcium and sodium were present in meager amounts.

2.6 Biofumigant crops for control of soil borne diseases

J.A. Kirkegaard coined the term 'biofumigation' which is the process of growing and incorporating *Brassica* species into the soil. The hydrolysis of glucosinolate (GSL) compounds which are present in the plant tissues leads to the release of isothiocyanate compounds (ITCs) in the soil which suppresses the soil borne pests (Kirkegaard *et al*., 1993).

Some of the important groups of pathogens including *Aphanomyces, Fusarium, Gaumannomyces, Phytophthora, Pythium, Rhizoctonia, Sclerotinia* and *Verticillium* as well as species of endoparasitic and semi-endoparasitic nematodes such as *Globodera, Meloidogne, Pratylenchus* and *Tylenchus* have been suppressed by the use of biofumigant plants (Matthiessen and Kirkegaard, 2006 and Motisi *et al*., 2010).

In a study conducted by Al-Abed *et al.,* (2011) where they had applied the residues of cauliflower and cabbage green manures @ 25 kg /plot in controlling the root-knot nematode disease in the cucumber field. They found that it had significantly reduced disease severity of root galling to 15% and 19% compared to 48% and 54% in the controls in the first and second seasons, respectively and significantly increased cucumber yield to 121 and 116 kg/plot, respectively compared to 92 kg/ plot in the control in the second season. They concluded that field application of cauliflower and cabbage green manures has effectively controlled the root-knot nematode disease and increased the yield of cucumber. A similar study was conducted by Anita (2012) in suppressing the root-knot nematode in celery using crucifer vegetable leaf waste as a biofumigant. Youssef and Lashein (2013) conducted an experiment on the effect of cabbage (*brassica oleracea*) leaf residue as a biofumigant, on root knot nematode, *meloidogyne incognita* infecting tomato. The crushed leaves were added in different rates (2.5, 5 and 10g per pot), 10 days before transplanting tomato cv. Super Strain B and at different time interval (5 g at transplanting, and 5 and 10 days before transplanting) for managing root knot nematode. The result indicated that higher the rate of residue, the higher the percentage of nematode reduction.

2.7 Disease of rhizome in ginger

Soft rot is a serious disease of all ginger growing areas in India and affect the rhizome production to the tune of 70 per cent. The soft rot is caused by a complex of fungus (*Pythium, Fusarium* and *Rhizactonia*), bacterium (*Ralstonia solanacearum*) and root knot nematode.

The *Pythium* species are classified as fungi and it belongs to the kingdom Straminopila; phylum Oomycota; class Oomycetes; subclass Peronosporomycetidae; order Pythiales and family Pythiaceae (Webster and Weber, 2007). It is a soil borne organism which is favored by excessive moisture in the soil. Among the different species of Pythium, *P. aphanidermatum* has a wide range of host that includes the family of Amaranthaceae, Amaryllidaceae, Araceae, Basellaceae, Bromeliaceae, Cactaceae, Chenopodiaceae, Compositae, Coniferae, Convolvulaceae, Cruciferae, Cucurbitaceae, Euphorbiaceae, Gramineae, Leguminosae, Linaceae, Malvaceae, Moraceae, Passifloraceae, Rosaceae, Solanaceae, Umbelliferae, Violaceae, Vitaceae, Zingiberaceae (Waterhouse and Waterston, 1964). *P. aphanidermatum* can enter the host plant through contaminated potting media, and contaminated irrigation water as water is the main source for the transmission of disease from one plant to other so water stagnation should be avoided near the plant. It can survive as oospores and sporangia in the debris, soils and tools (Moorman *et al.,* 2002). When a plant is infected by the pathogen it reduces the vigor, quality and yield of crops.

Sarma (1994) reported that soft rot is caused mostly by *Pythium aphanidermatum* but other species like *P. deliense, P. myriotylum, P. pleroticum, P. vexans* and *P. ultimum* were also reported by many workers from different states. Soft rot is also called rhizome rot or *Pythium* rot. Butler (1907) recorded the incidence of this disease for the first time from Surat (Gujarat) in India. The disease is prevalent in India, Japan, China, Nigeria, Fiji, Taiwan, Australia, Hawaii, Sri Lanka, and Korea. Nepali *et al*., (2000) reported the severity of rhizome rot in Nepal and found that the losses due to this disease were 25 and 24 percent in the field and storage, respectively. In India this disease has been reported from almost all states, including Kerala, Rajasthan, Himachal Pradesh, Orissa, Maharashtra, Tamil Nadu, Andhra Pradesh, and Sikkim. Soft rot reduces the potential yield to a great extent in the field, storage, and market and may cause losses of even more than 50 percent (Joshi and Sharma, 1980). Crop loss depends on the growth stage at which infection starts. Total loss results if the infection occurs in the early stage of crop growth. In Kerala, the loss can be as high as 90 percent during heavy infection (Rajan and Agnihotri, 1989).

A correlation study on population dynamics of ginger soft rot inciting pathogens under different organic amendments, disease incidence and its survival in Darjeeling hill soils was done by Tarafdar and Saha in 2007. Lalfakawma *et al*., (2014) studied the integrated disease management of *Zingiber officinale* Rosc.

rhizome rot. The efficacy of some biological control agents were tested for their antagonistic ability against *Fusarium oxysporum* f.sp *zingiberi* both in vitro and in vivo. Among the biological control agents assayed, *Trichoderma viride* (68.3%) and *Trichoderma harzianum* (66.7%) exhibited the maximum mycelial growth inhibition in dual culture under in vitro. Under field condition, seed treatment with *T.viride* @ 4g 10 ml-1 of water kg-1 of seed resulted in maximum reduction in plant mortality (4.2.%) with consequent increase in disease control (84.9%), plant stand over control (32.8.%), plant height (48.9 cm), number of tillers (18.0) and yield (10.5 kg plot-1), respectively(Khatso and Ao, 2013).

Yadav (2014) conducted a study on biocontrol agent and organic amendments against the tomato wilt disease. Organic amendments viz, FYM, Pressmud and Vermicompost inoculated with talc based formulations of *Trichoderma harzianum* (2x107cfu/g) and *Pseudomonas fluorescens* (2x107cfu/g) and suspensions of both the formulations were evaluated as soil treatment and seedlings treatment for the control of tomato wilt caused by *Fusarium oxysporum* f. sp. *lycopersici* in field condition. Vermicompost inoculated with *Trichoderma harzianum* and *Pseudomonas fluorescens* as soil treatment were found to be more effective in controlling of the wilt disease up to 73.46% and 74.71% respectively but FYM inoculated with both the formulations was least effective (40.41% and 53.90%). The results revealed that *Trichoderma harzianum* and *Peudomonas fluorescens* strongly inhibited the growth of *Fusarium oxysporum* f. sp. *lycopersici*. In the field experiment *Peudomonas fluorescens* with vermicompost provided maximum protection to the crop by giving maximum fruit yield followed by field treated with *Trichoderma harzianum.* The researcher concluded that *Trichoderma harzarium* and *Pseudomonas fluorescens* were prove to be effective biocontrol agents.

Experiments were conducted for three years by Mishra and Pandey (2015) to find out the amicable solution to this devastating disease with integrated nutrient supplement trials with 12 treatments *viz.,* T1- Vermicompost @ 20q/ha, T2- Vermicompost @ 5.0q/ha, T3- FYM @ 10.0t/ha + Vermicompost @ 10.0q/ha, T4- FYM @ 5.0t/ha + Vermicompost @ 15.0 q/ha, T5-FYM @ 15.0 t/ ha + Vermicompost @ 5.0 q/ha, T6- Recommended dose of fertilizer (NPK @ 120:80:80 Kg/ha), T7- NPK @ 60:40:40 Kg/ha + FYM @10 t/ha + Vermicompost @ 5.0 q/ha + Azospirillum @ 5.0Kg/ha + Trichoderma viride @ 50.0g/Kg rhizome seed treatment, T8- Control (without any nutrient supplement). Integrated nutrient supplement was found very effective in reducing the disease 10.5 PDI in comparison to control 41.1 PDI. The same treatment showed highest increase of yield per cent (104.0) over the control. It also stands as best treatment from the point of not only reducing disease incidence, but also in high number of primary rhizome (4.3), secondary rhizome (5.6) and dry matter recovery (19.3%) from fresh rhizome ginger.

Deng *et al*., (2014) *Rhizoctonia cerealis* and *Bipolaris maydis* are fungal plant pathogens that cause enormous agricultural losses of wheat and maize. *Bacillus amyloliquefaciens* PEBA20 inhibited mycelial growth and spore germination of the pathogens and reduced fungal infections in wheat and maize, indicating its potential for application as a biocontrol agent.

Yuan *et al.,* (2013) *Bacillus amyloliquefaciens* strain NJN-6 is an important plant growth-promoting rhizobacteria (PGPR) which can produce secondary metabolites antagonistic to several soil-borne pathogens. Effects of transplant type, plant growth-promoting rhizobacteria, and soil treatment on growth and yield of strawberry in Florida (Kokalis-Burelle, 2003).

2.8 Pest of Ginger

The shoot borer is ginger's most serious pest, especially in India, but little information is available on its distribution in various areas in the country. In Kerala, 23.6 to 25 % of pseudostems were damaged by the pest at Kottayam and Idukki districts (Nybe, 2001). The shoot borer is also widely prevalent in Asia, Africa, America and Australia, but authentic records of the pest on ginger are limited. The shoot borer is highly polyphagous and has been recorded on 65 hosts belonging to 30 families. The level of infestation by the shoot borer *(Dichocrocis punctiferalis* Guen.) that results in a significant reduction in yield of ginger rhizomes has been evaluated by Koya *et al.,* (1986) these levels were 60, 45 and 50% of pseudostems damaged per plant during August, September and October respectively.

Shoot borer is a serious pest of ginger in Sikkim, infestation starts from June. The severity of shoot borer damage is upto 15-35 % in West and East Sikkim. The caterpillar bores through the central shoot of the plant and feeds on the growing buds resulting in withered and dried shoot referred to as 'dead heart'. The bore hole and frass extruded is the characteristic symptom of pest infestation. Two sprays of neem oil 0.15 EC @ 3ml/l at 15 days interval was found to be effective (Yadav *et al*., 2014).

Secondary metabolites are organic compounds that are present in the plant but do not involve in the plant growth and development. They are the metabolites that help in plant defense, metal transport and competition (Demain and Fang, 2000). One of the secondary metabolite i.e., terpenes, play important role in plant interactions, plant defenses and the other environmental stresses (Chen *et al*., 2011). Colonization of roots by AM fungi is known to influence secondary metabolism in plants; this includes alteration of the concentration and composition of terpenoids, which can boost both direct and indirect plant defence against herbivorous insects. Enhanced nutrient uptake facilitated by AM, changes in plant morphology and physiology and increased transcription levels of certain genes involved in the terpenoid biosynthesis pathway result in alterations in plant terpenoid profiles (Sharma *et al.*, 2017).

Plant derived preparations and formulated commercial products have great potential for eco friendly management of pests and diseases of spice and condiment crops in India. These products act as antifeedant, growth regulator, repellent and a direct mortality factor against pests and as inhibitor of sporulation and development of hyphae of fungal pathogens (Gahukar, 2011).

CHAPTER - 3

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation entitled "Standardization of single window organic technology for safe production of ginger" was carried out in the farmer's field in Khamdong, East Sikkim and in the Department of Horticulture, Sikkim University, Gangtok, for two years during 2017 and 2018. The materials used for the experiment, the experimental methods and the procedures utilized during present investigation are described as below:

3.1 Collection and plantation

Healthy, bold and diseased free planting material i.e., rhizomes of varieties Bhaise and Majouley were collected in the month of January 2017 for the 1^{st} season and in January 2018 for the 2^{nd} season. Planting was carried out in the month of March 2017 for the 1^{st} season and March 2018 for the 2^{nd} season.

3.2 Field Preparation

The study was carried out under three different experiments *viz.*

Experiment1: Input effect on growth, yield and quality parameters and multi elemental status.

Experiment2: Input effect on pest tolerance.

Experiment3: Input effect on disease tolerance

A total of 43 different treatments with two replications each were adopted for each experiment. It was planted in $1m^2$ plot where spacing was kept as 25 cm either way making 16 plants per plot for each replication of the treatment.

3.3 Treatment Details

All the three experiments were having 43 different treatment including absolute control and a check with two replications each and planted in randomized block design

3.3.1 Effect of inputs on growth, yield and quality parameters and multi elemental status

Traditional organic inputs like Farm Yard Manure (FYM), Vermicompost and Vesicular Arbuscular Mycorrhiza (VAM) along with new generation inputs of Bio capsules like Capsule 1 (GRB35, *Bacillus amyloliquefaciens*), Capsule 2 (FL18, *Microbacterium paraoxydans)* Capsule 3 (BRB, *Micrococcus* sp) and *Trichoderma harzianum* was utilized in the experiment both alone and in combination. The treatment combinations are given in the Table.3.1. Same treatment combinations were adopted for all three experiments except for check. Check in experiment 1 was Rich Ferti Plus, for experiment 2 it was spray of organic pesticide Rich Help Guard I (2 mL L^{-1}) and for experiment 3 it was spray of organic fungicide Rich Agri Guard (2 mL L^{-1}) was sprayed The capsules were obtained from IISR, Calicut. FYM, vermicompost and VAM were given 3g respectively for each rhizome wherever applicable.

3.3.1.1 Preparation of PGPR capsules

One capsule from each different PGPR was suspended in 10 litre of water and dissolved properly. As per the treatment requirement the rhizomes which were to be treated were soaked in it for about 30 minutes before sowing.

Table 3.1 Different combinations of treatments of organic inputs and PGPR

Sl. No.	Name of the Treatment	Sl. No.	Name of the Treatment
1	Control*	23	Cap 1+ 2
2	Farm Yard Manure (FYM)	24	Cap 1+3
3	Vesicular Abuscular Mycohriza (VAM)	25	Cap 2+3
4	Vermicompost	26	Cap 1+ Trichoderma
5	Capsule 1 GRB-35 (*Bacillus amyloliquefaceins*)	27	Cap 2+ Trichoderma
6	Capsule 2FL-18 (*Microbacterium paraoxydans*)	28	Cap 3 + Trichoderma
7	Capsule 3 BRB (*Micrococcus* sps)	29	FYM+VAM+Cap 1
8	Trichoderma	30	FYM+VAM+Cap 2
9	Vermicompost+VAM	31	FYM+VAM+Cap3
10	Vermicompost+Cap 1	32	FYM+VAM+Trichoderma
11	Vermicompost+Cap 2	33	Vermi+VAM+Cap1
12	Vermicompost+Cap 3	34	Vermi+VAM+Cap2
13	Vermicompost+Trichoderma	35	Vermi+VAM+Cap3
14	FYM+Cap 1	36	Vermi+VAM+Trichoderma
15	FYM+Cap 2	37	FYM+VAM+Cap1+Trichoderma
16	FYM+Cap 3	38	FYM+VAM+Cap2+Trichoderma
17	FYM+Trichoderma	39	FYM+VAM+Cap3+Trichoderma
18	FYM+VAM	40	Vermi+VAM+Cap1+Trichoderma
19	VAM+Cap 1	41	Vermi+VAM+Cap2+Trichoderma
20	VAM+Cap 2	42	Vermi+VAM+Cap3+Trichoderma
21	VAM+Cap 3	43	Check**
22	VAM+Trichoderma	*Control: No organic inputs **Check: Recommended dose of NPK was supplied in the form of Rich Ferti Plus for Expt.1; Rich Help Guard for Expt.2 and Rich Agri Guard for Expt.3	

3.3.2 Effect of inputs on pest tolerance

To test the input effect on pest tolerance, major pest *viz.* Shoot borer (*Conogethes punctiferalis)* has been challenge infested in the month of July 2017 and July 2018 for first and second season of growing respectively. According to the symptoms shown, visual scoring (scale of 1-10, higher the number less resistance to the pest and lower the number more resistance to the pest) was assigned to each treatment as well as yield and quality parameters were observed and recorded.

3.3.3 Challenge inoculation of Disease

For soft rot inoculation, the field was first biofumigated before the plantation of the rhizome. Biofumigation was done using leaves of Brassicaceae family. As the plants belonging to this family contains glucosinolates which are hydrolysed by the enzyme myrosinase and as a result of tissue damage volatile products like isothiocyanates are released which had fungistatic or fungicidal properties. Leaves of cabbage were collected and chopped properly and then incorporated in the soil and it was covered with mulching sheet for a month before sowing of the rhizome.

Cultures of *Pythium aphanidermatum* a causal organism of soft rot disease of ginger was obtained from the Indian Type Culture Collection Centre (ITCC), IARI, New Delhi and it was challenged inoculated in the month of July 2017 for 1st season and July 2018 for 2nd season as it was the peak season for the soft rot infestation coinciding with South West monsoon. According to the symptoms shown, visual scoring was given (scale of 1-10, higher the number more susceptible to the disease and lower the number more resistance to the disease) as well as yield and quality parameters were observed and recorded.

3.4 Estimation of yield parameters

3.4.1 Measurement of plant height

Plant height was measured from 60 DAP and continued at 40 days interval till its harvesting stage. It was measured with the help of centimeter scale.

3.4.2 Estimation of number of leaves and tillers

Number of leaves for each replication was counted from randomly selected plants from each bed. Number of tillers was counted from 4 plants tagged at the middle of each bed at 14 weeks after planting.

3.4.3 Estimation of leaf area

Leaves of randomly selected plants from each replication were taken for the measurement of leaf area by Leaf area meter.

3.4.4 Estimation of rhizome weight

Rhizome weight was taken at harvest. Harvesting of the rhizomes was done after nine months of planting when all the leaves had changed its color from green to yellow and shriveled down indicating its harvest time.

3.5 Estimation of quality parameters

3.5.1 Estimation of volatile oil

The fresh harvested rhizomes were pooled from one plot. They were cleaned, washed with distilled water, peeled and cut into small pieces and dried in hot air oven at 50°C for 6 hrs. Dried rhizome were then powdered by willow mill grinder. Three gram of each sample (w) were taken in a thimble and placed in the beaker, the weight of the empty beaker (W_1) was taken and acetone was used as the solvent. The volatile oil was then extracted using essential oil extractor, Socsplus-SES 06 DLS, PELICAN. 80mL of acetone was used as a solvent. The extraction is faster as compared to the other conventional method; moreover, the solvent can be reclaimed.

The beaker was placed in the extraction system and the tap water was opened for the condensation to take place and then the machine was switched on. At the first phase, boiling took place at 90°C in 45 min. and the condensation took place at 150°C in another 45 min.

After running both the phases, the beaker containing the volatile oil was placed inside the hot air oven for few minutes so as to remove the solvent vapours. The final weight of the beaker (W_2) was taken and the oil percentage was calculated. After calculation an empty beaker was placed in the system and then the stopper was opened so that the solvent could be recovered and reused for the next batch.

$$\text{Essential Oil (\%)} = \frac{W_2 - W_1}{w} \times 100$$

W_1= Initial weight of beaker

W_2= Final weight of beaker with oil

w= Weight of sample

3.5.2 Estimation of fiber

Oil free extract was used for analyzing the fiber content using fiber estimation system, Fibra plus-FES 04 AS DLS, PELICAN, India. One gram of the sample was taken and 1.25% H_2SO_4 was used in the first phase to boil at 500°C for 30 min. and 1.25% NaOH was used in the second phase to digest at 400°C for 45 min. The fiber content was expressed in percentage.

$$\text{Crude fiber (\%)} = \frac{W_1 - W_2}{w} \times 100$$

W_1= Initial weight of crucible

W_2= Final weight of crucible with sample

w= Weight of sample

3.5.3 Estimation of essential oil

Fresh harvested rhizomes were washed, peeled and cut into slices and 100 g of the rhizome slices was placed in the 1 liter conical flask and connected to the Clevenger apparatus. 500 mL of distilled water was added into the flask and it was heated with the help of heating mantle. The vapour produced due to the boiling of the content was collected along with the essential oil into a graduated cylinder. The distillation took 5 hours and then the aqueous layer separated from the essential oil. It was collected in the screw cap bottle of 15 mL capacity. The collected oil sample was kept in the refrigerator until required for further analysis.

Samples of best treatment based on the observation on growth and yield parameters along with check and control were analyzed for GCMS profile in all three experiments for both the varieties. The GCMS analysis of the essential oil sample was outsource at Opal Research and Analytical Services, Ghaziabad, Uttar Pradesh.

3.5.4 Estimation of nutrients

3.5.4.1 Estimation of Phosphorus and Sulphur

Phosphorus was analyzed by (Pal, 2019) colourimetry and Sulphur by Turbidimetry (Pal, 2019) using Lambda 35 UV/Vis Spectrometer (Perkin Elmer.USA).

3.5.4.2 Estimation of Potassium

Potassium was analyzed using Flame Photometer 130 (Pal, 2019).

3.5.4.3 Estimation of Calcium, Magnesium, Sodium, Copper, Iron, Manganese, Zinc

Ca, Mg, Na, Cu, Fe, Mn, Zn was analyzed using Atomic Absorption Spectrophotometer (AAS 200, Perkin Elmer, USA) as per the procedures of the suppliers manual.

3.6 STATISTICAL ANALYSIS

Statistical analysis of the data was carried out by using STPR package. The data obtained from different observations during field experimentation and laboratory analysis were subjected to the analysis of variance by Factorial Randomized Block deign for field experiments and Completely Randomized Design for the laboratory analysis.

Factor 1: Different organic input treatments.
Factor 2: Two varieties.
Replication: 2

CHAPTER - 4

RESULTS

RESULTS

The present study entitled "Standardization of single window organic technology for safe production of ginger" was carried out at farmer's field in Khamdong and laboratory analysis at the Department of Horticulture, Sikkim University, Gangtok, East Sikkim during 2017-2018. The results obtained from the different experiments are presented in the following sub heads.

i) Experiment no. 1. Input effect on growth, yield and quality parameters and multi elemental status.

ii) Experiment no. 2. Input effect on pest tolerance .

iii) Experiment no. 3. Input effect on disease tolerance.

4.1 Input effect on growth, yield, quality parameters and multi elemental status.

Rhizomes of Bhaise and Majouley were treated with different organic inputs alone and in combinations and growth; yield and quality parameters and multi elemental status were recorded.

4.1.1 Plant height (cm)

The highest plant height was observed in T39 (53.25 cm) followed by T41 (53.08 cm). These treatments were at par with each other and significantly superior to the other treatments. Comparison of two varieties showed that Bhaise was significantly superior as far as the plant height was concerned. Treatment effect on individual varieties was observed highest height in variety Bhaise was observed in T39 (56.77 cm) which was superior to the other treatments. Similarly significantly superior height was observed in T41 (56.80 cm) for the variety Majouley (Table 4.1.1).

4.1.2 Number of leaves

The highest number of leaves was observed in T41 (17.25 cm) which was followed by T39 (16.75 cm). T41 was significantly superior then the other treatments. Comparison of two varieties showed that Majouley was significantly superior as far as number of leaves is concerned. When treatment effect on individual varieties for more number of leaves it was observed in variety Bhaise T39 (17.75) was significantly superior and in Majouley T41 (18.00) was superior (Table 4.1.1).

4.1.3 Number of tillers

Among the treatments T39 (3.62) was at par with all the other treatments and no treatment was found to be significantly superior. Between the two varieties Bhaise was significantly superior to the variety Majouley in number of tillers. When treatment effect on individual varieties the variety Bhaise T39 (4.25) was superior and similarly T41 (4.00) was superior in the variety Majouley (Table 4.1.1).

4.1.4 Leaf area (cm^2)

It was observed that the treatment 41 with 45.75 cm^2 was having the highest leaf area and it was at par with T39 (44.75 cm^2). When the two varieties were compared, it showed that variety Bhaise was superior to variety Majouley. The treatment effect on individual varieties showed that T39 (46.75 cm^2) of Bhaise was superior and in case of Majouley T41 (46.50 cm^2) was at par with T27 (45.00 cm^2) and T33 (45.25 cm^2) (Table 4.1.1).

4.1.5 Rhizome weight (g) of individual plant

The maximum individual plant rhizome weight was observed in T39 (366.50 g) which was significantly superior to all other treatments and among the two varieties, Bhaise was significantly superior to the variety Majouley. The treatment effect on individual varieties showed that T39 (385.25 g) of Bhaise and T41 (375 g) Majouley were significantly superior to the other treatments (Table 4.1.2).

4.1.6 Volatile Oil (%)

The volatile oil content in the treatment T41 (3.62 %) was at par with T39 (3.57 %) and these two varieties were significantly superior to all other treatments. Comaparision varieties showed no significant variations. The treatment effect on individual varieties showed that T39 (3.77 %) was at par with T41 (3.63 %) of the variety Bhaise and in Majouley T41 (3.62 %) was at par with T42 and T43 with 3.43 % of volatile oil (Table 4.1.2).

4.1.7 Crude Fiber (%)

The treatment T41 (3.23 %) was at par with T34 (3.22 %), T37 (3.21 %), T39 (3.19 %), T35 (3.18 %), T43 (3.17 %), T23 (3.16 %) and T20 (3.15 %). The comparison of the two varieties showed that the variety Majouley was significantly superior to variety Bhaise. The treatment effect on individual varieties showed that there was no any significant difference (Table 4.1.2).

Table 4.1.1 Effect of different organic inputs in growth parameters of ginger

Growth Parameters	Plant Height (cm)			Number of leaves(no)			Tillers (no)			Leaf area(cm²)		
Treatments	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean
T1	37.45	34.09	**35.77**	13.00	12.25	**12.62**	2.00	2.25	**2.12**	18.25	19.50	**18.87**
T2	40.24	38.52	**39.38**	13.25	13.00	**13.12**	3.00	2.75	**2.87**	21.00	22.00	**21.50**
T3	41.26	39.77	**40.51**	14.50	14.00	**14.25**	3.00	3.00	**3.00**	21.50	29.75	**25.62**
T4	40.28	39.02	**39.65**	13.75	13.00	**13.37**	3.00	3.00	**3.00**	23.75	31.50	**27.62**
T5	40.62	38.38	**39.50**	13.50	13.00	**13.25**	3.00	2.75	**2.87**	37.75	41.25	**39.50**
T6	41.51	39.93	**40.72**	14.50	13.50	**14.00**	3.50	3.00	**3.25**	40.75	40.75	**40.75**
T7	41.23	41.52	**41.38**	14.00	14.00	**14.00**	2.75	2.75	**2.75**	41.25	40.00	**40.62**
T8	41.01	39.06	**40.04**	14.00	13.00	**13.50**	2.75	3.00	**2.87**	39.50	42.75	**41.12**
T9	43.24	42.66	**42.95**	14.50	15.00	**14.75**	3.50	3.00	**3.25**	43.00	40.00	**41.50**
T10	42.75	43.70	**43.23**	14.75	14.25	**14.50**	3.00	2.75	**2.87**	41.75	41.75	**41.75**
T11	42.49	41.65	**42.07**	15.00	14.25	**14.62**	3.25	3.00	**3.12**	42.75	42.75	**42.75**
T12	43.30	42.52	**42.91**	14.75	14.00	**14.37**	3.25	2.75	**3.00**	41.00	42.75	**41.87**
T13	44.19	42.49	**43.34**	15.50	14.50	**15.00**	3.00	2.75	**2.87**	43.00	41.25	**42.12**
T14	45.09	42.48	**43.78**	16.75	14.25	**15.50**	2.75	2.25	**2.50**	41.75	43.00	**42.37**
T15	44.52	42.68	**43.60**	15.00	14.00	**14.50**	3.00	3.00	**3.00**	41.75	42.50	**42.12**
T16	43.50	43.18	**43.34**	15.00	15.50	**15.25**	3.00	3.00	**3.00**	43.50	41.75	**42.62**
T17	43.29	44.29	**43.79**	15.00	14.50	**14.75**	3.25	3.00	**3.12**	42.25	41.25	**41.75**
T18	45.71	42.91	**44.31**	16.75	14.50	**15.62**	3.75	3.25	**3.50**	43.75	42.50	**43.12**
T19	41.23	43.99	**42.61**	14.00	15.75	**14.87**	3.00	3.25	**3.12**	39.00	41.50	**40.25**
T20	43.34	41.94	**42.64**	14.50	14.50	**14.50**	2.75	2.75	**2.75**	41.50	44.75	**43.12**
T21	42.75	43.01	**42.88**	15.25	14.50	**14.87**	3.50	2.75	**3.12**	43.25	44.50	**43.87**
T22	41.85	41.27	**41.56**	14.25	14.25	**14.25**	3.50	3.25	**3.37**	42.50	42.50	**42.50**
T23	41.14	42.13	**41.64**	15.25	15.00	**15.12**	3.25	2.25	**2.75**	44.00	41.25	**42.62**
T24	40.89	41.23	**41.06**	15.00	14.00	**14.50**	3.25	3.50	**3.37**	43.00	41.00	**42.00**
T25	40.95	41.63	**41.29**	13.25	15.00	**14.12**	3.00	3.00	**3.00**	43.75	41.75	**42.75**
T26	41.90	39.75	**40.83**	13.75	13.75	**13.75**	2.75	3.25	**3.00**	42.50	42.75	**42.62**
T27	41.17	42.76	**41.96**	15.00	14.25	**14.62**	3.50	3.25	**3.37**	43.00	45.00	**44.00**
T28	44.00	42.36	**43.18**	14.00	15.25	**14.62**	3.00	3.25	**3.12**	43.75	43.75	**43.75**
T29	44.20	43.35	**43.77**	15.25	16.00	**15.62**	3.25	3.50	**3.37**	41.25	43.37	**42.31**
T30	44.83	44.55	**44.69**	15.75	14.00	**14.87**	3.00	3.50	**3.25**	42.75	42.25	**42.50**
T31	42.86	42.98	**42.92**	15.50	14.75	**15.12**	3.75	2.75	**3.25**	41.50	43.00	**42.25**
T32	41.13	44.04	**42.58**	14.00	15.00	**14.50**	3.25	3.00	**3.12**	43.50	43.00	**43.25**
T33	45.68	42.23	**43.95**	15.50	15.00	**15.25**	3.00	2.75	**2.87**	41.75	45.25	**43.50**
T34	42.50	43.28	**42.89**	15.75	15.50	**15.62**	3.25	3.00	**3.12**	43.50	40.50	**42.00**
T35	43.40	42.34	**42.87**	15.50	14.75	**15.12**	3.00	3.25	**3.12**	40.00	40.25	**40.12**
T36	43.99	43.61	**43.80**	14.75	14.25	**14.50**	3.00	2.75	**2.87**	43.75	44.00	**43.87**
T37	46.56	44.99	**45.77**	15.75	15.25	**15.50**	3.50	3.25	**3.37**	42.35	42.50	**42.42**
T38	39.89	42.59	**41.24**	14.75	15.75	**15.25**	3.25	3.00	**3.12**	41.75	41.25	**41.50**
T39	56.77	49.74	**53.25**	17.75	15.75	**16.75**	4.25	3.00	**3.62**	46.75	42.75	**44.75**
T40	47.42	46.35	**46.88**	16.00	17.00	**16.50**	3.00	3.25	**3.12**	44.50	41.50	**43.00**
T41	49.36	56.80	**53.08**	16.50	18.00	**17.25**	3.00	4.00	**3.50**	45.00	46.50	**45.75**
T42	44.98	47.98	**46.48**	17.00	16.25	**16.62**	3.50	3.00	**3.25**	44.75	43.75	**44.25**
T43	48.39	48.75	**48.57**	16.25	16.00	**16.12**	3.50	3.50	**3.50**	40.25	41.00	**40.62**
Mean	**43.32**	**42.85**		**14.97**	**14.65**		**3.15**	**3.00**		**40.43**	**40.85**	
CD5%FactorA(Treatment)	1.37			0.41			0.92			1.19		
Factor B(Varieties)	0.29			0.88			0.19			1.25		
AXB	1.94			0.58			0.13			1.69		

Table 4.1.2 Effect of different organic inputs on yield and quality parameters of ginger

Yield and quality parameters	Rhizome weight (g) of individual plant			Volatile oil(%)			Crude fiber(%)		
Treatments	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean
T1	141.25	132.50	**136.87**	2.43	2.61	**2.52**	2.16	1.83	**1.99**
T2	205.00	180.00	**192.50**	2.75	2.76	**2.75**	2.34	1.99	**2.16**
T3	214.75	197.50	**206.12**	3.28	3.02	**3.15**	3.02	2.39	**2.70**
T4	198.75	177.50	**188.12**	3.38	2.88	**3.13**	3.05	2.28	**2.66**
T5	200.00	177.50	**188.75**	2.73	3.22	**2.98**	2.55	2.49	**2.52**
T6	212.50	192.50	**202.50**	2.99	2.94	**2.96**	2.72	2.63	**2.68**
T7	216.25	218.00	**217.12**	2.87	2.74	**2.80**	2.59	2.45	**2.52**
T8	212.50	200.25	**206.37**	2.79	2.97	**2.88**	2.48	2.51	**2.49**
T9	195.25	182.50	**188.87**	2.85	3.02	**2.93**	2.68	2.49	**2.58**
T10	218.75	196.50	**207.62**	3.27	3.27	**3.27**	3.01	3.19	**3.10**
T11	227.75	201.25	**214.50**	3.02	3.17	**3.09**	2.63	2.99	**2.81**
T12	223.75	233.75	**228.75**	3.12	3.25	**3.18**	2.56	2.63	**2.60**
T13	216.00	227.60	**221.80**	2.87	3.29	**3.08**	2.60	3.14	**2.87**
T14	230.25	212.75	**221.50**	3.33	3.46	**3.39**	3.08	3.17	**3.12**
T15	235.00	220.00	**227.50**	3.33	3.47	**3.40**	3.12	3.12	**3.12**
T16	230.00	208.75	**219.37**	3.31	3.29	**3.30**	3.08	2.73	**2.90**
T17	226.25	237.50	**231.87**	3.26	3.44	**3.35**	3.10	3.11	**3.10**
T18	232.75	220.25	**226.50**	3.24	3.44	**3.34**	2.84	3.20	**3.02**
T19	219.00	211.25	**215.12**	3.39	3.49	**3.44**	3.08	3.20	**3.14**
T20	241.50	231.50	**236.50**	3.22	3.40	**3.31**	3.11	3.20	**3.15**
T21	231.50	225.10	**228.30**	3.35	3.25	**3.30**	3.16	3.12	**3.14**
T22	226.50	224.25	**225.37**	3.23	3.40	**3.32**	3.06	3.22	**3.14**
T23	230.00	245.00	**237.50**	3.38	3.38	**3.38**	3.11	3.21	**3.16**
T24	226.00	226.25	**226.12**	3.20	3.33	**3.26**	3.08	3.15	**3.11**
T25	220.00	230.00	**225.00**	3.29	3.29	**3.29**	3.10	2.62	**2.86**
T26	232.50	232.50	**232.50**	3.17	3.32	**3.24**	3.01	3.17	**3.09**
T27	245.00	240.00	**242.50**	3.11	3.30	**3.20**	2.98	3.16	**3.07**
T28	245.00	245.00	**245.00**	3.18	3.31	**3.24**	2.96	3.11	**3.03**
T29	236.50	238.75	**237.62**	3.18	3.33	**3.25**	3.05	3.13	**3.09**
T30	240.00	235.25	**237.62**	3.25	3.33	**3.29**	3.09	3.04	**3.06**
T31	230.25	237.50	**233.87**	3.13	3.23	**3.18**	2.98	2.69	**2.83**
T32	235.00	245.00	**240.00**	3.40	3.39	**3.39**	3.15	3.23	**3.14**
T33	237.25	242.50	**239.87**	3.26	3.28	**3.27**	3.11	3.10	**3.10**
T34	220.27	237.50	**228.88**	3.52	3.44	**3.48**	3.22	3.13	**3.22**
T35	247.50	250.00	**248.75**	3.52	3.43	**3.47**	3.24	3.13	**3.18**
T36	245.00	245.00	**245.00**	3.28	3.27	**3.28**	3.14	3.12	**3.13**
T37	312.50	300.00	**306.25**	3.38	3.37	**3.38**	3.19	3.23	**3.21**
T38	312.75	319.00	**315.87**	3.50	3.44	**3.47**	3.07	3.13	**3.10**
T39	385.25	347.75	**366.50**	3.77	3.37	**3.57**	3.22	3.17	**3.19**
T40	327.75	325.00	**326.37**	3.52	3.47	**3.49**	3.17	3.16	**3.16**
T41	332.50	375.00	**353.75**	3.63	3.62	**3.62**	3.19	3.28	**3.23**
T42	332.50	335.00	**333.75**	3.53	3.53	**3.53**	3.12	3.15	**3.13**
T43	345.00	332.50	**338.75**	3.50	3.53	**3.51**	3.15	3.20	**3.17**
Mean	**241.71**	**237.05**		**3.22**	**3.27**		**2.96**	**2.94**	
CD5%FactorA(Treatment)	7.18			0.10			0.08		
Factor B(Varieties)	1.55			0.02			0.01		
AXB	10.16			0.14			0.12		

4.1.8 GCMS analysis of different compounds present in essential oil of ginger

Among the seventeen different compounds analyzed from the essential oil of ginger, zingiberene content in both the varieties were significantly superior to the other compounds present in the essential oil of ginger. T39 of Bhaise was significantly superior in compounds like camphene (2.29 %), endo-borneol (0.75 %), geraniol (2.32 %), ar-curcumene (17.51 %), zingiberene (35.59 %), beta-bisabolene (9.26 %), delta-cadinene (13.22 %) and beta-sesqiphellandrene (0.78 %) than the control and check. Similarly, in variety Majouley T41 was the best treatment and had significantly superior amount of compounds like geraly acetate (1.59 %), zingiberene (34.14 %), alpha-farnesene (6.89 %), beta-bisabolene (9.16 %) and 4,5-dimethyl-1-1-methylene tricycle 7 (3.57%) (Table 4.1.3).

Table 4.1.3 Effect of organic inputs on different compounds present in essential oil of ginger

Sl. No.	Parameters	Bhaise				Majouley			
		Control	check	T39	G.M.	control	check	T41	G.M.
1.	Camphene	1.60	0.96	2.29	**1.61**	1.16	1.60	1.24	**1.33**
2.	Beta-Phellandrene	1.05	1.69	1.04	**1.26**	1.02	1.90	0.98	**1.30**
3.	Endo- Borneol	0.66	0.63	0.75	**0.68**	0.57	0.53	0.60	**0.56**
4.	Geraniol	1.19	1.40	2.32	**1.63**	0.82	2.32	0.85	**1.33**
5.	Geraly Acetate	1.30	1.56	1.40	**1.42**	1.15	1.22	1.59	**1.32**
6.	AR-Curcumene	12.66	15.51	17.51	**15.22**	12.42	16.98	15.22	**14.87**
7.	Zingiberene	28.68	33.16	35.59	**32.47**	26.36	32.22	34.14	**30.90**
8.	Alpha Farnesene	4.49	7.38	5.31	**5.72**	4.18	4.78	6.89	**5.28**
9.	Beta-Bisabolene	8.58	7.53	9.26	**8.45**	6.11	7.46	9.16	**7.57**
10.	4,5- Dimethyl-1-1-Methylene Tricycle 7	2.67	5.13	2.50	**3.43**	2.77	2.81	3.57	**3.05**
11.	Gamma-Cadinene	3.64	4.50	3.59	**3.91**	3.17	3.62	3.32	**3.37**
12.	Delta- Cadinene	10.22	12.95	13.22	**12.13**	12.10	16.04	14.55	**14.23**
13.	Beta-Sesquiphellandrene	0.35	0.63	0.78	**0.58**	0.28	0.37	0.38	**0.34**
14.	Nerolidol	2.16	2.70	2.06	**2.30**	1.69	2.81	1.77	**2.09**
15.	7-Alpha-(1-Hydroxy-1-Methylethyl)	1.61	2.23	1.94	**1.92**	1.24	1.89	1.40	**1.51**
16.	Germacrene B	1.32	1.39	1.25	**1.32**	1.27	1.30	1.35	**1.30**
17.	Alpha-Eudesmol	3.28	4.67	3.18	**3.71**	3.32	3.22	4.00	**3.51**
	Mean	**5.02**	**6.11**	**6.11**		4.68	5.94	5.91	
	Cd 5% factor a(parameters)	0.18				0.21			
	Factor b (treatments)	0.07				0.09			
	axb	0.32				0.37			

4.1.9 Multi elemental analysis of ginger

Calcium content in T39 (1.78 %) was significantly superior to all the other treatments and it was followed by T41 (1.61 %). Comparison of the two varieties showed that the calcium content in Bhaise was significantly superior to the variety Majouley. The treatment effect on individual varieties showed that T39 (2.14 %) of Bhaise and T41 (1.54 %) of Majouley was significantly superior to the other treatments (Table 4.1.4).

Magnesium content in the treatments was non significant but in variety Bhaise Mg content was significantly superior than the variety Majouley. The treatment effect on individual varieties showed that T39 was significantly superior in Bhaise but in the variety Majouley it was non significant (Table 4.1.4).

Sulphur content in T41 (0.21 %) was significantly superior to the other treatments. Between the two varieties S content in Majouley was significantly superior than the variety Bhaise. The treatment effect on individual varieties showed that T39 (0.21%) of variety Bhaise and T41 (0.27 %) of Majouley was significantly superior (Table 4.1.4).

Phosphorus content in T41 (0.032 %) was significantly superior than the other treatments, and it was followed by T43 (0.024 %). Comparison of the two varieties showed that the Phosphorus content in Majouley was significantly superior to the variety Bhaise. The treatment effect on individual varieties showed that T41 (0.052 %) of variety Majouley and T39 (0.014%) of variety Bhaise was significantly superior (Table 4.1.4).

Table 4.1.4 Effect of different organic inputs on nutrient contents of ginger

TREATMENTS	Ca(%)			Mg(%)			S(%)			P(%)			K(%)		
	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean
CONTROL	0.96	0.60	0.78	2.45	2.41	2.43	0.08	0.11	0.09	0.007	0.010	0.008	1.87	1.03	1.45
T35	1.83	0.98	1.40	2.56	2.29	2.43	0.12	0.21	0.16	0.012	0.018	0.015	3.02	0.55	1.78
T36	1.07	1.10	1.08	2.42	2.35	2.39	0.18	0.13	0.16	0.017	0.024	0.021	2.02	1.03	1.53
T37	1.41	0.58	1.00	2.40	2.46	2.43	0.16	0.11	0.13	0.016	0.006	0.011	3.09	1.42	2.25
T38	0.92	0.81	0.87	2.42	2.08	2.25	0.16	0.17	0.17	0.014	0.011	0.012	1.51	0.55	1.03
T39	2.14	1.42	1.78	2.66	2.43	2.55	0.21	0.17	0.19	0.014	0.026	0.020	3.41	0.89	2.15
T40	1.05	0.55	0.80	2.45	2.45	2.45	0.16	0.21	0.18	0.012	0.032	0.022	2.18	0.28	1.23
T41	1.69	1.54	1.61	2.44	2.52	2.48	0.15	0.27	0.21	0.013	0.052	0.032	3.12	2.21	2.66
T42	0.64	0.28	0.46	2.53	2.05	2.29	0.11	0.09	0.10	0.011	0.004	0.008	2.77	2.10	2.44
Check	1.42	0.90	1.16	2.53	2.50	2.51	0.11	0.13	0.12	0.018	0.030	0.024	2.78	1.68	2.23
MEAN	1.31	0.87		2.49	2.35		0.14	0.16		0.013	0.021		2.57	1.17	
CD5%FactorA (Treatment)	0.04			0.06			0.003			0.0006			0.06		
Factor B (Varieties)	0.01			0.02			0.001			0.0002			0.02		
AXB	0.05			0.09			0.005			0.0008			0.09		

TREATMENTS	Fe(mgL^{-1})			Na(mgL^{-1})			Cu(mgL^{-1})			Mn(mgL^{-1})			Zn(mgL^{-1})		
	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean
CONTROL	0.71	0.68	0.69	0.86	0.45	0.65	0.12	0.13	0.12	0.21	0.10	0.15	0.25	0.24	0.25
T35	0.76	0.61	0.68	0.63	0.44	0.53	0.12	0.22	0.17	0.24	0.06	0.15	0.23	0.20	0.22
T36	1.04	0.55	0.79	1.03	0.69	0.86	0.13	0.22	0.18	0.20	0.17	0.18	0.16	0.24	0.20
T37	0.58	0.88	0.73	0.15	0.31	0.23	0.18	0.20	0.19	0.21	0.17	0.19	0.19	0.25	0.22
T38	0.65	0.55	0.60	0.24	0.18	0.21	0.12	0.19	0.15	0.20	0.08	0.14	0.23	0.24	0.24
T39	1.20	0.63	0.92	1.03	0.49	0.76	0.22	0.14	0.18	0.26	0.15	0.20	0.33	0.21	0.27
T40	1.08	0.39	0.73	0.62	0.59	0.60	0.15	0.20	0.17	0.17	0.13	0.15	0.21	0.20	0.20
T41	0.77	0.93	0.85	0.49	1.04	0.76	0.15	0.25	0.20	0.20	0.14	0.17	0.29	0.31	0.30
T42	0.95	0.89	0.92	0.30	0.39	0.34	0.19	0.20	0.19	0.10	0.14	0.12	0.21	0.19	0.20
Check	0.99	1.07	1.03	2.04	0.89	1.46	0.20	0.34	0.27	0.18	0.28	0.23	0.25	0.35	0.30
MEAN	0.87	0.72		0.74	0.55		0.16	0.21		0.20	0.14		0.24	0.24	
CD5%FactorA (Treatment)	0.02			0.010			0.005			0.005			0.007		
Factor B (Varieties)	0.01			0.008			0.002			0.002			0.003		
AXB	0.03			0.020			0.008			0.008			0.010		

Potassium content in T41 (2.66 %) was significantly superior to the other treatments, it was followed by T42 (2.44 %). Comparison of the two varieties showed that the Potassium content in Bhaise was significantly superior to the variety Majouley. T39 (3.41 %) of variety Bhaise and T41 (2.21 %) of Majouley was significantly superior (Table 4.1.4).

Micro nutrients like iron (1.03 mgL^{-1}), sodium (1.46 mgL^{-1}), copper (0.27 mgL^{-1}) and manganese (0.23 mgL^{-1}) were significantly superior in check. The zinc content in check and T41 were at par. Comparison of the two varieties showed that the Fe and Na content in Bhaise were significantly superior than the variety Majouley whereas, Cu, Mn and Zn were significantly superior in Majouley than the variety Bhaise. The treatment effect on Fe, Na, Cu, Mn and Zn in individual varieties showed that T39 in case of Bhaise was superior and incase of Majouley only one element i.e., Na in T41 was significantly superior (Table 4.1.4).

4.1.10 Soil analysis of input effect on growth, yield and quality parameters and multi elemental status

Soil samples were collected from the field before and after application of organic manures. The results revealed significant reduction of nutrients after the plant growth has taken place in N, P, Ca and S. In potassium no difference could be seen before and after the application of organic inputs. Whereas, micronutrients like Fe, Na and Zn were found to be significantly higher after the application of the organic inputs in the soil and Mn and Cu remained unaffected before and after application of inputs (Table 4.1.5).

Table 4.1.5 Soil analysis of input effect on growth, yield and quality parameters and multi elemental status

Soil	N(%)	P(%)	K(%)	Ca(%)	Mg(%)	S(%)
before	0.30	0.03	0.24	6.63	2.82	0.03
after	0.28	0.02	0.24	4.25	2.83	0.02
Mean	0.29	0.02	0.24	5.44	2.82	0.02
C.D 5%	0.01	0.001	0.01	0.20	0.22	0.001
SEM	0.004	0.0003	0.004	0.52	0.58	0.0003

Soil	Fe (mgL^{-1})	Na (mgL^{-1})	Cu (mgL^{-1})	Mn (mgL^{-1})	Zn (mgL^{-1})
before	3.01	2.70	0.14	0.15	0.68
after	3.75	3.51	0.14	0.14	0.73
mean	3.38	3.10	0.14	0.14	0.71
C.D 5%	0.23	0.20	0.02	0.02	0.02
SEM	0.59	0.53	0.005	0.005	0.007

4.2 Input effect on pest incidence and tolerance.

The treated rhizomes were challenge infested with the ginger shoot borer and growth; yield and quality parameters, visual scoring of pest incidence symptom and multi elemental status were recorded.

4.2.1 Plant height (cm)

The data recorded in case of the plant height found significantly superior in T41 (59.83 cm). There was no significant difference between the two varieties. Treatment effect on individual varieties was observed highest height in variety Majouley was observed in T41 (63.82 cm) which was superior to the other treatments. Similarly significantly superior height was observed in T40 (63.65 cm) for the variety Bhaise (Table 4.2.1).

4.2.2 Number of leaves

When number of leaves was recorded, there was no significant difference between the treatments and between the varieties. The treatment effect on individual varieties for more number of leaves was observed in T40 (23.50) of variety Bhaise and in T41 (22.50 cm) of Majouley which were significantly superior (Table 4.2.1).

4.2.3 Number of tillers

In case of number of tillers there was no significant difference between the treatments as well as between the varieties. When treatment effect on individual varieties the treatment number T40 (3.52) was at par with T42 (3.50) of the variety Bhaise and in the variety Majouley the treatment number T41 (3.52) was at par with T34 (3.50), T37 (3.50) and T40 with 3.40 number of tillers (Table 4.2.1).

4.2.4 Leaf area (cm^2)

Treatments 40 and 41 with 45.87 cm^2 were having the highest leaf area and it was significantly superior to all other treatments. Comparision of two varieties showed that the variety Bhaise was superior to variety Majouley. The treatment effect on individual varieties showed that T40 (47.25 cm^2) of Bhaise was significantly superior and similarly T41 (46.50 cm^2) of the Majouley was significantly superior (Table 4.2.1).

4.2.5 Rhizome weight (g) of individual plant

The treatment T40 (327.50 g) was significantly superior to all other treatments and it was followed by T41 (310 g). Varieties when compared, it was observed that Bhaise was significantly superior to Majouley. Treatment on individual varieties showed that T40 (352.50 g) of Bhaise was significantly superior to other treatments and similarly T41 (342.50 g) of the variety Majouley was found to be superior to other treatments (Table. 4.2.2).

4.2.6 Volatile Oil (%)

The volatile oil content in T40 (4.46 %) was at par with T41 (4.42 %), T42 (4.38 %) and T43 (4.38 %) and were significantly superior than other treatments. Among the varieties Bhaise was significantly superior to Majouley. Treatment on individual varieties showed that T40 (4.55 %) was significantly superior to other treatments in variety Bhaise whereas, in Majouley there was no significant difference between the treatments (Table 4.2.2).

4.2.7 Crude Fiber (%)

The data recorded from the analysis of crude fiber showed that there was no significant difference between the treatments. In case of the comparison between two varieties, the variety Majouley was significantly superior to the variety Bhaise. The treatment effect on individual varieties showed that T40 (4.12 %) was at par with T39 (4.07%), T41 (4.07 %), T43 (4.07 %), T42 (4.05 %) and T34 (3.99 %) in variety Bhaise and in variety Majouley T41 (4.18 %) was at par with T42 (4.13 %), T43 and T40 with 4.10 % and T37 with 4.06 % (Table 4.2.2).

4.2.8 Visual scoring of pest

According to the symptoms shown by the plants of different treatments upon introduction of insect pest, the visual scoring was assigned. Based on observation on visual score T40 (4.21) and T41 (4.27) were significantly superior than other treatments and were at par with each other. Comparing the varieties, Bhaise was significantly superior to variety Majouley. The observation on treatment effect on individual varieties revealed that T40 (4.00) was at par with T41 (4.25) in variety Bhaise and in variety Majouley T41 with 4.30 was significantly superior to all other treatments (Table 4.2.2).

Table 4.2.1 Effect of different organic inputs on growth parameters of ginger after pest incidence

Growth Parameters	Plant Height (cm)			Number of leaves(no)			Tillers (no)			Leaf area(cm²)		
Treatments	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean
T1	31.48	31.03	31.26	12.50	12.62	12.56	2.50	2.75	2.62	17.00	19.00	18.00
T2	33.98	34.28	34.13	15.00	14.50	14.75	2.75	3.00	2.87	22.25	22.00	22.12
T3	35.43	33.28	34.35	14.25	15.00	14.62	3.00	3.00	3.00	21.25	27.25	24.25
T4	37.26	34.25	35.75	13.75	14.00	13.87	3.07	3.00	3.03	22.75	28.00	25.37
T5	39.93	36.09	38.01	15.00	13.50	14.25	3.12	3.05	3.08	34.00	36.75	35.37
T6	37.74	37.25	37.49	13.50	14.50	14.00	3.02	3.00	3.01	41.00	36.75	38.87
T7	37.69	46.31	42.00	14.75	14.25	14.50	3.00	3.00	3.00	42.00	39.50	40.75
T8	37.37	40.93	39.15	14.25	14.25	14.25	3.00	3.12	3.06	38.75	42.25	40.50
T9	39.42	41.67	40.54	13.50	14.50	14.00	3.00	3.05	3.02	43.75	38.00	40.87
T10	47.04	35.65	41.34	17.00	14.50	15.75	3.00	3.25	3.12	42.00	39.25	40.62
T11	44.17	35.12	39.64	15.00	14.25	14.62	3.00	3.30	3.15	40.25	43.00	41.62
T12	41.62	39.77	40.69	16.00	14.50	15.25	3.00	3.10	3.05	41.25	40.75	41.00
T13	39.17	38.28	38.72	15.25	14.50	14.87	3.10	3.00	3.05	41.25	42.25	41.75
T14	44.69	46.04	45.36	15.75	15.25	15.50	3.25	3.25	3.25	41.75	41.25	41.50
T15	40.35	39.13	39.74	15.00	16.50	15.75	3.27	3.25	3.26	42.50	42.75	42.62
T16	43.18	43.12	43.15	14.25	15.50	14.87	3.00	3.25	3.12	41.50	42.25	41.87
T17	44.60	39.68	42.14	15.25	15.50	15.37	3.25	3.25	3.25	40.00	41.00	40.50
T18	45.51	40.41	42.96	15.50	15.25	15.37	3.00	3.25	3.12	41.75	41.75	41.75
T19	44.51	44.22	44.36	14.00	14.50	14.25	3.02	3.25	3.13	39.50	42.25	40.87
T20	38.80	45.43	42.12	15.75	15.00	15.37	3.27	3.25	3.26	40.25	43.75	42.00
T21	46.80	41.10	43.95	16.25	14.50	15.37	3.00	3.25	3.12	41.75	41.50	41.62
T22	47.52	44.10	45.81	15.00	15.25	15.12	3.00	3.15	3.07	39.75	42.00	40.87
T23	50.30	39.01	44.65	18.75	14.25	16.50	3.10	3.07	3.08	41.75	39.75	40.75
T24	47.01	43.99	45.50	17.50	15.50	16.50	3.15	3.25	3.20	42.50	40.75	41.62
T25	48.84	42.83	45.83	17.75	14.75	16.25	3.30	3.37	3.33	42.25	41.00	41.62
T26	50.63	42.51	46.57	16.25	15.75	16.00	3.00	3.25	3.12	40.75	42.00	41.37
T27	41.67	43.56	42.61	14.75	14.75	14.75	3.00	3.25	3.12	43.00	41.50	42.25
T28	43.17	39.89	41.53	14.25	14.50	14.37	3.10	3.25	3.17	44.00	40.75	42.37
T29	46.32	42.24	44.28	16.00	15.00	15.50	3.10	3.00	3.05	41.75	42.50	42.12
T30	44.10	45.40	44.75	15.75	15.75	15.75	3.00	3.12	3.06	38.75	42.75	40.75
T31	46.00	49.05	47.52	17.00	16.50	16.75	3.00	3.25	3.12	43.00	40.50	41.75
T32	50.50	43.75	47.12	17.75	14.75	16.25	3.05	3.00	3.02	41.50	42.75	42.12
T33	44.26	42.84	43.55	16.00	16.75	16.37	3.25	3.25	3.25	42.75	41.00	41.87
T34	42.33	40.86	41.59	14.25	16.00	15.12	3.27	3.50	3.38	43.00	39.50	41.25
T35	49.92	48.76	49.34	16.00	17.00	16.50	3.00	3.10	3.05	40.75	41.75	41.25
T36	46.99	43.41	45.20	16.25	15.50	15.87	3.25	3.25	3.25	44.75	43.00	43.87
T37	45.37	50.43	47.90	15.00	18.00	16.50	3.30	3.50	3.40	44.00	42.75	43.37
T38	44.97	45.17	45.07	17.25	15.75	16.50	3.00	3.30	3.15	43.25	41.75	42.50
T39	54.45	48.30	51.37	19.00	17.50	18.25	3.10	3.07	3.08	40.50	41.50	41.00
T40	63.65	50.30	56.97	23.50	17.50	20.50	3.52	3.40	3.46	47.25	44.50	45.87
T41	55.84	63.82	59.83	17.75	22.50	20.12	3.35	3.52	3.43	45.25	46.50	45.87
T42	47.97	50.18	49.07	17.50	18.00	17.75	3.50	3.15	3.32	41.00	44.25	42.37
T43	52.55	52.79	52.67	17.75	18.25	18.00	3.30	3.22	3.26	43.50	44.50	44.00
Mean	44.53	42.70		15.87	15.49		3.10	3.18		39.79	39.96	
CD5%FactorA(Treatment)	1.43			0.44			0.09			1.11		
Factor B(Varieties)	0.30			0.09			0.02			0.24		
AXB	2.02			0.63			0.14			1.57		

Table 4.2.2 Effect of different organic inputs on yield, quality and visual symptom (score) of ginger after pest incidence

Yield,quality and pest incidence	Rhizome weight (g) of individual plant			Volatile oil(%)			Crude fiber(%)			Visual scoring of disease		
Treatments	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean
T1	127.25	128.50	126.62	2.79	2.67	2.73	2.31	2.44	2.37	7.25	7.37	7.31
T2	156.35	135.00	145.67	2.90	2.79	2.84	2.41	2.53	2.47	6.75	5.50	6.12
T3	138.75	140.05	139.40	3.07	2.85	2.95	2.70	2.56	2.63	6.00	5.87	5.93
T4	139.00	146.50	142.75	3.56	2.82	3.19	3.26	2.60	2.93	6.00	5.50	5.75
T5	137.62	163.75	150.68	3.76	2.76	3.26	3.57	2.51	3.04	5.25	5.25	5.25
T6	145.00	225.00	185.00	3.59	3.15	3.37	3.25	2.92	3.08	5.00	4.25	4.62
T7	145.25	146.25	145.75	3.59	3.18	3.38	3.44	2.93	3.18	5.30	5.37	5.33
T8	137.75	145.00	141.37	3.68	3.59	3.63	3.49	3.44	3.46	5.40	5.12	5.26
T9	137.75	156.25	147.00	3.65	3.66	3.65	3.28	3.33	3.30	5.62	5.37	5.49
T10	163.75	207.50	185.62	3.51	3.78	3.64	3.21	3.49	3.35	5.30	5.00	5.15
T11	147.75	196.25	175.00	3.27	3.23	3.25	3.10	3.07	3.08	5.37	5.87	5.62
T12	237.50	186.25	211.87	3.33	3.30	3.31	3.15	3.06	3.10	5.27	5.12	5.19
T13	165.00	160.25	162.62	3.38	3.36	3.37	3.15	3.02	3.09	5.50	5.45	5.47
T14	168.75	163.75	166.25	3.26	3.65	3.45	3.10	3.46	3.28	5.00	5.25	5.12
T15	154.00	180.00	167.00	3.71	3.74	3.72	3.52	3.34	3.43	5.50	5.75	5.62
T16	201.25	190.00	195.62	3.98	3.68	3.83	3.56	3.41	3.49	5.00	5.50	5.25
T17	211.25	177.00	194.12	3.90	3.79	3.84	3.62	3.58	3.60	5.50	5.12	5.31
T18	268.75	175.00	221.87	3.91	3.78	3.84	3.54	3.54	3.54	5.25	5.37	5.31
T19	212.50	256.25	234.37	4.01	3.62	3.81	3.53	3.39	3.46	5.00	5.50	5.25
T20	142.50	262.50	202.50	3.95	3.82	3.88	3.62	3.47	3.55	5.50	5.62	5.56
T21	143.75	225.00	184.37	3.98	3.79	3.88	3.65	3.58	3.62	5.35	5.50	5.42
T22	160.00	238.75	199.37	3.73	3.80	3.76	3.49	3.60	3.54	5.25	6.25	5.75
T23	155.00	189.00	172.00	3.74	3.86	3.80	3.55	3.60	3.57	5.00	5.00	5.00
T24	236.25	197.25	216.75	4.06	3.84	3.95	3.67	3.60	3.63	5.40	5.00	5.20
T25	142.50	190.00	166.25	3.92	3.83	3.87	3.64	3.59	3.61	5.25	5.62	5.43
T26	145.25	238.75	195.00	3.93	3.80	3.86	3.70	3.60	3.65	5.22	5.25	5.23
T27	141.25	268.75	205.00	3.82	3.40	3.91	3.51	3.67	3.59	5.65	5.00	5.32
T28	140.00	216.25	178.12	3.86	3.70	3.78	3.57	3.51	3.54	5.50	5.75	5.62
T29	177.50	200.25	188.87	3.86	3.90	3.94	3.63	3.61	3.62	5.50	5.50	5.50
T30	195.00	200.00	195.50	3.98	3.76	3.89	3.71	3.57	3.64	5.00	5.00	5.00
T31	200.25	263.75	232.00	4.02	3.95	4.02	3.60	3.65	3.62	5.75	5.17	5.46
T32	191.25	258.75	225.00	4.09	4.04	4.01	3.66	3.84	3.75	5.00	5.25	5.12
T33	257.50	242.50	250.00	3.98	4.02	3.97	3.59	3.71	3.65	5.60	5.35	5.47
T34	262.50	251.25	256.87	3.92	3.91	4.06	3.99	3.64	3.81	5.37	5.00	5.18
T35	227.50	277.50	252.50	4.21	4.11	4.20	3.72	3.87	3.80	5.00	5.25	5.12
T36	287.50	223.50	255.50	4.28	4.21	4.24	3.88	3.97	3.92	5.30	5.00	5.15
T37	298.75	270.00	284.37	4.14	4.27	4.20	3.84	4.06	3.95	5.00	5.25	5.12
T38	290.00	290.00	290.00	4.31	4.26	4.28	3.92	4.02	3.97	4.75	5.25	5.00
T39	305.00	300.00	302.50	4.23	4.32	4.27	4.07	3.98	4.03	4.62	4.75	4.68
T40	352.50	302.50	327.50	4.55	4.38	4.46	4.12	4.10	4.11	4.00	4.42	4.21
T41	277.50	342.50	310.00	4.35	4.50	4.42	4.07	4.18	4.13	4.25	4.30	4.27
T42	292.50	282.50	287.50	4.32	4.43	4.38	4.05	4.13	4.09	4.32	4.50	4.48
T43	295.00	317.50	306.25	4.36	4.40	4.38	4.07	4.10	4.08	4.62	4.80	4.41
Mean	197.96	216.91		3.83	3.72		3.52	3.47		5.29	5.28	
CD5%FactorA(Treatment)	6.34			0.11			0.09			0.16		
Factor B(Varieties)	1.36			0.02			0.02			0.03		
AXB	8.96			0.15			0.14			0.23		

4.2.9 GCMS analysis of different compounds present in essential oil of ginger after pest incidence

Essential oil was subjected to GCMS for elucidation of different compounds present in the oil and it was recorded that zingiberene was statistically superior in Bhaise (30.48 %) and in Majouley (30.66 %). Treatments T40 (33.22 %) and T41 (37.66 %) of Bhaise and Majouley were also statistically superior than the control and check (Table 4.2.3).

The different treatment results revealed that T40 of Bhaise was statistically superior in Ar-curcumene (14.72 %), zingiberene (33.22 %), beta-bisabolene (9.17) and delta-cadinene (14.33 %) than control and check.

Similarly in case of Majouley T41 was statistically superior in endo-borneol (1.52 %), ar-curcumene (16.57 %), zingibererne (37.66 %) and delta-cadinene (15.27 %) than control and check (Table 4.2.3).

Table 4.2.3 Effect of different organic inputs on different compounds present in essential oil of ginger after pest incidence

Sl. No.	Parameters	Bhaise				Majouley			
		Control	check	T40	G.M.	control	check	T41	G.M.
1.	Camphene	0.83	1.16	0.93	**0.97**	0.54	0.89	0.89	**0.77**
2.	Beta- Phellandrene	0.38	0.56	0.45	**0.46**	0.87	0.79	0.85	**0.83**
3.	Endo- Borneol	0.63	0.83	0.75	**0.73**	0.83	0.46	1.52	**0.93**
4.	Geraniol	0.94	1.29	1.01	**1.08**	1.51	1.78	1.27	**1.52**
5.	Geraly Acetate	1.59	1.41	1.50	**1.50**	1.55	1.41	1.50	**1.48**
6.	AR-Curcumene	12.40	13.71	14.72	**13.61**	14.79	14.85	16.57	**15.40**
7.	Zingiberene	28.49	29.74	33.22	**30.48**	28.94	30.39	37.66	**30.66**
8.	Alpha Farnesene	4.73	5.30	5.22	**5.08**	4.91	5.93	5.27	**5.37**
9.	Beta-Bisabolene	7.84	8.38	9.17	**8.46**	8.86	7.94	7.75	**8.18**
10.	4,5- Dimethyl-1-1-Methylene Tricycle 7	2.80	3.37	3.00	**3.05**	2.88	3.48	2.96	**3.10**
11.	Gamma-Cadinene	4.11	2.84	4.17	**3.70**	3.37	3.55	3.31	**3.41**
12.	Delta- Cadinene	12.67	12.23	14.33	**13.07**	12.66	13.07	15.27	**13.66**
13.	Beta-Sesquiphellandrene	0.44	0.56	0.58	**13.39**	0.52	0.46	0.62	**0.53**
14.	Nerolidol	2.04	2.68	2.61	**2.44**	2.00	1.64	1.57	**1.77**
15.	7-Alpha-(1-Hydroxy-1-Methylethyl)	1.46	1.46	1.40	**1.44**	2.04	1.84	1.94	**1.94**
16.	Germacrene B	1.33	1.48	1.11	**1.30**	1.37	1.09	1.40	**1.28**
17.	Alpha-Eudesmol	2.40	3.44	3.32	**3.05**	2.98	2.91	3.00	**3.16**
	Mean	5.00	5.32	5.73		0.49	5.33	5.44	
	Cd 5% factor a(parameters)	0.25				0.26			
	Factor b (treatments)	0.10				0.11			
	axb	0.44				0.46			

4.2.10 Multi elemental analysis of ginger after pest incidence

Calcium content in T40 (2.02 %) was significantly superior than all the other treatments. Among the two varieties calcium content in Bhaise was significantly superior to the variety Majouley. The treatment effect on individual varieties showed that T40 (2.19 %) of Bhaise was significantly superior to other treatments and also in the variety Majouley T40 (1.86 %) was significantly superior than other treatments (Table 4.2.4).

In case of Mg the treatments were not having any significant differences among each other. Magnesium content in Bhaise was significantly superior to the variety Majouley. The treatment effect on individual varieties showed that T40 (2.69 %) was at par with T39 (2.65 %), T35 (2.62 %) and T41 (2.62 %) in the variety Bhaise and in Majouley T41 (2.64 %) was at par with T40 (2.56 %) (Table 4.2.4).

Sulphur content in T40 (0.21 %) was significantly superior than the other treatments. Here, sulphur content in Majouley was significantly superior to the variety Bhaise. Based on the treatment effect on individual varieties, it was found that T40 (0.22 %) of Bhaise was significantly superior and in variety Majouley T41 (0.27%) was significantly superior than other treatments (Table 4.2.4).

Phosphorus was significantly superior in T43 (0.030 %) i.e., check than the other treatments. Bhaise was significantly superior to the variety Majouley, when compared for P content. The treatment effect on individual varieties showed that T43 (0.036 %) of Bhaise was significantly superior and in variety Majouley T41 (0.029 %) was significantly superior than other treatments (Table 4.2.4).

T41 (3.02 %) was significantly superior in K. A comparison of the two varieties showed that the Potassium content in Bhaise was significantly superior than the variety Majouley. Based on the interaction effect it was observed that the T40 (3.87 %) of variety Bhaise was significantly superior and in variety Majouley T41 (2.67 %) was significantly superior then other treatments (Table. 4.2.4).

Micro nutrients analysis of Fe, Na, Cu, Mn and Zn revealed that Fe content in T43 (check) and T41 had 1.10 mgL^{-1} which was significantly superior then the other treatments. The Iron content in Bhaise was significantly superior than the variety Majouley. The treatment effect on individual varieties showed that T43 (1.42 mgL^{-1}) of variety Bhaise was significantly superior and in variety Majouley T41 (0.87 mgL^{-1}) was at par with T37 (0.85 mgL^{-1}) and T36 (0.84 mgL^{-1}) (Table 4.2.4).

Na content in T40 (1.55 mgL^{-1}) was significantly superior than the other treatments. Comparison of the two varieties showed that the sodium content in Bhaise was significantly superior to the variety Majouley. The treatment effect on individual varieties showed that T40 (1.70 mgL^{-1}) of variety Bhaise was significantly superior and in variety Majouley T41 (1.57 mgL^{-1}) was significantly superior than other treatments (Table 4.2.4).

T43 with 0.21 mgL^{-1} of Cu and 0.32 mgL^{-1} of Mn was significantly superior in Cu and Mn content, while comparing Cu content it was significantly superior in Bhaise and Mn was superior in Majouley. The treatment effect on individual varieties on Cu content showed that T43 (0.22 mgL^{-1}) of variety Bhaise was significantly superior and in Majouley it was non significant and the treatment effect on individual varieties in Mn showed that T43 (0.31 mgL^{-1}) of variety Bhaise and T43 (0.34 mgL^{-1}) of Majouley was significantly superior than other treatments (Table 4.2.4).

Table 4.2.4 Effect of different organic inputs on nutrient content of ginger after pest incidence

Treatments	Ca(%)			Mg(%)			S(%)			P(%)			K(%)		
	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean
control	0.52	0.39	0.45	2.06	2.20	2.13	0.08	0.12	0.10	0.010	0.004	0.007	2.13	0.39	1.26
T35	1.54	1.40	1.47	2.62	2.41	2.51	0.11	0.23	0.17	0.022	0.012	0.017	1.74	1.40	1.57
T36	0.52	0.70	0.61	1.85	2.22	2.03	0.11	0.21	0.16	0.017	0.027	0.022	1.06	0.50	0.78
T37	1.43	1.42	1.43	2.12	2.34	2.23	0.08	0.18	0.13	0.003	0.013	0.008	0.62	0.54	0.58
T38	0.75	0.96	0.85	2.11	2.38	2.24	0.11	0.16	0.13	0.009	0.015	0.012	3.15	0.87	2.01
T39	0.91	0.33	0.62	2.65	1.66	2.16	0.14	0.18	0.16	0.022	0.007	0.014	3.43	0.82	2.12
T40	2.19	1.86	2.02	2.69	2.56	2.62	0.22	0.20	0.21	0.025	0.012	0.018	3.87	0.77	2.32
T41	2.04	0.84	1.44	2.62	2.64	2.63	0.12	0.27	0.19	0.019	0.029	0.024	3.37	2.67	3.02
T42	1.36	0.69	1.03	2.54	2.50	2.52	0.12	0.24	0.18	0.020	0.008	0.014	0.93	2.37	1.65
Check	0.91	0.45	0.68	2.42	2.31	2.37	0.18	0.23	0.21	0.036	0.025	0.030	1.53	1.81	1.67
mean	1.22	0.90		2.37	2.32		0.132	0.20		0.018	0.015		2.18	1.21	
CD5%FactorA (Treatment)	0.03			0.06			0.004			0.0006			0.06		
Factor B (Varieties)	0.01			0.02			0.002			0.0002			0.03		
AXB	0.05			0.08			0.006			0.0008			0.09		

Treatments	Fe(mgL^{-1})			Na(mgL^{-1})			Cu(mgL^{-1})			Mn(mgL^{-1})			Zn(mgL^{-1})		
	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean
control	0.60	0.33	0.46	0.55	0.44	0.49	0.13	0.12	0.12	0.15	0.14	0.15	0.14	0.14	0.14
T35	0.80	0.38	0.59	0.96	0.86	0.91	0.13	0.12	0.13	0.06	0.13	0.10	0.52	0.20	0.36
T36	0.55	0.84	0.69	0.82	1.21	1.02	0.19	0.15	0.17	0.18	0.26	0.22	0.24	0.22	0.23
T37	0.79	0.85	0.82	0.54	0.71	0.63	0.12	0.12	0.12	0.15	0.28	0.22	0.21	0.24	0.22
T38	0.46	0.40	0.43	1.38	0.81	1.10	0.13	0.13	0.13	0.19	0.25	0.22	0.37	0.25	0.31
T39	0.66	0.50	0.58	1.36	1.38	1.37	0.15	0.19	0.17	0.24	0.15	0.19	0.30	0.12	0.21
T40	1.64	0.54	1.09	1.70	1.39	1.55	0.20	0.15	0.17	0.28	0.23	0.26	0.45	0.17	0.31
T41	1.34	0.87	1.10	0.71	1.57	1.14	0.17	0.18	0.17	0.14	0.22	0.18	0.39	0.28	0.34
T42	1.22	0.82	1.02	0.90	1.08	0.99	0.18	0.12	0.15	0.22	0.26	0.24	0.40	0.20	0.30
Check	1.43	0.77	1.10	1.54	0.88	1.21	0.22	0.20	0.21	0.31	0.34	0.32	0.26	0.21	0.23
mean	0.95	0.63		1.05	1.03		0.16	0.14		0.19	0.22		0.33	0.20	
CD5%FactorA (Treatment)	0.02			0.03			0.004			0.006			0.008		
Factor B (Varieties)	0.01			0.01			0.001			0.002			0.003		
AXB	0.03			0.04			0.006			0.009			0.01		

Zinc content in T41 (0.34 mgL^{-1}) was significantly superior than the other treatments. Comparison of the two varieties showed that the Zinc content in Bhaise was significantly superior to the variety Majouley. The treatment effect on individual varieties showed that T35 (0.52 mgL^{-1}) of variety Bhaise was significantly superior and in variety Majouley T41 (0.28 mgL^{-1}) was significantly superior than other treatments (Table 4.2.4).

4.2.11 Soil analysis of input effect on pest tolerance

The soil samples which were collected from the field before and after the application of organic manures were analyzed and the results revealed that the elements such as K, Ca, Mg, Fe, Na, Cu, Mn were found to be lower in content after the application of the organic inputs in the soil thus indicating the higher uptake of the elements by the plants (Table 4.2.5).

Table 4.2.5 Soil analysis of input effect on pest tolerance

Soil	N(%)	P(%)	K(%)	Ca(%)	Mg(%)	S(%)
before	0.22	0.02	0.30	7.25	2.34	0.02
after	0.21	0.03	0.26	4.05	1.48	0.03
Mean	0.21	0.02	0.28	5.65	1.91	0.02
C.D 5%	0.01	0.001	0.02	11.95	3.98	0.001
sem	0.003	0.0003	0.005	3.05	1.01	0.0003

Soil	Fe(mgL^{-1})	Na(mgL^{-1})	Cu(mgL^{-1})	Mn(mgL^{-1})	Zn(mgL^{-1})
before	3.90	3.37	0.14	0.65	0.88
after	2.77	2.34	0.13	0.16	0.89
mean	3.34	2.85	0.13	0.40	0.88
C.D 5%	6.88	5.90	0.27	0.96	1.80
sem	1.76	1.51	0.71	0.24	0.46

4.3 Input effect on disease incidence and tolerance.

4.3.1 Plant height (cm)

The highest plant height was observed in T40 (60.28 cm) which was significantly superior than other treatments, it was followed by T37 (58.52 cm). Comparison of two varieties showed that Bhaise was significantly superior to variety Majouley. When treatment effect on individual varieties was observed, highest height in variety Bhaise was observed in T40 (68.89 cm) which was superior to the other treatments. Similarly significantly superior height was observed in T37 (62.11 cm) for the variety Majouley (Table 4.3.1).

4.3.2 Number of leaves

The highest number of leaves was observed in T40 (20.72) and it was at par with T37 (20.37). Comparison of two varieties showed that Bhaise was significantly superior to the variety Majouley. When treatment effect on individual varieties for more number of leaves was observed, in variety Bhaise T40 (23.75) was superior to the other treatments. Significantly superior number of leaves was observed in T37 (22.00) for the variety Majouley (Table 4.3.1).

4.3.3 Number of tillers

Among the treatments T40 (3.40) was at par with T42 (3.32) and T43 with 3.33 number of tillers. When comparing the two varieties it showed that variety Bhaise was significantly superior to the variety Majouley. Interaction of treatment and varieties yielded T40 (3.60) was significantly superior than other treatments and in Majouley the treatment number T37 (3.57) was significantly superior to other treatments (Table 4.3.1).

4.3.4 Leaf area (cm^2)

T37 (44.25 cm^2) and T40 (43.50 cm^2) were having the highest leaf area and it was at par with each other. Comparison of two varieties showed that the variety Bhaise was superior to the variety Majouley. The treatment effect on individual varieties showed that T40 (48.75 cm^2) of Bhaise was significantly superior and on the same way T37 (46.75 cm^2) of the Majouley was significantly superior (Table 4.3.1).

4.3.5 Rhizome weight (g) of individual plant

T37 (356.50 g) was at par with T40 (350.37 g) and was significantly superior to all other treatments. Comparison of two varieties revealed that the variety Bhaise was significantly superior to Majouley. The interaction effect showed that T40 (390.50 g) of Bhaise was significantly superior to other treatments and similarly T37 (387.25 g) of the variety Majouley was found to be superior to other treatments (Table 4.3.2).

4.3.6 Volatile Oil (%)

The volatile oil content in T37 (4.15 %) was at par with T38 (4.07 %) and were significantly superior than other treatments. Among the varieties Majouley was significantly superior to Bhaise. The treatment effect on individual varieties showed that T40 (4.27 %) was significantly superior to other treatments of the variety Bhaise and in the variety Majouley T37 (4.30 %) was significantly superior to the other treatments (Table 4.3.2).

4.3.7 Crude Fiber (%)

The treatment38 (3.74 %) was at par with T37 (3.65 %) in crude fiber content. The comparison of the two varieties showed that the variety Bhaise was significantly superior than the variety Majouley. The treatment effect on individual varieties showed that T40 (3.99 %) was significantly superior to other treatments of the variety Bhaise and in the variety Majouley T37 (3.90 %) was at par with T38 (3.83 %) (Table 4.3.2).

4.3.8 Visual scoring of disease

T37 (3.00) and T40 (3.01) were significantly superior than other treatments and were at par with each other. Comparing the varieties, Bhaise was at par with the variety Majouley. The treatment effect on individual varieties showed that T40 (2.87) was significantly superior to the other treatments in the variety Bhaise and in variety Majouley T37 with 2.85 was significantly superior than the other treatments (Table 4.3.2).

Table 4.3.1 Effect of different organic input on growth parameters of ginger after disease incidence

Growth Parameters	Plant Height (cm)			Number of leaves(no)			Tillers (no)			Leaf area(cm^2)		
Treatments	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean
T1	30.86	30.62	30.74	14.00	15.00	14.50	2.50	2.75	2.62	17.50	18.75	18.12
T2	35.74	35.92	35.83	14.50	14.00	14.25	2.50	2.75	2.62	22.75	22.50	22.62
T3	32.95	36.07	34.51	13.50	14.50	14.00	3.15	3.00	3.07	21.50	26.50	24.00
T4	36.37	33.98	35.17	15.00	14.50	14.75	3.25	3.15	3.20	25.50	24.00	24.75
T5	40.59	37.17	38.88	17.25	15.25	16.25	2.75	2.75	2.75	31.50	27.32	29.41
T6	39.35	38.99	39.17	16.25	15.25	15.75	2.75	2.90	2.82	29.75	27.75	28.75
T7	32.44	35.07	33.75	15.25	14.00	14.62	2.75	2.85	2.80	26.50	29.00	27.75
T8	40.60	33.95	37.27	15.00	14.75	14.87	2.75	2.75	2.75	37.75	27.75	32.75
T9	42.09	39.33	40.71	17.00	14.75	15.87	3.25	3.00	3.12	35.25	36.00	35.62
T10	44.03	41.85	42.94	15.50	14.50	15.00	3.00	3.10	3.05	35.00	33.50	34.25
T11	39.77	34.62	37.19	15.75	13.50	14.62	2.75	2.75	2.75	36.00	28.25	32.12
T12	35.20	33.73	34.46	14.25	13.50	13.87	3.25	3.00	3.12	30.25	32.75	31.50
T13	44.68	36.80	40.74	16.25	14.00	15.12	3.25	3.00	3.12	34.25	28.25	31.25
T14	45.76	36.91	41.34	17.75	14.50	16.12	3.25	3.00	3.12	32.50	30.25	31.37
T15	48.67	34.54	41.60	15.75	14.50	15.12	3.15	3.15	3.15	37.00	29.50	33.25
T16	35.52	32.45	33.99	15.25	14.00	14.62	3.10	3.20	3.15	28.00	29.25	28.62
T17	36.88	34.19	35.54	14.00	13.00	13.50	3.15	3.20	3.07	31.75	31.25	31.50
T18	34.69	35.11	34.90	14.00	14.75	14.37	3.00	3.15	2.90	27.00	29.50	28.25
T19	34.42	38.74	36.58	13.75	15.50	14.62	2.75	3.05	3.12	32.00	31.75	31.87
T20	36.37	42.09	39.23	15.00	16.25	15.62	3.25	3.00	2.80	34.25	34.37	34.31
T21	46.77	43.02	44.89	18.00	15.25	16.62	2.50	3.10	3.12	36.00	34.50	35.25
T22	38.84	45.88	42.36	15.75	17.50	16.62	3.10	3.15	3.15	36.50	36.00	36.25
T23	31.58	35.94	33.76	16.00	15.00	15.50	3.25	3.05	3.12	28.25	33.00	30.62
T24	39.44	38.96	39.20	16.25	17.00	16.62	3.20	3.20	3.15	33.50	33.75	33.62
T25	45.50	38.39	41.95	16.75	16.25	16.50	3.20	3.15	3.20	34.75	32.75	33.75
T26	35.95	43.76	39.85	16.50	16.50	16.50	3.00	3.10	3.17	30.00	34.00	32.00
T27	41.09	41.10	41.09	16.25	15.25	15.75	3.00	3.00	3.05	34.75	35.50	35.12
T28	43.97	43.16	43.56	16.25	15.50	15.87	3.25	3.00	3.00	32.50	33.25	38.87
T29	40.93	46.44	43.69	15.75	17.00	16.37	3.15	3.05	3.12	36.00	34.50	35.25
T30	40.18	47.23	43.70	15.50	17.00	16.25	3.20	3.00	3.10	37.75	37.00	37.37
T31	45.99	35.84	40.91	17.05	15.50	16.27	3.00	3.15	3.10	34.25	29.75	32.00
T32	42.50	46.15	44.32	16.00	16.25	16.12	3.25	3.05	3.07	35.75	34.00	34.87
T33	41.80	39.56	40.68	17.00	16.75	16.37	3.20	3.10	3.15	35.25	33.25	34.25
T34	40.35	40.22	40.28	14.50	16.25	15.37	3.15	3.15	3.15	36.62	33.00	34.81
T35	52.45	46.44	49.44	17.25	16.75	17.00	3.10	3.10	3.15	41.00	38.75	39.87
T36	50.43	48.12	49.27	18.30	17.25	17.77	3.15	3.15	3.15	38.25	38.00	38.12
T37	54.93	62.11	58.52	18.75	22.00	20.37	3.25	3.57	3.41	41.75	46.75	44.25
T38	58.46	51.24	54.85	20.75	17.00	18.87	3.00	3.15	3.07	44.00	42.25	43.12
T39	50.08	48.73	49.40	17.50	17.85	17.67	3.20	3.20	3.20	39.25	40.50	39.87
T40	68.89	51.67	60.28	23.75	17.70	20.72	3.60	3.20	3.40	48.75	38.25	43.50
T41	49.98	50.03	50.01	18.10	17.25	17.67	3.15	3.20	3.17	39.75	41.62	40.68
T42	55.24	51.77	53.50	19.00	17.80	18.40	3.35	3.30	3.32	43.00	41.75	42.37
T43	52.11	51.55	51.83	18.50	17.25	17.87	3.40	3.27	3.33	40.25	41.05	40.65
Mean	42.66	41.15		16.38	15.74		3.07	3.06		34.04	33.05	
CD5%FactorA(Treatment)	1.14			0.46			0.08			1.03		
Factor B(Varieties)	0.24			0.10			0.01			0.22		
AXB	1.62			0.65			0.12			1.46		

Table 4.3.2 Effect of different organic inputs on yield, quality and disease incidence

Yield,quality and disease incidence	Rhizome weight (g) of individual plant			Volatile oil(%)			Crude fiber(%)			Visual scoring of disease		
Treatments	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean
T1	132.50	138.75	135.62	2.79	2.28	2.53	2.48	2.11	2.29	6.75	6.50	6.62
T2	147.50	145.20	146.35	2.99	2.50	2.75	2.66	2.15	2.40	5.50	5.50	5.50
T3	152.65	155.75	154.20	3.11	2.70	2.91	3.06	2.57	2.81	5.00	4.25	4.62
T4	146.25	150.25	148.25	3.42	3.29	3.36	3.13	3.13	3.13	5.50	5.00	5.25
T5	152.50	161.75	157.12	3.32	3.33	3.32	3.16	3.06	3.11	4.00	4.25	4.12
T6	168.75	165.25	167.00	3.74	3.41	3.57	3.38	3.17	3.27	4.00	4.00	4.00
T7	161.25	166.50	163.87	3.21	3.20	3.20	2.74	2.97	2.85	4.75	4.00	4.37
T8	200.00	145.25	172.62	3.19	3.18	3.18	2.75	2.90	2.82	4.50	4.75	4.62
T9	185.00	150.00	167.75	3.17	3.15	3.16	2.91	3.01	2.96	5.00	4.50	4.75
T10	216.75	154.50	185.62	3.18	3.44	3.31	2.85	3.19	3.02	4.50	4.50	4.50
T11	170.50	161.20	165.85	3.18	3.31	3.24	2.99	3.20	3.09	4.00	4.00	4.00
T12	150.25	165.25	157.75	2.60	3.25	2.93	2.52	3.06	2.79	5.00	4.00	4.50
T13	253.75	155.50	204.62	2.98	3.13	3.05	2.71	3.00	2.85	4.00	4.50	4.25
T14	245.50	165.25	205.37	3.46	3.18	3.32	3.18	3.04	3.11	4.25	4.25	4.25
T15	263.75	162.00	212.87	3.39	3.23	3.31	2.90	3.08	2.99	4.00	4.00	4.00
T16	175.00	150.75	162.87	3.29	3.20	3.24	3.03	3.07	3.05	4.00	4.50	4.25
T17	170.00	152.50	161.25	3.54	3.18	3.36	3.22	3.04	3.13	4.25	4.50	4.37
T18	165.25	155.00	160.12	3.44	3.09	3.27	3.35	2.88	3.12	4.75	4.50	4.62
T19	180.25	163.75	172.00	3.87	3.14	3.50	3.56	2.90	3.23	4.00	4.00	4.00
T20	182.25	168.00	175.12	2.92	3.15	3.04	2.81	3.10	2.95	4.00	4.00	4.00
T21	255.75	170.25	213.00	3.23	3.07	3.15	3.07	2.92	3.00	3.85	4.00	3.92
T22	174.25	215.00	194.62	3.17	3.13	3.15	2.97	2.74	2.85	4.60	3.75	4.17
T23	170.50	230.75	200.62	3.32	3.25	3.28	3.20	2.94	3.07	4.50	3.50	4.00
T24	192.25	169.25	180.75	3.19	3.26	3.22	3.06	3.12	3.09	4.25	3.75	4.00
T25	253.50	172.75	213.12	3.23	3.24	3.23	3.07	3.09	3.08	4.05	3.75	3.90
T26	180.00	177.50	178.75	3.19	3.17	3.18	3.03	2.99	3.01	4.10	3.50	3.80
T27	257.50	240.75	249.12	2.94	3.27	3.11	2.76	2.92	2.84	4.00	4.00	4.00
T28	272.00	230.00	251.00	3.30	3.42	3.36	3.11	3.12	3.11	3.75	3.75	3.75
T29	264.75	235.75	250.25	3.87	3.76	3.82	3.41	3.49	3.45	3.75	3.50	3.62
T30	272.25	242.50	257.37	3.42	3.26	3.34	3.21	3.12	3.16	3.75	3.50	3.62
T31	285.50	245.75	265.62	3.60	3.24	3.42	3.21	3.01	3.11	4.00	3.50	3.75
T32	262.50	185.25	223.87	3.92	3.27	3.59	3.50	3.10	3.30	4.20	4.00	4.10
T33	195.25	235.75	215.50	3.46	3.25	3.36	3.13	3.07	3.10	4.25	3.85	4.05
T34	200.50	180.25	190.37	3.04	3.26	3.15	2.74	2.83	2.78	4.00	4.00	4.00
T35	312.25	235.25	273.75	3.32	3.88	3.60	3.12	3.19	3.16	3.50	4.10	3.80
T36	300.50	225.50	263.00	3.39	3.68	3.54	3.25	3.51	3.38	3.30	3.55	3.42
T37	325.75	387.25	356.50	4.00	4.30	4.15	3.41	3.90	3.65	3.15	2.85	3.00
T38	330.25	320.25	325.25	4.08	4.07	4.07	3.65	3.83	3.74	3.30	3.50	3.40
T39	310.50	315.25	312.87	3.91	3.39	3.65	3.61	3.21	3.41	3.80	4.00	3.90
T40	390.50	310.25	350.37	4.27	3.19	3.73	3.99	3.06	3.52	2.87	3.15	3.01
T41	315.20	300.75	307.97	4.10	3.30	3.70	3.73	3.20	3.46	3.25	3.22	3.23
T42	325.00	315.50	320.25	3.60	3.53	3.56	3.58	3.33	3.45	3.20	3.25	3.22
T43	315.75	325.75	320.75	3.76	3.62	3.69	3.46	3.32	3.36	3.55	3.95	3.75
Mean	227.48	204.64		3.40	3.28		3.13	3.06		4.30	4.03	
CD5%FactorA(Treatment)	6.87			0.09			0.09			0.12		
Factor B(Varieties)	1.48			0.02			0.02			0.02		
AXB	9.72			0.13			0.13			0.17		

4.3.9 GCMS analysis of different compounds present in essential oil of ginger after disease incidence

From the GCMS analysis of essential oil, the compound zingiberene was significantly superior in both the varieties Bhaise (29.91 %) and in Majouley (29.15 %). It was followed by delta-cadinene in Bhaise (15.26 %) and in Majouley (14.80 %). The treatment 40 of Bhaise produced significantly superior amount of camphene (0.77 %), ar-curcumene (13.92 %), 4, 5-dimethyl-1-1-methylene tricycle 7 (2.88 %), 7-alpha-(1-hydroxy-1-methylethyl) (2.19 %), germacrene B (2.00 %) and alph-eudesmol (3.89 %).

The treatment 37 of Majouley was significantly superior in ar-curcumene (15.80 %), zingiberene (31.63 %), gamma-cadinene (4.02 %), delta-cadinene (15.21 %) and 7-alpha-(1-hydroxy-1-methylethyl) (1.85 %) (Table 4.3.3).

4.3.10 Multi elemental analysis of ginger after disease incidence

The percentage of Ca content in the treatments varied from 2.08 % (T37) to 0.42 % (control) and T37 was significantly superior than all the other treatments. The calcium content in Bhaise was significantly superior than the variety Majouley. The treatment effect on individual varieties showed that T40 (2.48 %) of Bhaise and T37 (1.95 %) of Majouley were significantly superior to other treatments (Table 4.3.4).

Mg content varied from 2.61 % (T40) to 1.61 % (control) and T40 was significantly superior than other treatments. Comparison of the two varieties showed that the magnesium content in Bhaise was significantly superior to the variety Majouley. The treatment effect on individual varieties showed that T40 (2.92 %) was significantly superior to the other treatments in the variety Bhaise and in Majouley

T37 (2.35 %) was at par with T41 (2.32 %), T40 (2.31 %), T43 (2.30 %) and T42 (2.29 %) (Table 4.3.4).

S content of T40 and T43 (0.15 % each) was significantly superior than the other treatments. There was no significant difference between the S content in Bhaise and Majouley. The treatment effect on individual varieties showed that T43 (0.18 %) of Bhaise was significantly superior and in variety Majouley T37 (0.18 %) was significantly superior than other treatments (Table 4.3.4).

P content in T43 (0.014 %) was at par with T37 (0.013 %) and was significantly superior to the other treatments. Bhaise was significantly superior in P content than the variety Majouley. The treatment effect on individual varieties showed that T43 (0.018 %) of Bhaise was significantly superior than and in variety Majouley T37 (0.012 %) was at par with T39 (0.011 %) (Table 4.3.4).

Potassium content in T43 (1.68 %) was at par with T40 (1.63 %) and was significantly superior to the other treatments. Comparison of the two varieties showed that the Potassium content in Bhaise was significantly superior than the variety Majouley. The treatment effect on individual varieties showed that T40 (1.84 %) of variety Bhaise was at par with T39 (1.78 %) and in variety Majouley T43 (1.67 %) was significantly superior than other treatments (Table 4.3.4).

Table 4.3.3 Effect of different organic inputs on different compounds present in essential oil of ginger after disease incidence

Sl. No.	Parameters	Bhaise				Majouley			
		Control	check	T40	G.M.	control	check	T37	G.M.
1.	Camphene	0.42	0.69	0.77	0.62	0.33	0.81	0.50	0.54
2.	Beta- Phellandrene	0.83	1.10	0.71	0.88	0.48	1.05	0.77	0.76
3.	Endo- Borneol	0.97	1.25	0.67	0.96	0.77	0.90	0.94	0.87
4.	Geraniol	0.80	1.11	0.80	0.90	1.02	1.07	0.88	0.99
5.	Geraly Acetate	1.17	1.57	1.23	1.32	1.27	1.38	1.38	1.34
6.	AR-Curcumene	12.42	13.33	13.92	13.22	12.73	14.29	15.80	14.27
7.	Zingiberene	28.26	30.19	31.29	29.91	26.77	29.06	31.63	29.15
8.	Alpha Farnesene	5.15	5.61	5.18	5.31	6.03	4.55	6.09	5.55
9.	Beta-Bisabolene	7.85	9.21	9.03	8.70	8.70	10.05	9.46	9.40
10.	4,5- Dimethyl-1-1-Methylene Tricycle 7	2.15	2.52	2.88	2.52	3.35	1.32	2.67	2.44
11.	Gamma-Cadinene	3.88	3.41	3.87	3.72	2.93	3.38	4.02	3.44
12.	Delta- Cadinene	15.33	15.55	14.92	15.26	14.73	13.93	15.21	14.80
13.	Beta-Sesquiphellandrene	0.48	0.79	0.75	0.67	0.54	0.98	0.33	0.61
14.	Nerolidol	2.50	1.90	2.09	2.16	2.54	2.34	2.52	2.47
15.	7-Alpha-(1-Hydroxy-1-Methylethyl)	1.28	1.43	2.19	1.63	1.18	1.26	1.85	1.42
16.	Germacrene B	1.51	1.72	2.00	1.74	0.90	1.63	1.14	1.22
17.	Alpha-Eudesmol	2.91	3.65	3.89	3.48	2.85	4.19	3.19	3.41
	Mean	5.17	5.59	5.65		5.12	5.42	5.78	
	Cd 5% factor a(parameters)	0.21				0.24			
	Factor b (treatments)	0.09				0.10			
	axb	0.37				0.42			

Table 4.3.4 Effect of different organic inputs on nutrient content of ginger after disease incidence

TREATMENTS	Ca(%)			Mg(%)			S(%)			P(%)			K(%)		
	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean
CONTROL	0.58	0.27	0.42	1.93	1.29	1.61	0.09	0.09	0.09	0.006	0.009	0.007	1.34	1.22	1.28
T35	0.83	0.14	0.48	1.97	1.33	1.65	0.11	0.12	0.11	0.007	0.002	0.005	1.28	1.31	1.29
T36	2.24	0.47	1.35	2.65	1.86	2.26	0.12	0.07	0.10	0.014	0.008	0.011	1.56	1.43	1.49
T37	2.22	1.95	2.08	2.62	2.35	2.49	0.07	0.18	0.13	0.013	0.012	0.013	1.62	1.59	1.60
T38	2.07	1.22	1.64	2.71	1.87	2.29	0.10	0.12	0.11	0.011	0.006	0.008	1.27	1.18	1.22
T39	2.14	1.17	1.65	2.58	2.11	2.35	0.13	0.09	0.11	0.012	0.011	0.011	1.78	1.06	1.42
T40	2.48	1.08	1.78	2.92	2.31	2.61	0.15	0.15	0.15	0.015	0.009	0.012	1.84	1.42	1.63
T41	2.13	1.25	1.69	2.08	2.32	2.20	0.12	0.13	0.13	0.011	0.008	0.009	1.64	1.32	1.48
T42	2.22	1.28	1.75	2.65	2.29	2.47	0.13	0.14	0.14	0.013	0.007	0.010	1.68	1.45	1.56
Check	2.34	1.44	1.89	2.40	2.30	2.35	0.18	0.12	0.15	0.018	0.010	0.014	1.70	1.67	1.68
mean	1.92	1.02		2.45	2.00		0.12	0.12		0.012	0.008		1.57	1.36	
CD5%FactorA (Treatment)	0.05			0.06			0.004			0.0003			0.05		
Factor B (Varieties)	0.02						0.001			0.0001			0.02		
AXB	0.07			0.02			0.006			0.0004			0.07		

TREATMENTS	Fe (mgL^{-1})			Na (mgL^{-1})			Cu (mgL^{-1})			Mn (mgL^{-1})			Zn (mgL^{-1})		
	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean
CONTROL	0.54	0.40	0.47	1.59	1.22	1.40	0.26	0.16	0.21	0.18	0.10	0.14	0.28	0.25	0.26
T35	0.49	0.26	0.37	1.98	1.39	1.68	0.24	0.15	0.19	0.14	0.17	0.15	0.27	0.23	0.25
T36	0.48	0.64	0.56	1.81	1.28	1.54	0.24	0.28	0.26	0.18	0.15	0.16	0.27	0.20	0.23
T37	0.49	0.83	0.66	1.81	1.55	1.68	0.31	0.34	0.33	0.13	0.28	0.20	0.38	0.28	0.33
T38	0.55	0.81	0.68	1.19	1.45	1.32	0.30	0.27	0.29	0.17	0.22	0.19	0.41	0.22	0.32
T39	0.56	0.44	0.50	1.99	1.21	1.60	0.24	0.25	0.25	0.15	0.18	0.17	0.44	0.21	0.32
T40	0.64	0.53	0.58	2.39	1.21	1.80	0.38	0.24	0.31	0.22	0.10	0.16	0.57	0.19	0.38
T41	0.51	0.52	0.51	2.22	1.24	1.73	0.27	0.19	0.23	0.21	0.18	0.20	0.41	0.23	0.32
T42	0.42	0.58	0.50	2.34	1.42	1.88	0.24	0.30	0.27	0.18	0.22	0.20	0.40	0.25	0.33
Check	0.54	0.60	0.58	2.45	1.39	1.92	0.34	0.21	0.28	0.24	0.20	0.22	0.42	0.30	0.36
mean	0.52	0.56		1.97	1.33		0.28	0.24		0.18	0.18		0.39	0.23	
CD5%FactorA (Treatment)	0.010			0.05			0.007			0.006			0.008		
Factor B (Varieties)	0.008			0.02			0.003			0.002			0.003		
AXB	0.020			0.08			0.010			0.002			0.01		

Iron content in T38 (0.68 mgL^{-1}) was significantly superior to the other treatments. Comparison of the two varieties showed that the iron content in Majouley was significantly superior to the variety Bhaise. The treatment effect on individual varieties showed that T40 (0.64 mgL^{-1}) of variety Bhaise was significantly superior and in variety Majouley T38 (0.81 mgL^{-1}) was significantly superior than other treatments (Table 4.3.4).

Sodium content in T43 (1.92 mgL^{-1}) was at par with T42 (1.88 mgL^{-1}) and was significantly superior than the other treatments. Comparison of the two varieties showed that the sodium content in Bhaise was significantly superior than the variety Majouley. The treatment effect on individual varieties showed that T43 (2.45 mgL^{-1}) of variety Bhaise was at par with T40 (2.39 mgL^{-1}) and in variety Majouley T37 (1.55 mgL^{-1}) was significantly superior than other treatments (Table 4.3.4).

Copper content in T37 (0.33 mgL^{-1}) was significantly superior to the other treatments. Comparison of the two varieties showed that the copper content in Bhaise was significantly superior to the variety Majouley. The treatment effect on individual varieties showed that T40 (0.38 mgL^{-1}) of variety Bhaise was at par with T43 (0.34 mgL^{-1}) and in Majouley T37 (0.34 mgL^{-1}) was significantly superior than other treatments Table 4.3.4).

Manganese content in T43 (0.22 mgL^{-1}) was significantly superior than the other treatments. Comparison of the two varieties showed that the Manganese content in Majouley was significantly superior to the variety Bhaise. The treatment effect on individual varieties showed that T43 (0.24 mgL^{-1}) of variety Bhaise was significantly superior and in variety Majouley T37 (0.28 mgL-1) was significantly superior to other treatments (Table 4.3.4).

Zinc content in T40 (0.38 mgL^{-1}) was significantly superior to the other treatments. Comparison of the two varieties showed that the Zinc content in Bhaise was significantly superior to the variety Majouley. The treatment effect on individual varieties showed that T40 (0.57 mgL^{-1}) of variety Bhaise was significantly superior and in variety Majouley T43 (0.30 mgL^{-1}) was significantly superior to other treatments (Table 4.3.4).

4.3.11 Soil analysis of input effect on disease tolerance

The soil samples which were collected from the field before and after the application of organic manures were analyzed and the results revealed that the elements such as N, K, Ca, Mg, S, Fe, Na, Cu, Zn were found to be lower in content after the application of the organic inputs in the soil thus indicating the higher uptake of the elements by the plants (Table 4.3.5).

Table 4.3.5 Soil analysis of input effect on disease tolerance

Soil	N(%)	P(%)	K(%)	Ca(%)	Mg(%)	S(%)
before	0.29	0.01	1.76	7.37	2.91	0.05
after	0.27	0.03	0.19	5.96	2.89	0.03
Mean	0.28	0.02	0.97	6.66	2.90	0.04
C.D 5%	0.002	0.0003	0.10	13.63	5.90	0.0007
SEM	0.0003	0.00009	0.02	3.48	1.50	0.0003

Soil	Fe (mgL^{-1})	Na(mgL^{-1})	Cu (mgL^{-1})	Mn (mgL^{-1})	Zn(mgL^{-1})
before	2.97	3.35	0.14	0.13	0.15
after	2.26	2.48	0.13	0.13	0.14
mean	2.62	2.92	0.14	0.13	0.14
C.D 5%	5.37	5.99	0.007	0.009	0.02
SEM	1.37	1.53	0.002	0.002	0.005

4.4 Comparative metabolite analysis in Bhaise

Comparative metabolite analysis across three experiments revealed that Camphene content in control was superior in experiment no. 1 (1.60 %) than the contents in experiment no. 2 (0.83 %) and experiment no. 3 (0.42 %), whereas in check the content was superior in experiment no. 2 (1.16 %) than the contents in experiment no. 1(0.96 %) and experiment no. 3 (0.69 %) . In the treatment T39, a combination of FYM+VAM+Cap 3(BRB *Micrococcus* sps)+*Trichoderma harzianum* of experiment no. 1 was superior than T40 a combination of Vermicompost+ VAM+Cap 1 (GRB35 *Bacillus amyloliquefaceins*)+*Trichoderma harzianum* (0.93 %) of experiment no. 2 and T40 (0.77 %) of experiment no. 3 (Table 4.4).

Beta- Phellandrene content in control was superior in experiment no. 1 (1.05 %) than the contents in experiment no. 3 (0.83 %) and experiment no. 2 (0.38 %). In check the content was superior in experiment no. 1(1.69 %) than the contents in experiment no. 3 (1.10 %) and experiment no. 2 (0.56 %). In the treatments T39 of experiment no. 1 (1.04 %) was superior than T40 (0.71 %) of experiment no. 3 and T40 (0.45 %) of experiment no. 2 (Table 4.4).

Endo- Borneol content in control was superior in experiment no. 3 (0.97 %) than the contents in experiment no. 1(0.66 %) and experiment no. 2 (0.63 %). In check the content was superior in experiment no. 3 (1.25 %) than the contents in experiment no. 2 (0.83 %) and experiment no. 1(0.63 %). In the treatments T39 and T40 of experiment no. 2 and experiment no. 1had 0.75 % of endo-borneol content and it was followed by T40 (0.67 %) of experiment no. 3 (Table 4.4).

Geraniol content in control was superior in experiment no. 1 (1.19 %) than the contents in experiment no. 2 (0.94 %) and experiment no. 3 (0.80 %). In check the content in experiment no. 1(1.40 %) was at par with 1.29 % of experiment no. 2 and experiment no. 3 (1.11 %). In the treatments T39 of experiment no. 1 (2.32 %) was superior than T40 (1.01 %) of experiment no. 2 and T40 (0.80 %) of experiment no. 3 (Table 4.4).

Geraly Acetate content in control of experiment no. 2 condition (1.59 %) was at par with experiment no. 1 (1.30 %) and experiment no. 3 (1.17 %); in check the content in experiment no. 3 (1.57 %) and experiment no. 1(1.56 %) was at par with 1.41 % of experiment no. 2. In the treatments T40 of experiment no. 2 (1.50 %) was at par with T39 (1.40 %) of experiment no. 1 and T40 (1.23 %) of experiment no. 3 (Table 4.4).

AR-Curcumene of content in control of experiment no. 1 (12.66 %) was at par with experiment no. 3 (12.42 %) and experiment no. 2 (12.40 %); in check the content in experiment no. 1(15.51 %) was superior than experiment no. 2 (13.71 %) and experiment no. 3 13.33 %. In the treatments T39 of experiment no. 1(17.51 %) was superior than experiment no. 2 (14.72 %) and experiment no. 3 (13.92 %) (Table 4.4).

Zingiberene content in control of experiment no. 1 (28.68 %) was at par with experiment no. 2 (28.49 %) and experiment no. 3 (28.26 %); in check the content in experiment no. 1(33.16 %) was superior than experiment no. 3 (30.19 %) and experiment no. 2 29.74 %. In the treatments T39 of experiment no. 1(35.59 %) was superior than experiment no. 2 (33.22 %) and experiment no. 3 (31.29 %) (Table 4.4).

Alpha Farnesene content in control of experiment no. 3 condition (5.15 %) was superior than experiment no. 2 (4.73 %) and experiment no. 1(4.49 %); in check the content in experiment no. 1(7.38 %) was superior than experiment no. 3 (5.61 %) and experiment no. 2 (5.30 %). In the treatments T39 of experiment no. 1(5.31 %) was at par with experiment no. 2 (5.22 %) and experiment no. 3 (5.18 %) (Table 4.4).

Beta-Bisabolene content in control of experiment no. 1 (8.58 %) was superior than experiment no. 3 (7.85 %) and experiment no. 2 (7.84 %); in check the content in experiment no. 3 (9.21 %) was superior than experiment no. 2 (8.38 %) and experiment no. 1(7.53 %). In the treatments T39 of experiment no. 1(9.26 %) was at par with experiment no. 2 (9.17 %) and experiment no. 3 (9.03 %) (Table 4.4).

4,5- Dimethyl-1-1-Methylene Tricycle 7 content in control of experiment no. 2 condition (2.80 %) was at par with experiment no. 1(2.67 %) and experiment no. 3 (2.15 %) ; in check the content in experiment no. 3 (3.93 %) was superior than experiment no. 1(3.37 %) and experiment no. 2 (2.52 %). In the treatments T40 of experiment no. 2 (3.00 %) was superior than experiment no. 3 (2.88 %) and experiment no. 1 (2.50 %) (Table 4.4).

Gamma-Cadinene content in control of experiment no. 2 condition (4.11 %) was at par with experiment no. 3 (3.88 %) and experiment no. 1(3.64 %); in check the content experiment no. 1in (4.50 %) was superior than experiment no. 3 (3.41 %) and experiment no. 2 (2.84 %). In the treatments T40 of experiment no. 2 (4.17 %) was superior than experiment no. 3 (3.87 %) and experiment no. 1 (3.59 %) (Table 4.4).

Delta- Cadinene content in control of experiment no. 3 (15.33 %) was superior than experiment no. 2 (12.67 %) and experiment no. 1(10.22 %); in check the content in experiment no. 3 (15.55 %) was superior than experiment no. 1(12.95 %) and experiment no. 2 (12.23 %). In the treatments T40 of experiment no. 2 (14.92 %) was at par with T39 experiment no. 1(14.33 %) and T40 experiment no. 3 (13.65 %) (Table 4.4).

Beta- Sesquiphellandrene content in control of experiment no. 3 condition (0.48 %) was superior than experiment no. 2 (0.44 %) and experiment no. 1(0.35 %); in check the content in experiment no. 2 (0.79 %) was at par with experiment no. 3 (0.73 %) and experiment no. 1(0.56 %). In the treatments T39 of experiment no. 1(0.78 %) was at par with experiment no. 3 T40 (0.75 %) and experiment no. 2 (0.58 %) (Table 4.4).

Nerolidol content in control of experiment no. 3 (2.50 %) was superior than experiment no. 1(2.16 %) and experiment no. 2 (2.04 %); in check the content in experiment no. 1(2.68 %) was at par with experiment no. 3 (2.66 %) and experiment no. 2 (1.90 %). In the treatments T40 of experiment no. 2 (2.61 %) was superior than experiment no. 3 T40 (2.09 %) and experiment no. 1 (2.06 %) (Table 4.4).

7-Alpha-(1-Hydroxy-1-Methylethyl) content in control of experiment no. 1 (1.61 %) was at par with experiment no. 2 (1.46 %) and experiment no. 3 (1.28 %); in check the content in experiment no. 1(2.23 %) was superior than experiment no. 2 (1.46 %) and experiment no. 3 (1.43 %). In the treatments T40 of experiment no. 3 (2.19 %) was superior than experiment no. 1(1.94 %) and experiment no. 2 T40 (1.40 %) (Table 4.4).

Germacrene B content in control of experiment no. 2 (1.51 %) was at par with experiment no. 2 (1.33 %) and experiment no. 3 (1.32 %); in check the content in experiment no. 3 (1.72 %) was superior than experiment no. 2 (1.48 %) and experiment no. 1(1.39 %). In the treatments T40 of experiment no. 3 (2.00 %) was superior than experiment no. 1(1.25 %) and experiment no. 2 T40 (1.11 %) (Table 4.4).

Alpha-Eudesmol content in control of experiment no. 1 (3.28 %) was at par with experiment no. 3 (2.91 %) and experiment no. 2 (2.40 %); in check the content in experiment no. 1(4.67 %) was superior than experiment no. 3 (3.65 %) and experiment no. 2 (3.44 %). In the treatments T40 of experiment no. 3 (3.89 %) was superior than T40 of experiment no. 2 (3.32 %) and experiment no. 1(3.18 %) (Table 4.4).

Table 4.4 Comparative metabolite profile across the experiments in the variety Bhaise

Sl No	Parameters	Control (Expt. 1)	Control (Expt.2)	Control (Expt. 3)	G.M.	C.D. (5%)	Sem	Check (Expt.1)	Check (Expt.2)	Check (Expt.3)	G.M.	C.D. (5%)	Sem	T39 (Expt.1)	T40 (Expt.2)	T40 (Expt.3)	G.M.	C.D. (5%)	Sem
1	Camphene	1.60	0.83	0.42	**0.95**	**0.008**	**0.025**	0.96	1.16	0.69	**0.98**	**0.05**	**0.01**	2.29	0.93	0.77	**1.28**	**0.02**	**0.007**
2	Beta- Phellandrene	1.05	0.38	0.83	**0.69**	**0.029**	**0.008**	1.69	0.56	1.10	**1.11**	**0.04**	**0.01**	1.04	0.45	0.71	**0.79**	**0.03**	**0.010**
3	Endo- Borneol	0.66	0.63	0.97	**0.66**	**0.035**	**0.010**	0.63	0.83	1.25	**0.90**	**0.03**	**0.01**	0.75	0.75	0.67	**0.81**	**0.05**	**0.015**
4	Geraniol	1.19	0.94	0.80	**0.97**	**0.049**	**0.014**	1.40	1.29	1.11	**1.26**	**0.69**	**0.20**	2.32	1.01	0.80	**1.37**	**0.07**	**0.022**
5	Geraly Acetate	1.30	1.59	1.17	**1.25**	**0.590**	**0.170**	1.56	1.41	1.57	**1.63**	**0.88**	**0.25**	1.40	1.50	1.23	**1.36**	**0.52**	**0.150**
6	AR-Curcumene	12.66	12.40	12.42	**12.49**	**0.700**	**0.200**	15.51	13.71	13.33	**14.71**	**0.66**	**0.19**	17.51	14.72	13.92	**14.85**	**0.52**	**0.150**
7	Zingiberene	28.68	28.49	28.26	**28.47**	**1.060**	**0.300**	33.16	29.74	30.19	**32.55**	**1.40**	**0.40**	35.59	33.22	31.29	**31.84**	**1.56**	**0.450**
8	Alpha Farnesene	4.49	4.73	5.15	**4.68**	**0.260**	**0.770**	7.38	5.30	5.61	**6.17**	**0.22**	**0.65**	5.31	5.22	5.18	**5.27**	**0.15**	**0.460**
9	Beta-Bisabolene	8.58	7.84	7.85	**8.09**	**0.520**	**0.150**	7.53	8.38	9.21	**8.44**	**0.19**	**0.57**	9.26	9.17	9.03	**9.08**	**0.52**	**0.150**
10	4,5- Dimethyl-1-1-Methylene Tricycle 7	2.67	2.80	2.15	**2.37**	**0.800**	**0.230**	5.13	3.37	2.52	**3.93**	**0.16**	**0.47**	2.50	3.00	2.88	**2.69**	**0.10**	**0.290**
11	Gamma-Cadinene	3.64	4.11	3.88	**3.30**	**0.240**	**0.720**	4.50	2.84	3.41	**4.22**	**0.20**	**0.58**	3.59	4.17	3.87	**3.82**	**0.20**	**0.600**
12	Delta- Cadinene	10.22	12.67	15.33	**12.38**	**0.720**	**0.200**	12.95	12.23	15.55	**14.43**	**1.09**	**0.31**	13.22	14.33	14.92	**13.65**	**0.74**	**0.210**
13	Beta-Sesquiphellandrene	0.35	0.44	0.48	**0.40**	**0.017**	**0.005**	0.63	0.56	0.79	**0.73**	**0.03**	**0.01**	0.78	0.58	0.75	**0.64**	**0.03**	**0.011**
14	Nerolidol	2.16	2.04	2.50	**2.03**	**0.110**	**0.330**	2.70	2.68	1.90	**2.66**	**0.13**	**0.40**	2.06	2.61	2.09	**2.21**	**0.83**	**0.240**
15	7-Alpha-(1-Hydroxy-1-Methylethyl)	1.61	1.46	1.28	**1.42**	**0.560**	**0.160**	2.23	1.46	1.43	**1.91**	**0.85**	**0.24**	1.94	1.40	2.19	**1.67**	**0.10**	**0.290**
16	Germacrene B	1.32	1.33	1.51	**1.36**	**0.590**	**0.170**	1.39	1.48	1.72	**1.69**	**0.97**	**0.28**	1.25	1.11	2.00	**1.30**	**0.90**	**0.260**
17	Alpha-Eudesmol	3.28	2.40	2.91	**2.84**	**0.120**	**0.350**	4.67	3.44	3.65	**4.06**	**0.20**	**0.58**	3.18	3.32	3.89	**3.33**	**0.21**	**0.610**

4.5 Comparative metabolite of Majouley

Camphene content in control was superior in experiment no. 1 (1.16 %) than the contents in experiment no. 2 (0.54 %) and experiment no. 3 (0.33 %), whereas in check the content was superior in experiment no. 1 (1.60 %) than the contents in experiment no. 2 (0.89 %) and experiment no. 3 (0.81 %). In the treatments T41, a combination of Vermicompost+VAM+Cap 2 (FL-18 *Microbacterium paraoxydans*)+ *Trichoderma harzianum* of experiment no. 1 (1.24 %) was superior than T41 of experiment no. 2 (0.89 %) and T37, a combination of FYM+VAM+Cap 1(GRB 35 *Bacillus amyloquefaciens*) +*Trichoderma harzianum* (0.50 %) of experiment no. 3 (Table 4.5).

Beta- Phellandrene content in control was superior in experiment no. 1 (1.02 %) than the contents in experiment no. 2 (0.87 %) and experiment no. 3 (0.48 %); in check the content was superior in experiment no. 1 (1.90 %) than the contents in experiment no. 3 (1.05 %) and experiment no. 2 (0.79 %). In the treatments T41 of experiment no. 1 (0.98 %) was superior than T41 (0.85 %) of experiment no. 2 and T37 (0.77 %) of experiment no. 3 (Table 4.5).

Endo- Borneol content in control was superior in experiment no. 2 (0.83 %) than the contents in experiment no. 3 (0.77 %) and experiment no. 1 (0.57 %); in check the content was superior in experiment no. 3 (0.90 %) than the contents in experiment no. 1 (0.53 %) and experiment no. 2 (0.46 %). In the treatments T41 of experiment no. 2 1.52 % of endo-borneol content was superior and it was followed by T37 (0.94 %) of experiment no. 3 and T41 (0.60 %) of experiment no. 1 (Table 4.5).

Geraniol content in content in control was superior in experiment no. 2 (1.51%) than the contents in experiment no. 3 (1.02 %) and experiment no. 1 (0.82 %); in check the content in experiment no. 1 (2.32 %) was superior than 1.78 % of experiment no. 2 and experiment no. 3 (1.07 %) . In the treatments T41 of experiment no. 2 (1.27 %) was superior than T37 (0.88 %) experiment no. 3 and T41 (0.85 %) of experiment no. 1 (Table 4.5).

Geraly Acetate content in control of experiment no. 2 (1.55 %) was at par with experiment no. 3 (1.27 %) and experiment no. 1 (1.15 %); in check the content in experiment no. 2 (1.41 %) was at par with experiment no. 3 (1.38 %) and experiment no. 1 1.22 % of . In the treatments T41 of experiment no. 1 (1.59 %) was at par with T41 (1.50 %) of experiment no. 2 and T37 (1.38 %) of experiment no. 3 (Table 4.5).

AR-Curcumene content in control of experiment no. 2 (14.79 %) was superior than experiment no. 3 (12.73 %) and experiment no. 1 (12.42 %); in check the content in experiment no. 1 (16.98 %) was superior than experiment no. 2 (14.85 %) and experiment no. 3 (14.29 %). In the treatments T41 (16.57 %) of experiment no. 2 was superior than experiment no. 3 (15.80 %) and experiment no. 1 (15.22 %) (Table 4.5).

Zingiberene content in control of experiment no. 2 (28.94 %) was superior than experiment no. 3 (26.77 %) and experiment no. 1 (26.36 %); in check the content in experiment no. 1 (32.22 %) was superior than experiment no. 2 (30.39 %) and experiment no. 3 (29.06 %). In the treatments T41 of experiment no. 2 (37.66 %) was superior than T41 of experiment no. 1 (34.14 %) and experiment no. 3 T37 (31.63 %) (Table 4.5).

Alpha Farnesene content in control of experiment no. 3 (6.03 %) was superior than experiment no. 2 (4.91 %) and experiment no. 1 (4.18 %); in check the content in experiment no. 2 (5.93 %) was superior than experiment no. 1 (4.78 %) and experiment no. 3 (4.55 %). In the treatments T41 of experiment no. 1 (6.89 %) was superior than T37 experiment no. 3 with (6.09 %) and experiment no. 2 of T41 (5.27 %) (Table 4.5).

Beta-Bisabolene content in control of experiment no. 2 (8.86 %) was at par with experiment no. 3 (8.70 %) and experiment no. 1 (6.11 %); in check the content in experiment no. 3 (10.05 %) was superior than experiment no. 2 (7.94 %) and experiment no. 1 (7.46 %). In the treatments T37 of experiment no. 3 (9.46 %) was at par with experiment no. 1 (9.16%) and experiment no. 2 (7.75 %) (Table 4.5).

4,5- Dimethyl-1-1-Methylene Tricycle 7 content in control of experiment no. 3 (3.35 %) was superior than experiment no. 2 (2.88 %) and experiment no. 1 (2.77 %); in check the content in experiment no. 2 (3.48 %) was superior than experiment no. 1 (2.81 %) and experiment no. 3 (1.32 %). In the treatments T41 of experiment no. 1 (3.57 %) was superior than experiment no. 2 (2.96 %) and experiment no. 3 (2.67 %) (Table 4.5).

Gamma-Cadinene content in control of experiment no. 2 (3.37 %) was superior than experiment no. 1 (3.17 %) and experiment no. 3 (2.93 %); in check the content experiment no. 1 in (3.62 %) was at par with experiment no. 2 (3.55 %) and experiment no. 3 (3.38 %). In the treatments T37 of experiment no. 3 (4.02 %) was superior than experiment no. 2 (3.31 %) and experiment no. 1 (3.32 %) (Table 4.5).

Delta- Cadinene content in control of experiment no. 3 (14.73 %) was superior than experiment no. 2 (12.66 %) and experiment no. 1 (12.10 %); in check the content in experiment no. 1 (16.04 %) was superior than experiment no. 3 (13.93 %) and experiment no. 2 (13.07 %). In the treatments T41 of experiment no. 2 (15.27 %) was at par with T37 experiment no. 3 (15.21 %) and T41 experiment no. 1 (14.55 %) (Table 4.5).

Beta- Sesquiphellandrene content in control of experiment no. 3 (0.54 %) was superior than experiment no. 2 (0.52 %) and experiment no. 1 (0.28 %); in check the content in experiment no. 3 (0.98 %) was superior than experiment no. 2 (0.46 %) and experiment no. 1 (0.37 %). In the treatments T41 of experiment no. 2 (0.62 %) was superior than experiment no. 1 T41 (0.38 %) and experiment no. 3 (0.33 %) (Table 4.5).

Nerolidol content in control of experiment no. 3 (2.54 %) was superior than experiment no. 2 (2.00 %) and experiment no. 1 (1.69 %); in check the content in experiment no. 1 (2.81 %) was superior than experiment no. 3 (2.34 %) and experiment no. 2 (1.64 %). In the treatments experiment no. 3 T37 (2.52 %) was superior than (1.77 %) and experiment no. 1 (1.77 %) and experiment no. 2 (1.57 %) (Table 4.5).

7-Alpha-(1-Hydroxy-1-Methylethyl) content in control of experiment no. 2 (2.04 %) was superior than experiment no. 1 (1.24 %) and experiment no. 3 (1.18 %); in check the content in experiment no. 1 (1.89 %) was at par with experiment no. 2 (1.84 %) and experiment no. 3 (1.26 %). In the treatments experiment no. 2 T41 of (1.94 %) was at par with experiment no. 3 T37 (1. 85 %) and experiment no. 1 T41 (1.40 %) (Table 4.5).

Germacrene B content in control of experiment no. 2 (1.37 %) was superior than experiment no. 1 (1.27 %) and experiment no. 3 (0.90 %); in check the content in experiment no. 3 (1.63 %) was superior than experiment no. 1 (1.30 %) and experiment no. 2 (1.09 %). In the treatments T41 of experiment no. 2 (1.40 %) was at par with T41 of experiment no. 1 (1.35 %) and experiment no. 3 T37 (1.14 %) (Table 4.5).

Alpha-Eudesmol content in control of experiment no. 1 (3.32 %) was superior than experiment no. 2 (2.98 %) and experiment no. 3 (2.85 %); in check the content in experiment no. 3 (4.19 %) was superior than experiment no. 1 (3.22 %) and experiment no. 2 (2.91 %). In the treatments T41 of experiment no. 1 (4.00 %) was superior than T40 of experiment no. 2 (3.00 %) and experiment no. 1 (3.19 %) (Table 4.5).

Table 4.5 Comparative metabolite profile across the experiments in the variety Majouley

Sl No.	Parameters	Control (expt.1)	Control (expt.2)	Control (expt.3)	G.M.	C.D. (5%)	Sem	Check (expt.1)	Check (expt.2)	Check (expt.3)	G.M.	C.D. (5%)	Sem	T41 (expt.1)	T41 (expt.2)	T37 (expt.3)	G.M.	C.D. (5%)	Sem
1	Camphene	1.16	0.54	0.33	**0.67**	**0.03**	**0.010**	1.60	0.89	0.81	**1.10**	**0.04**	**0.01**	1.24	0.89	0.50	**0.87**	**0.043**	**0.012**
2	Beta- Phellandrene	1.02	0.87	0.48	**0.79**	**0.02**	**0.007**	1.90	0.79	1.05	**1.240**	**0.054**	**0.015**	0.98	0.85	0.77	**0.86**	**0.035**	**0.01**
3	Endo- Borneol	0.57	0.83	0.77	**0.72**	**0.05**	**0.017**	0.53	0.46	0.90	**0.63**	**0.027**	**0.007**	0.60	1.52	0.94	**1.02**	**0.006**	**0.001**
4	Geraniol	0.82	1.51	1.02	**1.11**	**0.02**	**0.006**	2.32	1.78	1.07	**1.72**	**0.11**	**0.32**	0.85	1.27	0.88	**1.00**	**0.083**	**0.024**
5	Geraly Acetate	1.15	1.55	1.27	**1.32**	**0.65**	**0.180**	1.22	1.41	1.38	**1.33**	**0.84**	**0.24**	1.59	1.5	1.38	**1.49**	**0.62**	**0.17**
6	AR-Curcumene	12.42	14.79	12.73	**13.31**	**0.63**	**0.180**	16.98	14.85	14.29	**15.37**	**0.96**	**0.27**	15.22	16.57	15.8	**15.86**	**0.87**	**0.25**
7	Zingiberene	26.36	28.94	26.77	**27.35**	**1.61**	**0.460**	32.22	30.39	29.06	**30.55**	**1.37**	**0.39**	34.14	37.66	31.63	**34.47**	**1.61**	**0.46**
8	Alpha Farnesene	4.18	4.91	6.03	**5.04**	**0.18**	**0.530**	4.78	5.93	4.55	**5.08**	**0.36**	**0.10**	6.89	5.27	6.09	**6.08**	**0.27**	**0.78**
9	Beta-Bisabolene	6.11	8.86	8.70	**7.89**	**0.73**	**0.21**	7.46	7.94	10.05	**8.48**	**0.32**	**0.93**	9.16	7.75	9.46	**8.79**	**0.43**	**0.12**
10	4,5- Dimethyl-1-1-Methylene Tricycle 7	2.77	2.88	3.35	**3.00**	**0.10**	**0.310**	2.81	3.48	1.32	**2.53**	**0.20**	**0.59**	3.57	2.96	2.67	**3.06**	**0.12**	**0.37**
11	Gamma-Cadinene	3.17	3.37	2.93	**3.15**	**0.11**	**0.330**	3.62	3.55	3.38	**3.51**	**0.89**	**0.26**	3.32	3.31	4.02	**3.55**	**0.21**	**0.63**
12	Delta- Cadinene	12.1	12.66	14.73	**13.16**	**0.68**	**0.190**	16.04	13.07	13.93	**14.34**	**0.89**	**0.25**	14.55	15.27	15.21	**15.01**	**0.93**	**0.27**
13	Beta-Sesquiphellandrene	0.28	0.52	0.54	**0.44**	**0.01**	**0.005**	0.37	0.46	0.98	**0.60**	**0.04**	**0.01**	0.38	0.62	0.33	**0.44**	**0.01**	**0.003**
14	Nerolidol	1.69	2.00	2.54	**2.07**	**0.40**	**0.110**	2.81	1.64	2.34	**2.26**	**0.15**	**0.44**	1.77	1.57	2.52	**1.95**	**0.05**	**0.01**
15	7-Alpha-(1-Hydroxy-1-Methylethyl)	1.24	2.04	1.18	**1.48**	**0.66**	**0.190**	1.89	1.84	1.26	**1.66**	**0.89**	**0.25**	1.40	1.94	1.85	**1.73**	**0.66**	**0.19**
16	Germacrene B	1.27	1.37	0.90	**1.18**	**0.03**	**0.009**	1.30	1.09	1.63	**1.34**	**0.44**	**0.12**	1.35	1.40	1.14	**1.29**	**0.55**	**0.15**
17	Alpha-Eudesmol	3.32	2.98	2.85	**3.05**	**0.18**	**0.540**	3.22	2.91	4.19	**3.44**	**0.18**	**0.54**	4.00	3.00	3.19	**3.39**	**0.21**	**0.61**

CHAPTER - 5

DISCUSSION

DISCUSSION

The present study titled “Standardization of single window organic technology for safe production of ginger” was carried out for two cropping years during 2017 and 2018 in a farmer’s field at Khamdong, East Sikkim. The study was conducted under three different experiments.

i) Experiment no. 1. Input effect on growth, yield and quality parameters and multi elemental status.

ii) Experiment no. 2. Input effect on pest tolerance.

iii) Experiment no. 3. Input effect on disease tolerance.

Based on the results obtained the discussion is made as here under:

5.1 Effect of organic inputs on growth, yield and quality and multi elemental status

Results on different growth and yield parameters revealed that T39 (FYM+VAM+Cap3 BRB *Micrococcus* sps +*Trichoderma harzianum*) and T41 (Vermi+VAM+Cap2 FL-18 *Microbacterium paraoxydans* +*Trichoderma harzianum*) were found to be superior to all other treatments. Specifically T39 was better for the variety Bhaise and T41 was good for the variety Majouley.

These two treatments were also found to be superior as far as quality parameter like volatile oil percentage. Hence, these two treatments, especially T39 for Bhaise and T41 for Majouley along with control and check were subjected to metabolic profiling using GCMS. The analysis revealed that compounds like camphene, endo-borneol, geraniol, ar-curcumene, zingiberene, beta-bisabolene, delta-cadinene and beta-sesqiphellandrene were higher in T39 of Bhaise and geraly acetate, zingiberene, alpha-farnesene, beta-bisabolene and 4,5-dimethyl-1-1-methylene tricycle were higher in T41 of Majouley. Thus, indicating these two treatments to the respective varieties were not only promoting the growth and yield but also induced more production of these flavoring compounds.

Multi elemental analysis of ginger revealed that T39 was significantly superior in Ca content and T41 was significantly superior in S, P and K. The micronutrients like Fe, Na, Cu, Mn and Zn content in variety Bhaise was superior and Na content in Majouley was superior.

In general organic manures in the form of FYM, vermicompost etc., were found to increase growth and yield characteristics in ginger (Egbuchua and Enujeke, 2013). In fact these manures increase soil organic carbon and it accelerates respiratory process of the plant which increases the cell permeability and hormonal growth action (Ismail *et al*., 1998) which ends in increase in growth and yield. By combining 50 % pig manure and 50 % poultry manure growth and yield parameters were significantly influenced in ginger and 50 % FYM and 50 % rural compost increased the quality parameters of ginger (Lepcha *et al*., 2019). Maximum plant height, number of tillers and number of leaves were recorded in when ginger was applied with 30 t ha^{-1} of farm yard manure whereas maximum plant height, number of tillers, maximum leaf number and yield were observed in the integrated nutrition of NPK+ azotobacter +PSB+ K mobilizing bacteria (Chandrashekhar and Hore, 2019). Effect of integrated organic and inorganic fertilizers on yield and quality of ginger were assessed by Rana and Korla (2010) and in their experiment highest rhizome yield was recorded with azospirillum alone. Similar finding was made by Shadap *et al*., (2018) where the best treatment was vermicompost+NPK 75 % + azospirllum +VAM +PSB. All this above mentioned works supports the contribution of organic manure and biofertilizer in increasing the growth and yield as well as their mode of creation of conducive environment for better growth and yield. Kumari and Ushakumari, (2002) revealed that vermicompost enriched with rock phosphate enhances the uptake of major nutrients like N, P, K, Ca and Mg in cowpea. In a similar study by Sharma *et al*., (2017) showed the combination of vermicompost along with the nutrients and individual application in Indian mustard significantly increased the uptake of N, S, Zn and Fe.

Vermicompost was found rich in nutrients like K, NO_3^- , Na, Ca, Mg and Cl^- and had the potential to improve the plant growth (Kandan and Subbulakshmi, 2015). In a study conducted by Gupta *et al.,* (2002) where VAM had significantly increased the uptake of N, P and K by shoot tissue and it markedly increased the uptake of P in mint. *Trichoderma harzianum* when inoculated in the roots of cucumber plant it had significantly increased the concentration of Cu, P, Fe, Zn, Mn and Na (Yedidia *et al.,* 2001).

Quality attributes in ginger were significantly increased by all the organic fertilizer treatments. Maximum dry matter (17.7%), oil (2.0%) and oleoresin (6.98%) was recorded under the application of azospirillum + phosphorus +wood ash (Rana and Korla, 2010). Similarly Datta *et al.,* (2018) had reported maximum dry recovery (22.43%) and oleoresin content (4.37%) in ginger was recorded in the treatment of sole application of FYM @ 15 t/ha. However, there is no earlier study on metabolic profiling in response to organic inputs.

5.2 Input effect on pest tolerance

The results revealed that the treatment T40 (Vermicompost+VAM+Cap 1 GRB 35 *Bacillus amyloliquefaceins*+*Trichoderma harzianum*) and T41 (Vermicompost+VAM+Cap 2 FL-18 *Microbacterium paraoxydans*+*Trichoderma harzianum*) were significantly superior in tolerance towards the pest infestation and more over it was superior in terms of growth, yield and quality parameters.

The essential oil extracted from the best treatment along with the control and check subjected to GCMS for its metabolite content revealed that T40 was statistically superior in ar-curcumene, zingiberene, beta-bisabolene and delta-cadinene. T41 contained endo-borneol, ar-curcumene, zingiberene and delta-cadinene. Multi elemental analysis revealed that Ca, S and Na content was significantly superior in T40 and in T41 the elements like K, Fe and Zn content was significantly superior.

Vermicompost as it has the ability to enhance the growth, yield and quality of the plant it also plays an important role in resisting the pest attack (Sarma *et al.*, 2010). The interaction between the plant and the AM fungi activates the plant defense mechanism and are subsequently suppressed (García-Garrido and Ocampo, 2002). The priming of the plant defenses in the inoculated plant may have the defensive characteristics towards the pest attack (Dar and Reshi, 2017). PGPR also colonizes the root and it has the ability to enhance the plant growth and yield (Kloepper, 1992). FL 18 resulted in higher growth and yield in fenugreek (Shivran *et al*., 2013). In an experiment conducted by Dinesh *et al*., 2015 several strains of PGPR were tested and found that GRB 35 has the ability to enhance the growth of ginger. Like PGPR and VAM, *Trichoderma* also associates with the root system of the plant and trigger localized or systemic resistance responses in the plant by releasing elicitor-like substances (Harman *et al*., 2004).

The plant compounds are triggered due to the associations of the different organic inputs, the plant secondary metabolite which is present in higher quantity of ginger is mainly of sesquiterpene which plays an important role in plant defenses (Chen *et al*., 2011).

5.3 Input effect on disease tolerance

The results revealed that the treatments 40 (Vermicompost+VAM+Cap1 GRB 35 *Bacillus amyloliquefaceins* + *Trichoderma harzianum*) and 37 (FYM+VAM+Cap1 *Bacillus amyloliquefaceins* + *Trichoderma harzianum*) were the most superior treatments than all the other treatment combinations. These treatments had the highest tolerance towards the disease infestations as well as significantly superior effect on other parameters like height, rhizome weight, number of leaves, leaf area, yield and quality parameters.

The essential oil analysis of the best treatments revealed that T40 was significantly superior in camphene, ar-curcumene, 4,5-dimethyl-1-1-methylene tricycle 7, 7-alpha-(1-hydroxy-1-methylethyl), germacrene B and alph-eudesmol. The treatment 37 was significantly superior in ar-curcumene, zingiberene, gamma-cadinene, delta-cadinene and 7-alpha-(1-hydroxy-1-methylethyl).

Multi elemental status of ginger revealed that Ca, Mg and Zn were significantly superior in T40 and only Cu was significantly superior in T37.

In these treatments VAM and *Trichoderma harzianum* were common input along with the PGPR i.e., Cap. 1, GRB-35 (*Bacillus amyloliquefaceins*). Similar results were obtained by earlier workers in different crops. According to the study of Kumar *et al*., (2018) on the effect of bio-fertilizers, vermicompost and *Trichoderma* on yield and economics of strawberry cv. Sweet Charlie had revealed that the highest yield per plant was recorded in the combination of 5 kg ha^{-1} *Trichoderma* + 2.5 ton ha^{-1} vermicompost + 7 kg ha^{-1} *Azotobactor* + 6 kg ha^{-1} PSB + 10 kg ha^{-1} VAM. The maximum cost benefit ratio of 1:3.97 was also found in the same treatment.

In another study by Dohroo and Gupta (2014), on the effect of bio agents on the management of rhizome diseases, plant growth parameters and nematode population in ginger stated that combined applications of bio agents were more effective in reducing the disease incidence than the individual treatments. *Trichoderma harzianum*+ *Pseudomonas fluorescens* + *Bacillus subtilis* gave minimum disease incidence on rhizomes (8.64 %) as well as on tillers (12.50 %). Combined treatment also proved more effective in increasing the plant growth parameters, i.e. number of tillers, plant height, fresh rhizome weight along with more recovery of old rhizome. Similarly, a study was carried out to see the influence of VAM, vermicompost and *Trichoderma harzianum* on vegetative growth parameters of banana, cv. Rajapuri by Sabarad *et al*., (2004) and it was found that VAM inoculated banana plants showed increased plant height, plant girth, number of leaves and number of suckers as compared to uninoculated plants. Sarma *et al.,* (2010), revealed that the role of vermicompost in plant growth promotion is largely believed to be due to its nutrient rich composition and the ability to modify soil physical and chemical properties for the growth and development of the plant. It also modulates plant's innate resistance response to resist microbial attack. Vermicompost favors growth and multiplication of saprophytic soil microbes, including the biocontrol agents and thus helps in enhancing the performance of most biocontrol agents against a wide range of phytopathogens.

Apart from the effect of VC the Trichoderma has the ability to inhibit the pathogens and promote the beneficial microorganism like the applied PGPR and VAM. This creates a favorable environment for the growth and development of plants at the micro climate of rhizosphere modified by the trichoderma known as 'trichorhizosphere' (Umadevi *et al.,* 2017a and b). The trichorhizosphere environment along with the additional benefit of PGPR, VC and VAM were available in the best treatments of our study, which had promoted the yield and growth parameters of ginger while importantly reducing the soft rot incidence.

5.4 Comparative metabolite profile

The comparative metabolite profiling of Bhaise had shown significant difference in the following metabolites across the three experiments in control, they are Camphene, Beta Phellandrene, Alpha Farnesene, Beta Bisabolene, Gamma Cadinene, Delta Cadinene, Nerolidol, and Alpha Eudesmol within this Alpha Farnesene, Delta Cadinene and Nerolidol were high in disease infected control. Gamma Cadinene was high in insect infected control rest of the metabolites were high in the control of neither disease infected nor insect infected. This indicated these metabolites had a specific role in pest and disease susceptibility/ tolerance without the influence of any treatment. Whereas, when compared the treatment effect on the metabolites across the three experiments most of the metabolites were produced in higher concentration than the respective control indicating the best treatments i.e., T39 and T40 were contributing not only for the growth and yield but also in pest and disease resistance.

In Majouley when the metabolites were compared throughout the experiment it had shown significant difference of metabolite like Camphene, Beta Phellandrene, Endo-Borneol, Geraniol, Ar-Curcumene, Zingiberene, Alpha Farnesene, 4,5-Dimethyl-1-1-Methylene Tricycle 7, Gamma Cadinene, Delta Cadinene, Beta-Sesquiphellandrene, Nerolidol, 7-Alpha-(1-Hydroxy-1-Methylethyl), Germacrene B and Alpha Eudesmol in the control within this Endo-Borneol, Geraniol, Ar-Curcumene, Zingiberene, Gamma Cadinene, 7-Alpha-(1-Hydroxy-1-Methylethyl) and Germacrene B were high in insect infected control. Alpha Farnesene, 4,5-Dimethyl-1-1-Methylene Tricycle 7, Delta Cadinene Beta- Sesquiphellandrene and Nerolidol, was high in disease infected control. This indicated these metabolites had a specific role in pest and disease susceptibility/ tolerance. Whereas when compared the treatment affect on the metabolites across the three experiments most of the metabolites were produced in higher concentration than the respective control indicating the best treatments i.e., T41 and T37 were contributing not only for the growth and yield but also in pest and disease resistance.

5.5. Soil Analysis

Soil analysis in all three experiments revealed that most of the nutrients were lesser after plant growth even after application of organic inputs. However, plant analysis indicated that the best treatments could supply adequate nutrients to optimum growth and development of ginger. The organic inputs especially PGPR treatments and VAM treatments could have improved the uptake behavior in plants, which was visible in soil analysis results. In addition, higher uptake of nutrients might have contributed to the pest and disease tolerance.

5.6 Facts and Reports

Hence, the results of the present study may be viewed based on the following facts and reports

- Vermicompost increased Microbial Biomass Content (MBC), Microbial Organic Content (MOC), decreased Dissolved Organic Carbon (DOC), Dissolved Oxygen Nitrogen (DON) indicating increase in the microbial population in the soil. Further, vermicompost increased concentration of **nitrate nitrogen** inside the plant apart from increasing soluble protein, carbohydrate, T.S.S., Vitamin C etc. (Song *et al*., 2015).

- Yedidia *et al*., (2001), reported that ***Trichoderma harzianum*** increased the concentration of **Cu, P, Fe, Zn, Mn and Na** in roots and increased the concentration of **Zn, P and Mn** in shoots.

- Cornejo *et al*., (2016) reported *Trichoderma* parasitize other fungi and supreses other deleterious plant microorganism in soil.

- Umadevi *et al*., (2017a) reported a *Trichoderma* induced "trichorhizosphere"- conducive for beneficial microorganisms in soil.

- Gupta *et al.,* (2002) reported that **VAM** increased the volatile oil content in Mint (*Mentha arvensis*).

- Mishra *et al.,* (2012) reported that being a nitrogenous compound, availability of N directly influences the level of alkaloids. N in NO3 form enhanced the alkaloid content upto 50%. Further, it was reported that Zn and N play an important role in synthesis of alkaloids. Zn is indispensable for the synthesis of tryptophan, which is the precursor of indole alkaloids.

- Dinesh *et al.,* (2013) reported that application of PGPR in combination with inorganic NPK promoted soil biological quality as evidenced by enhanced soil microbial biomass and enzyme activities.

- Dambonena *et al.,* (2016) had reviewed the insecticidal properties of various terpenes obtained from essential oil of the plants and reported that the terpenes act as a inhibitor for the neurotransfer activities of the insects and thus they can act as a compounds for the insect tolerance.

- de Azevedo *et al.,* (2003) had shown in tomato that the resistance to the arthropod pest due to action of allelochemical zingiberene present in the glandular trichomes.

CHAPTER - 6

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The present study titled "Standardization of single window organic technology for safe production of ginger" was carried in a farmer's field at Khamdong, East Sikkim during 2017 and 2018. The objective of the study was to evaluate the best treatment for growth, yield, quality, micronutrients, and the tolerance towards pest and disease. The following results were obtained:

- The input effect on growth, yield and quality parameters and multi elemental status revealed that T39 (FYM+VAM+Cap3 BRB *Micrococcus* sps +*Trichoderma harzianum*) and T41 (Vermi+VAM+ Cap2 FL-18 *Microbacterium paraoxydans* +*Trichoderma harzianum*) were among the best treatments that all the parameters like growth, yield, quality, multi elemental status of ginger variety were influenced by these treatments. T39 was best for Bhaise and T41 for Majouley.
- Input effect on pest tolerance revealed that treatment T40 (Vermicompost +VAM+ Cap1 GRB35 *Bacillus amyloliquefaceins*+ *Trichoderma harzianum*) and T41 (Vermicompost+ VAM+ Cap 2 FL-18 *Microbacterium paraoxydans* + *Trichoderma harzianum*) were superior among all the treatments. The combination of different organic inputs along with the PGPR had an effect on the pest tolerance of the ginger.
- Input effect on disease tolerance revealed that T40 (Vermicompost+ VAM+Cap1 GRB 35 *Bacillus amyloliquefaceins* + *Trichoderma harzianum*) and T37 (FYM+VAM+Cap1 *Bacillus amyloliquefaceins* +

Trichoderma harzianum) had a significant effect on the disease tolerance.

- In first of its kind, the effect of organic inputs on the metabolite was studied and a positive effect was found with T39 and T41 with combination of VAM, *Trichoderma harzianum* and PGPR.

Hence, it can be concluded that the interaction between different organic inputs had the mutualistic effect on each other which in turn helped the plant for better growth and development. Mainly due to FYM increased the soil organic carbon, and accelerated the respiratory process of the plant, Vermicompost modified plant nutrient content and made soil condition favorable for microorganisms growth, PGPR enhanced nutrient mobilization and use efficiency, *Trichoderma* modified tricho rhizosphere and plant nutrient concentration especially Cu, P, Fe, Zn, Mn and Na. The favorable condition in the soil made the VAM accelerate the activities which improved the growth and development of the plant. It increased the essential nutrient uptake from the soil. Regulatory elements required for growth, yield, quality, disease and pest resistance is increased within the plant by the above combination. The different role from different organic inputs in plants enhanced the alkaloid and secondary metabolite content in the plant which in turn increased the growth, yield, quality, multi elemental concentration and tolerance towards the pest and disease.

The result of the present study can be the ready source of information for the organic cultivation and safe production of ginger.

CHAPTER - 7

BIBLIOGRAPHY

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Ahmad, R. Azeem, M. and Ahmad, N. 2009. Productivity of ginger (*Zingiber officinale*) by amendment of vermicompost and biogas slurry in saline soils. Pakistan Journal of Botany. 41(6): 3107-3116.

Al-Abed, Naser, Z. and Mustafa, D. 2011. Field Application of Brassicaceous Amendments for the Control of Root Knot Nematode (*Meloidogyne incognita*) on Cucumber. Jordan Journal of Agricultural Sciences. 7(1):76-82

Amooaghaie, R. and Golmohammadi, S. 2017. Effect of vermicompost on growth, essential oil, and health of *Thymus Vulgaris*. Compost Science & Utilization 25 (3): 2326-2397.

Anita, B. 2012. Crucifer vegetable leaf wastes as biofumigants for the management of root knot nematode (*Meloidogyne hapla* Chitwood) in celery (*Apium graveolens* L.). Journal of Biopesticides.5 (supplementary): 111-114.

Anonymous. 1992. Vermicomposting. Kisan Word. 19(5):43.

Arsalan, M., Ahmed, S., Chauhdary, J. N. and Sarwar, M. 2016. Effect of vermicompost and phosphorus on crop growth and nutrient uptake in mung bean. Journal of Applied Agriculture and Biotechnology. 1(2): 38−46.

Atiyeh, R.M., Edwards, C.A., Subler, S. and Metzger, J.D. 2000. Earthworm processed organic wastes as components of horticultural potting media for growing marigold and vegetable seedlings. Compost Science and Utilization. 8(3): 215-223.

Baset Mia, M.A., Shamsuddin, Z.H., Wahab, Z. and Marziah, M. 2010. Effect of plant growth promoting rhizobacterial (PGPR) inoculation on growth and nitrogen incorporation of tissue-cultured musa plantlets under nitrogen-free hydroponics condition. Australian Journal of Crop Science. 4(2):85–90.

Baskaran, L., Ganesh, K.S., Chidambaram, A.L.A. and Sundaramoorthy, P. 2009. Amelioration of sugar mill effluent polluted soil and its effect of greengram (*Vigna radiata* L.). Botany Research International. 2(2): 131-135.

Bevivino, A., Sarrocco, S., Dalmastri, C., Tabacchioni, S., Cantale, C. and Chiarini, L. 1998. Characterization of a free-living maize rhizosphere population of Burkholderia cepacia: effect of seed treatment on disease suppression and growth promotion of maize. FEMS Microbiology Ecology. 27(3): 225-237.

Bhavalker, U.S. 1991. Vermiculture biotechnology . Proceeding on LEISSA seminar on low external input sustainable agriculture. Amsterdam, Netherlands.1-6.

Bohra, M. and Kumar, A. 2014. Studies on effect of organic manures and bioinoculants on vegetative and floral attributes of chrysanthemum Cv. Little Darlling. The Bioscan. 9(3): 1007-1010.

Butler, E.J. 1907. An account of genus *Pythium* and some Chytridiaceae. Memoirs of the Department of Agriculture India, Botanical Series. 1(5):70.

Chandrashekhar , G. and Hore, J.K. 2019. Effect of growth and yield of the ginger with the combination of organic, inorganic and biofertilizers. Journal of Pharmacognosy and Phytochemistry. 8(3): 1174-1176.

Chen, F., Tholl, D,, Bohlmann, J. and Pichersky, E. 2011. The family of terpene synthase in plants: a mid size family of genes for specialized metabolism that is highly diversified throughout the kingdom. Plant Journal. 66 (1):212–229.

Cornejo, H.A.C., Rodriguez, L.M., Val, E. and Larsen, J. 2016. Ecological functions of *Trichoderma* spp. and their secondary metabolites in the rhizosphere: interactions with plants. FEMS Microbiology Ecology. 92(4):1-17.

Dar, M.H. and Reshi, Z.A. 2017. Vesicular Arbuscular Mycorrhizal (VAM) Fungi-as a major biocontrol agent in modern sustainable agriculture system. Russian Agricultural Sciences. 43(2): 138-143.

Dambolena, J. S., Zunino, M. P., Herrera, J. M., Pizzolitto, R. P., Areco, V. A., and Zygadlo, J. A. 2016. Terpenes: natural products for controlling insects of importance to human health—a structure-activity relationship study. Psyche. 1-17.

Datta , S., Jana, J.C., Bhaisare, P. T., Thapa, A. and Islam, S. 2018. Effect of organic source of nutrients and biofertilizers on growth, yield and quality of ginger (*Zingiber officinale* Rosc.). Journal of Pharmacognosy and Phytochemistry. 7(6): 2311-2314.

de Azevedo, S.M., Faria, M. V., Maluf, W.R., de Oliveria, A.C.B. and de Freitas, J.A. 2003. Zingiberene-mediated resistance to the South American tomato pinworm derived from *Lycopersicon hirsutum* var. *hirsutum* . Euphytica. 134 : 347–351.

Demain, A.L. and Fang, A .2000. The natural functions of secondary metabolites. In: Fiechter, A. (Eds.), History of Modern Biotechnology I, Advances in Biochemical Engineering Biotechnology, Springer, Berlin. p. 1-39.

Deng, D.F., Wang, H.Y., Zhang, Q., Yan, Y.C., Zhao, C.Q. and Liu, Z.Y.2014. Evaluation of *Bacillus amyloliquefaciens* PEBA20 as a biocontrol agent for *Rhizoctonia cerealis* and *Bipolaris maydis.* Biocontrol Science and Technology. 24 (10): 1209–1215.

Dinesh, R., Anandaraj, M., Kumar, A., Srinivasan, V., Bini, Y.K., Subila, K.P., Aravind, R. and Hamza, S. 2013. Effects of plant growth-promoting rhizobacteria and NPK fertilizers on biochemical and microbial properties of soils under ginger (*Zingiber officinale*) cultivation. Agricultural Research. 2(4):346-353.

Dinesh, R., Anandaraj, M., Kumar, A., Bini, Y.K., Subila, K.P. and Aravind, R. 2015. Isolation, characterization, and evaluation of multi-trait plant growth promoting rhizobacteria for their growth promoting and diseasesuppressing effects on ginger. Microbiological Research. 173: 34–43.

Dohroo , N.P. and Gupta, M. 2014. Effect of bioagents on management of rhizome diseases, plant growth parameters and nematode population in ginger Agricultural Science Digest. 34(1): 41 – 44.

Duruigbo, C.I., Okereke-Ejiogu, E.N., Nwokeji, E.M., Peter-Onoh, C.A., Ogwudire, V.E.and Onoh, P.A. 2013. Integrated remediation strategies for sustaining agrobiodiverity degradation in Africa. IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS). 3(4): 16-23.

Ekundayo, O., Laakso, I. and Hiltunen, R. 1988. Composition of ginger (*Zingiber officinale* Roscoe) volatile oils from Nigeria. Flavour and Fragrance Journal. 3(2): 85–90.

Elbadry, M., Taha, R.M., Eldougdoug, K.A. and Gamal-Eldin, H. 2006. Induction of systemic resistance in faba bean (*Vicia faba* L.) to bean yellow mosaic potyvirus (BYMV) via seed bacterization with plant growth promoting rhizobacteria. Journal of Plant Diseases and Protection. 113(6):247-251.

Egbuchua, C.N. and Enujeke, E.C. 2013. Growth and yield responses of ginger (*Zingiber officinale*) to three sources of organic manures in a typical rainforest zone, Nigeria. Journal of Horticulture and Forestry. 5(7): 109-114.

Gahukar, R.T. 2011. Use of indigenous plant products for management of pests and diseases of spices and condiments: Indian perspective. Journal of Spices and Aromatic Crops. 20(1): 01–08.

García-Garrido, J.M. and Ocampo, J.A. 2002. Regulation of the plant defense response in arbuscular mycorrhizal symbiosis. Journal of Experimental Botany. 53(373): 1377–1386.

Ghosh, A.K., Banerjee, S., Mullick, H. I. and Banerjee J. 2011. *Zingiber Officinale*: A Natural Gold. International Journal of Pharma and Bio Sciences. 2(1): 283-294.

Glick, B.R., Karaturović, D.M. and Newell, P.C. 1995. A novel procedure for rapid isolation of plant growth-promoting pseudomonads. Canadian Journal of Microbiology. 41(6): 533-536.

Gupta, M.L., Prasad, A., Ram M. and Kumar S. 2002. Effect of the vesicular-arbuscular mycorrhizal (VAM) fungus *Glomus fasciculatum* on the essential oil yield related characters and nutrient acquisition in the crops of different cultivars of menthol mint (*Mentha arvensis*) under field conditions. Bioresource Technology. 81(1): 77-79.

Harman, G.E., Howell, C.R., Viterbo, A., Chet, I. and Lorito, M. 2004. *Trichoderma* species-opportunistic, avirulent plant symbionts. Nature Reviews Microbiology. 2(1): 43-56.

Harshavardhan, M., Kumar, D.P., Rajesh, A.M., Yathindra, H.A. and Hongal, S. 2016. Growth and development of carnation [*Dianthus Caryophyllus* L.] as influenced by integrated nutrient management. The Bioscan 11(4): 2691-2694.

Indian Institute of Spice Research. 2014. Ginger extension pamphlet. ICAR-Indian Institute of Spices Research, Kozhikode.

Ismail, S., Malewar, G.U., Rege, V.S. and Yelvikar, N.V. 1998. Influence of FYM and gypsum on soil properties and yield of groundnut grown in Vertisols. Agropedology. 8(2): 73-75

Joshi, L.K. and Sharma, N.D. 1980. Diseases of ginger and turmeric. In: Nair, M.K., Premkumar, T., Ravindran, P.N. and Sharma, Y.R. (Eds.), Proceedings of the national seminar on ginger and turmeric. Calicut. CPCRI, Kasaragod. pp.104-119.

Kamaliroostaa, Z., Kamaliroosta, L. and Elhamirad, A.H. 2013. Isolation and identification of ginger essential oil. Journal of Food Biosciences and Technology. 3(3): 73-80.

Khatso, K. and Ao, N.T. 2013. Biocontrol of rhizome rot disease of ginger (*Zingiber officinale* Rosc.) International Journal of Bio-resource and Stress Management. 4(2): 317-321.

Kirkegaard, J.A., Gardner, P.A., Desmarchelier, J.M. and Angus, J.F. 1993. Biofumigation-using *Brassica* species to control pests and diseases in horticulture and agriculture. In: Wratten, N. and Mailer, R.J. (Eds.), Proceedings of the 9th Australian Research Assembly on Brassicas. pp 77-78.

Kloepper, J. W. 1992. Plant growth-promoting rhizobacteria as biological agents. In: Metting, F.B. (Eds.), Soil Microbial Ecology- Application in Agricultural and Environmental Management. Marcel Dekker, New York. pp 255-274.

Kloepper, J.W., Ryu, C.M. and Zhang, S.A. 2004. Induced systemic resistance and promotion of plant growth by *Bacillus* spp. Phytopathology. 94(11): 1259-1266.

Kokalis-Burelle, N. 2003. Effects of transplant type, plant growth-promoting rhizobacteria, and soil treatment on growth and yield of strawberry in Florida. Plant and Soil. 256(2): 273-280.

Koya, K.M.A., Balakrishnan, R., Devasahayam, S. and Banerjee, S.K. 1986. A sequential sampling strategy for the control of shoot borer (*Dichocrocis punctiferalis* Guen.) in ginger (*Zingiber officinale* Rosc.) in India. Journal of Tropical Pest Management. 32(4): 343-346.

Kumar, A. and Sarma. Y.R. 2004. Characterization of *Ralstonia solanacearum* causing bacterial wilt in ginger. Indian Phytopathology. 57(1): 12-17.

Kumar, H.S.R., Janakiraman, N., Sheshadri, T., Gowda, J.V. and Mahantesh , V. 2012. Integrated organic nutrient supply systems on growth and yield of groundnut (*Arachis Hypogaea* L.). Environment & Ecology. 30 (1): 118-121.

Kumar, K. M., Somasundaram, E., Marimuthu, S. and Meenambigai, C. 2017. Growth, yield and quality of snake gourd (*Trichosanthes anguina* L.) as influenced by organic nutrient management practices. International Journal of Current Microbiology and Applied Sciences 6(11): 918-924.

Kumar, A., Prasad, V.M., Singh, D., Bahadur, V., David, A.A. and Beer, K. 2018. Effect of Bio-Fertilizers, Vermicompost and Trichoderma on Yield and Economics of Strawberry (Fragaria x annanasa Duch.) cv. Sweet Charlie. International Journal of Current Microbiology and Applied Sciences. 7(6): 1534-1538.

Kumari, M.S.S. and Ushakumari, K. 2002. Effect of vermicompost enriched with rock phosphate on the yield and uptake of nutrients in cowpea *(Vigna Unguiculata* L. Walp). Journal of Tropical Agriculture. 40(1/2): 27-30.

Kandan, T. and Subbulakshmi. 2015. Chemical nutrient analysis of vermicompost and their effect on the growth of SRI Rice Cultivation. International Journal of Innovative Research in Science, Engineering and Technology. 4(6): 4382-4388.

Lalfakawma, C., Nath, B.C., Bora, C., Srivastava, S. and Singh, J.P. 2014. Integrated disease management of *Zingiber Officinale* Rosc. rhizome rot. The Bioscan. 9(1): 265-269.

Latona, D. F., Oyeleke, G. O. and Olayiwola. O. A. 2012. Chemical Analysis of ginger root. IOSR Journal of Applied Chemistry (IOSRJAC). 1(1): 47-49.

Lepcha, B., Avasthe, R., Singh, R., Singh, N.J. and Phukan, P. 2019. Effect of organic nutrient sources on productivity, profitability and quality of ginger (*Zingiber officinale)* in acid soils of Eastern Himalayas. Indian Journal of Agricultural Sciences. 89 (7): 1103–1107.

Liu, L., Kloepper, J.W. and Tuzun, S. 1995. Induction of systemic resistance in cucumber against Fusarium wilt by plant growth promoting rhizobacteria. Phytopathology. 85(6): 695–698.

Lone, R., Shuab, R., Sharma, V., Kumar, V., Mir, R. and Koul, K.K. 2015. Effect of arbuscular mycorrhizal fungi on growth and development of potato (*Solanum tuberosum*) Plant. Asian Journal of Crop Science. 7(3): 233-243.

Lynch, J.M. 1990. Microbial metabolites. In: Lynch, J.M. (Eds.), The Rhizosphere. John Wiley, Chichester,UK. pp 177–206.

Matthiessen, J.N. and Kirkegaard, J.A. 2006. Biofumigation and enhanced biodegradation: opportunity and challenge in soilborne pest and disease management. Critical Reviews in Plant Sciences. 25(3): 235-65.

McCully, M.E. 2001. Niches for bacterial endophytes in crop plants: a plant biologist's view. Australian Journal of Plant Physiology. 28(9): 983-990.

Meena, D., Ram, R.B., Verma, R.S. and Shivran, B.C. 2019. Effect of phosphorus levels and bio-fertilizers on yield and quality parameters of garlic (*Allium sativum* L.) cv. G -282. The Pharma Innovation Journal. 8(6): 681-683.

Mishra, B.K., Rastogi, A. and Shukla S. 2012. Regulatory role of mineral elements in the metabolism of medicinal plants. Medicinal and Aromatic Plant Science and Biotechnology. 6(1): 1-23.

Mishra, R.S. and Pandey, V.P. 2015. Effect of integrated nutritional supplement on the soft rot, growth and yield of ginger. Plant Archives.15 (1): 47-49.

Moorman, G.W., Kang, S., Geiser, D.M., and Kim, S.H. 2002. Identification and characterization of *Pythium* species associated with greenhouse floral crops in Pennsylvania. Plant Disease. 86(11): 1227-1231.

Motisi,N., Doré, T., Lucas, P. and Montfort, F. 2010. Dealing with the variability in biofumigation efficacy through an epidemiological framework. Soil Biology and Biochemistry. 42(12): 2044-2057.

Nybe, E.V. 2001. Three decades of species research at KAU, Kerala Agricultural University, Thrissur, India.

Pal, S.K. 2019. Methods of Soil and Plant Analysis. New India Publishing Agency-Nipa, New Delhi. p 347-392.

Raina, V. K., Kumar, A. and Aggarwal, K. K. 2005. Essential oil composition of ginger (*Zingiber officinale* Roscoe) rhizomes from different place in India. Journal of Essential Oil Bearing Plants. 8(2): 187-191.

Rajan, K.M. and Agnihotri, V.P. 1989. *Pythium* induced rhizome rot of ginger, problems and progress. In: Agnihotri, V.P., Sing, N., Chaube, H.S., Sing, V.S. and Dwivedi, T.S. (Eds.), Perspectives in Phytopathology, Today and Tomorrow's Principles and Publishers, New Delhi, pp-189-198.

Ramesh, P., Panwar, N.R., Singh, A.B., Ramana, S., Yadav, S. K., Shrivastava, R. and Rao, A.S. 2010. Status of organic farming in India. Current Science. 98(9): 1190-1194.

Rana, N. and Korla, B.N. 2010. Integrated farming with organic and inorganic fertilizers on yield and quality of ginger (*Zingiber officinale* Rosc.). Agricultural Science Digest. 30(4): 250- 253.

Ryu, C.M., Farag, M.A., Hu, C-H., Reddy, M.S., Kloepper, J.W. and Pare, P.W. 2004. Bacterial volatiles induce systemic resistance in Arabidopsis. Plant Physiology. 134(3): 1017-1026.

Sabarad, A.I., Swamy, G.S.K., Patil, C.P., Patil, P.B. and Athani, S.I. 2004. Influence of VAM, Vermicompost and Trichoderma harzianum on growth of Banana, cv. Rajapuri (Musa AAB). Karnataka Journal of Agricultural Science. 17(3): 515-518.

Samanhudi, Y. A., Pujiasmanto, B. and Rahayu, M. 2014. Effect of organic manure and arbuscular mycorrhizal fungi on growth and yield of young ginger (*Zingiber officinale* Rosc.). IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS) 7(5): 01-05.

Sanchez, P.A. and Miller, R.H. 1986. Organic matter and soil fertility management in acid soils of the tropical soils. XVIII Congress of International Soil Science Soc. p.10.

Sarma, Y.R. 1994. Rhizome rot disease of ginger and turmeric. In: Chadha K.L. and Rethiman, P. (Eds.), Advances in Horticulture. Malhotra Publishing House, New Delhi. pp. 1113-1138.

Sarma, B.K., Singh, P., Pandey, S.K. and Singh, H.B. 2010. Vermicompost as modulator of plant growth and disease suppression. Dynamic Soil, Dynamic Plant. 4(1): 58-66.

Sasidharan, I. and Menon, N. 2010. Comparative chemical composition and antimicrobial activity fresh & dry ginger oils (*Zingiber Officinale Roscoe*). International Journal of Current Pharmaceutical Research. 2 (4): 40-53.

Sasidharan, I., Venugopal, V.V. and Menon, A.N. 2012. Essential oil composition of two unique ginger (*Zingiber officinale* Roscoe) cultivars from Sikkim. Natural Product Research. 26 (19): 1759-1764.

Shaikh, S.S., Sayyed, R.Z. and Reddy, M.S. 2016. Plant Growth-Promoting Rhizobacteria: An Eco-friendly Approach for Sustainable Agroecosystem. In: Hakeem, K., Akhtar, M. and Abdullah S. (Eds.), Plant, Soil and Microbes. Springer, Cham. p. 181-201.

Shadap, A., Pariari, A. and Lyngdoh, Y.A. 2018. Influence of organic manures, bio-fertilizers and graded dose of inorganic fertilizers on the growth and yield of ginger (*Zingiber Officinale* Rosc.). Plant Archives. 18(2): 1593-1597.

Sharma, P.K., Singh, V., Ali, M. 2016. Chemical composition and antimicrobial activity of fresh rhizome essential oil of *Zingiber Officinale* Roscoe. Pharmacognosy Journal. 8 (3): 185-190.

Sharma, E., Anand, G. and Kapoor, R. 2017. Terpenoids in plant and arbuscular mycorrhiza-reinforced defence against herbivorous insects. Annals of Botany. 119(5): 791–801.

Sharma, J.K., Jat, G., Meena, R.H. , Purohit, H.S. and Choudhary, R.S. 2017. Effect of vermicompost and nutrients application on soil properties, yield, uptake and quality of Indian mustard (*Brassica juncea*) Annals of Plant and Soil Research. 19(1): 17 – 22.

Shivran, A.C, Shekhawat, K.S., Sastry, E.V.D. and Rajput, S.S. 2013. Effect of plant growth promoting rhizobacteria (PGPR) coated bioformulations on fenugreek. International Journal of Seed Spices. 3(1):16-19.

Shukla, Y. and Singh, M. 2007. Cancer preventive properties of ginger: A brief review. Food Chemical Toxicology. 45(5): 683–690.

Silva, M.F., Rosete, P., Rebelo, R. A. and Stürmer, S. L. 2008. The effect of arbuscular mycorrhizal fungal isolates on the development and oleoresin production of micropropagated Z*ingiber officinale.* Brazilian Journal of Plant Physiology. 20(2): 119-130.

Singh, G., Kapoor, I.P.S., Singh, P., de Heluani, C.S., de Lampasona, M.P. and Catalan, C.A.N. 2008. Chemistry, antioxidant and antimicrobial investigations on essential oil and oleoresins of *Zingiber officinale*. Food and Chemical Toxicology. 46(18): 3295-3302.

Sivasothy, Y., Chong, W.K., Hamid, A., Eldeen, I.M. and Sulaiman, S.F. 2011. Essential oils of *Zingiber officinale* var. rubrum Theilade and their antibacterial activities Khalijah Awang. Food Chemistry. 124(2): 514–517.

Song, X., Liu, M., Wu, D., Griffiths, B.S. Jiao, J., Li, H., Hu, F. 2015. Interaction matters: Synergy between vermicompost and PGPR agents improves soil quality, crop quality and crop yield in the field. Applied Soil Ecology. 89: 25-34.

Sreekala, G.S. 2015. Effect of organic manures and biofertilizers on nutrient status of soil in ginger intercropped in coconut garden. International Journal of Current Research. 7(3): 13694-13698.

Tanweer, S., Shahzad, A. and Ahmed, W. 2014. Compositional and mineral profiling of *Zingiber officinale***.** Pakistan Journal of Food Science. 24(1): 21-26.

Tarafdar, J. and Saha, N. 2007. Correlation study on population dynamics of ginger soft rot inciting pathogens under different organic amendments, disease incidence and its survival in Darjeeling hill soils. In: Proceedings of the 13th ISTRC Symposium. Arusha, Tanzania. p. 165-169.

Umadevi, P., Anandaraj, M. and Benjamin, S. 2017a. Endophytic interactions of *Trichoderma harzianum* in a tropical perennial rhizo-ecosystem. Research Journal of Biotechnology. 2(3): 22-30.

Umadevi, P., Anandaraj, M., Srivastav, V. and Benjamin, S. 2017b. *Trichoderma harzianum* MTCC 5179 impacts the population and functional dynamics in microbial community in rhizosphere of black pepper (*Piper nigrum* L.). Brazilian. Journal of Microbiology. 49(3): 463-470.

Van Beek, T.A., Posthumus, M.A., Lelyveld, G.P., Hoang, V.P. and Yen, B.T. 1987. Investigation of the essential oil of Vietnamese ginger. Phytochemistry. 26(11): 3005–3010.

Verma, V.K., Patel, R.K., Deshmukh, N.A., Jha, A.K., Ngachan, S.V., Singh, A.K. and Deka, B.C. 2019. Response of ginger and turmeric to organic versus traditional production practices at different elevations under humid subtropics of north-eastern India. Industrial crops and products. 136: 21-27.

Vessey, J.K. 2003. Plant growth promoting rhizobacteria as biofertilizers. Plant and Soil. 255(2): 571-586.

Waterhouse, G.M. and Waterston, J.M.1964. *Pythium aphanidermatum.* CMI descriptions of pathogenic fungi and bacteria, No. 36.Commonwealth Mycological Institute: Kew, Surrey, U.K.

Webster, J. and Weber, R. 2007. Identification to Fungi. Cambridge University Press, Cambridge, U.K. p.95.

Yadav, R.S. 2014. Biocontrol potential of *Trichoderma harzianum* and *Pseudomonas fluorescens* with organic amendments against tomato wilt caused by *Fusarium oxysporum* f. sp. *Lycopersici.* International Journal of Microbial Resource Technology. 2(2): 13-17.

Yadav, A., Kumar, A., Gopi, R., Kalita, H. and Lepcha, B. 2014. Ginger (*Zingiber officinale* L.) In: Avasthe, R.K., Pradhan, Y. and Bhutia, K. (Eds.), Handbook of Organic Crop Production in Sikkim. Jointly published by Sikkim Organic Mission, Government of Sikkim, Gangtok, Sikkim and ICAR Research Complex for NEH Region,Sikkim Centre, Gangtok, Sikkim, India. p.129.

Yedidia, I, Srivastva, A.K., Kapulnik, Y. and Chet, I. 2001. Effect of *Trichoderma harzianum* on microelement concentrations and increased growth of cucumber plants. Plant and Soil. 235: 235-242.

Youssef , M.M.A and Lashein, M.S.2013. Effect of Cabbage (*Brassica Oleracea*) leaf residue as a biofumigant, on root knot nematode, *Meloidogyne Incognita* infecting tomato. Journal of Plant Protection Research. 53 (3): 271-274.

Yuan. J., Ruan Y., Wang, B., Zhang, J., Waseem, R., Huang, Q. and Shen, Q. 2013. Plant growth-promoting rhizobacteria strain *Bacillus amyloliquefaciens* NJN-6-enriched bio-organic fertilizer suppressed *Fusarium* wilt and promoted the growth of banana plants. Journal of Agricultural Food and Chemistry. 61(16): 3774–3780.

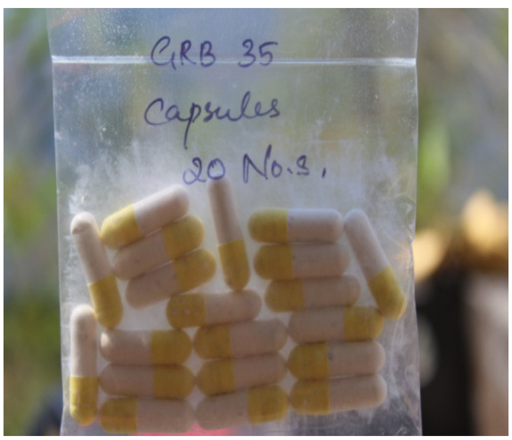
Zhang ,F., Dashti , N., Dashti, R. K. H and Smith, D.L. 1997. Plant Growth-promoting Rhizobacteria and Soybean [*Glycine max* (L.) Merr.] Growth and Physiology at Suboptimal Root Zone Temperatures .Annals of Botany.7(9): 243-249.

Zheng, W. and Wang, S.Y. 2001. Antioxidant activity and phenolic compounds in selected herbs. Journal of Agricultural and Food Chemistry. 49(11): 5165–70.

Plate No.1 Field preparation

Trichoderma harzianum

FL 18 ((*Microbacterium paraoxydans*)



GRB 35 (*Bacillus amyloliquefaceins*))

BRB (*Micrococcus* sps)

Plate No. 2 PGPR capsules

Plate No. 3 Experiment No.1. Input effect on growth, yield and quality parameters and multi elemental status.

Plate No. 4 Experiment No. 2. Input effect on pest tolerance

Plate No.5 Experiment No.3 Input effect on disease tolerance