

**STUDIES ON VEGETABLE BASED INTERCROPPING
SYSTEM IN SOLID SOILLESS MEDIA UNDER
PROTECTED CONDITION**

M.Sc (Hort.) Thesis

by

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**DEPARTMENT OF VEGETABLE SCIENCE
COLLEGE OF AGRICULTURE
FACULTY OF HORTICULTURE
INDIRA GANDHI KRISHI VISHWAVIDYALAYA
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**STUDIES ON VEGETABLE BASED INTERCROPPING
SYSTEM IN SOLID SOILLESS MEDIA UNDER
PROTECTED CONDITION**

Thesis

Submitted to the

Indira Gandhi Krishi Vishwavidyalaya, Raipur

by

Subhradeep Pramanik

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FOR THE DEGREE OF**

Master of Science

in

**Horticulture
(Vegetable Science)**

Roll No. 120116254

ID No. 20161725010

July, 2018

CERTIFICATE - I

This is to certify that the thesis entitled "**Studies on vegetable based intercropping system in solid soilless media under protected condition**" submitted in partial fulfillment of the requirements for the degree of "**Master of Science in Horticulture (Vegetable Science)**" of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **Subhradeep Pramanik** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or certificate course. All the assistance and help received during the course of the investigations have been duly acknowledged.

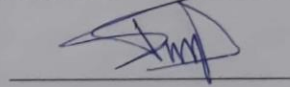


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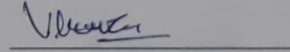
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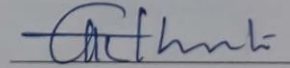
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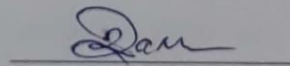
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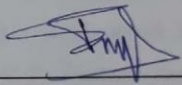
CERTIFICATE - II

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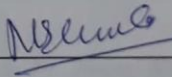
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Head of the Department



Faculty Dean

Approved/Not approved

Director of Instructions

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LIST OF SYMBOLS/NOTATIONS


| | |
|----------------------|--|
| % | Per cent |
| $^{\circ}\text{C}$ | Degree Celsius |
| <i>et al.</i> | Et alia that mean others/ and co-workers |
| <i>etc.</i> | And so on; other people/ things |
| <i>per se</i> | As such with mean |
| Fig. | Figure |
| <i>i.e.</i> | That is |
| <i>Ex</i> | Example |
| Plant^{-1} | Per plant |
| <i>viz.</i> | Namely |
| <i>vs.</i> | Against |
| Cm | Centimeter |
| / | Per |
| S. No. | Serial Number |
| Temp. | Temperature |
| ha | Hectare |
| Hrs | Hours |
| max. | Maximum |
| min. | Minimum |
| ms^{-1} | Meter per second |
| mm | Millimeter |
| m | Meter |
| g | Gram |
| Kg | Kilogram |
| Kg/ha | Kilogram per hectare |
| mg | Milligram |
| Q | Quintal |
| qha^{-1} | Quintal per hectare |
| q acre^{-1} | Quintal per acre |
| Min | Minute |
| No. | Number |
| L | Litre |
| L^{-1} | Per litre |
| ml | Millilitre |
| r | Number of replication |
| t | Number of treatments |
| M.S. | Mean sum of square |
| SE $m\pm$ | Standard Error of mean \pm |
| ` | Indian Rupee |

LIST OF ABBREVIATIONS

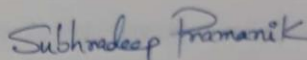
| | |
|----------|---|
| IGKV | Indira Gandhi Krishi Vishwavidyalaya |
| CRD | Completely Randomized Design |
| ANOVA | Analysis of variance |
| CD | Critical Difference |
| RF | Rain Fall |
| RH | Relative Humidity |
| d.f. | Degree of freedom |
| EMS | Error mean squares |
| S.S. | Sum of square |
| C.D. | Critical difference |
| CoE-PCPF | Centre of Excellence on Protected Cultivation and Precision Farming |
| N.B. | Nota Bene means important point |
| LER | Land equivalent ratio |

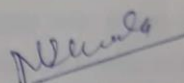
THESIS ABSTRACT

-
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- b) Full Name of the Student: Subhradeep Pramanik
- c) Major Subject: Vegetable Science
- d) Name and Address of the Major Advisor : Dr. Jitendra Singh, Professor,
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Signature of Major Advisor

Date: 23/07/18


Signature of Student


Signature of Head of the Department

ABSTRACT

The present investigation entitled "**Studies on vegetable based intercropping system in solid soilless media under protected condition**" was conducted during *Kharif* (July-December), 2017 under Naturally Ventilated Polyhouse at Centre of Excellence on Protected Cultivation and Precision Farming, Department of Vegetable Science, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh to identify suitable intercrops for tomato and to study the growth, yield parameters, yield and economics of different intercrops and tomato in solid soilless culture under protected condition. The experiment was comprised of nine treatments, laid out in completely randomized design with three replications.

The analysis of variance of growth, yield parameters and yield of tomato revealed that there was significant difference in performance of tomato plants in different intercropping systems with respect to the characters, viz., number of fruit cluster⁻¹, number of fruits plant⁻¹, fruit yield plant⁻¹ and total fruit yield. Among different intercropping systems, highest plant height was recorded in sole tomato closely followed by tomato + turmeric intercropping system. Sole tomato registered the highest number of fruits

cluster⁻¹ and highest number of fruits of fruits plant⁻¹. Among different intercropping systems, tomato + ginger registered highest number of fruits plant⁻¹. Tomato + elephant foot yam intercropping system took the highest duration for the first fruit harvest while the sole tomato which registered the shortest duration for the first fruit harvest. The average fruit weight of tomato + colocasia, tomato + turmeric and tomato + ginger intercropping systems were statistically *at par* with the average fruit weight of sole tomato. The highest fruit yield plant⁻¹ was observed in sole tomato followed by in tomato + ginger intercropping system. Among different intercropping systems, highest value for total fruit yield acre⁻¹ has been obtained with tomato + ginger intercropping systems.

For estimation of the effect of intercropping on growth, yield parameters and yield of different intercrops, t-test analysis was carried out. Among different growth and yield parameters *viz.*, plant height, weight of corms plant⁻¹, total corm yield acre⁻¹ and total corm yield hectare⁻¹, of elephant foot yam intercropped with tomato varied significantly as compared to the sole elephant foot yam, while, the number of shoots plant⁻¹ of the elephant foot yam intercropped with tomato was statistically *at par* with the sole elephant foot yam. Sole colocasia registered higher value for all the growth, yield parameters and yield *viz.*, plant height, numbers of tillers plant⁻¹, number of cormels plant⁻¹ and weight of cormels plant⁻¹, total tuber yield acre⁻¹ and total tuber yield ha⁻¹. Sole turmeric and sole ginger performed better as compared to the turmeric and ginger intercropped with tomato with respect to all the growth and yield parameters.

For assessment of the overall productivity potential and efficiency of all the intercropping systems studied in this experiment, tomato equivalent yield and LER were determined. Highest tomato equivalent yield was obtained in tomato + elephant foot yam intercropping system closely followed by tomato + ginger intercropping system. Tomato + turmeric intercropping system registered the highest LER value followed by tomato + ginger intercropping system.

Economic analysis of different intercropping systems revealed that tomato + elephant foot yam intercropping system had the highest net returns per acre followed by tomato + ginger which were higher than the net returns of sole tomato

crop. Tomato + elephant foot yam and tomato + ginger intercropping system were found most remunerative on the basis of benefit cost ratio among different intercropping systems.

Based on these experimental findings, it may be concluded that elephant foot yam and ginger were found to be the best intercrops. The tomato + elephant foot yam and tomato + ginger intercropping system may be recommended for achieving the much desired increased yield and monetary return for vegetable based intercropping system in solid soilless media under protected condition for food and nutrition security.

शोधग्रंथ सारांश

- अ) शोधग्रंथ का शीर्षक : "संरक्षित स्थिति में ठोस मृदा रहित मीडिया में सब्जी आधारित अंतर्वर्तीय खेती प्रणाली का अध्ययन"
- ब) छात्र का नाम : शुभ्रदीप प्रामाणिक
- स) प्रमुख विषय : सब्जी विज्ञान
- द) मुख्य सलाहकार का नाम एवं पता : डॉ. जितेन्द्र सिंह, प्राध्यापक, सब्जी विज्ञान विभाग, महाविद्यालय, रायपुर, इंदिरा गांधी कृषि विश्वविद्यालय, रायपुर-492012 (छ.ग.)
- ई) प्रदान की जाने वाली उपाधि : एम.एस.सी. (उद्यानिकी) सब्जी विज्ञान

प्रमुख सलाहकार के हस्ताक्षर

दिनांक: 25/07/2018

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Dr. Jitendra Singh

विभागाध्यक्ष के हस्ताक्षर

सारांश

शीर्षक "संरक्षित स्थिति में ठोस मृदा रहित मीडिया में सब्जी आधारित अंतर्वर्तीय खेती प्रणाली का अध्ययन" का परीक्षण खरीफ (जुलाई से दिसम्बर, 2017) में स्वतः वातानुकूलित पॉली हाउस के तहत उत्कृष्टता केन्द्र संरक्षित खेती, सब्जी विज्ञान विभाग, इंदिरा गांधी कृषि विश्वविद्यालय, रायपुर (छ.ग.) में टमाटर के लिए उपयुक्त अंतर्वर्तीय और बड़वार एवं उपज मानको का अध्ययन विभिन्न अंतर्वर्तीय फसलों और टमाटर की उपज और अर्थिकी का ठोस मृदा रहित उपचार (ट्रीटमेंट) शामिल थे जो तीन प्राकृतियों के साथ पूरी तरह से यादृच्छिक डिजाइन में रखे गये थे।

वृद्धि, उपज, मानक और टमाटर की उपज के प्रसरण विश्लेषण से प्रकट होता है कि टमाटर के पौधों के प्रदर्शन में सार्थक अंतर, अंतर्वर्तीय फसल प्रणाली के साथ विभिन्न गुणों जैसे प्रति गुच्छ फलों की संख्या, प्रति पाघा फलों की संख्या, फल उपज पाया गया। विभिन्न अंतर्वर्तीय पद्धति में सबसे ज्यादा पौध ऊँचाई अकेले टमाटर

में दर्ज की गयी, जो टमाटर और हल्दी अंतर्वर्तीय फसल के निकटतम रहा। अकेले टमाटर में सबसे ज्यादा फलों की संख्या प्रति गुच्छा और सबसे ज्यादा प्रति पौध फलों की संख्या दर्ज की गयी। विभिन्न अंतर्वर्तीय फसल पद्यति में से टमाटर और अदरक सबसे ज्यादा फलों की संख्या प्रति पौधा दर्ज की गयी। टमाटर और जिमीकंद अंतर्वर्तीय पद्यति में प्रथम फल तुड़ाई में सबसे ज्यादा समयावधि लगा जबकि अकेले टमाटर की फसल में प्रथम फल तुड़ाई के लिए सबसे कम समय लगा।

टमाटर + अरबी, टमाटर + हल्दी, टमाटर + अदरक अंतर्वर्तीय पद्यति का औसत फल वनज सांख्यिकीय रूप से अकेले टमाटर फसल के औसत फल वजन के बराबर था। उच्चतम फल उपज प्रति पौधा को अकेले टमाटर की फसल में देखा गया तत्पश्चात टमाटर + अदरक अंतर्वर्तीय पद्यति में रहा। विभिन्न अंतर्वर्तीय पद्यति में टमाटर + अदरक में कुल फल उपज प्रति एकड़ के लिए उच्चतम मूल्य प्राप्त किया गया।

अंतर्वर्तीय फसल को प्रभाव के आंकलन बड़वार उपज मानकों और विभिन्न अंतर्वर्तीय फसल की उपज के लिए टी-टेस्ट विश्लेषण किया गया। विभिन्न वृद्धि और उपज मानको के बीज जैसे : पौधे की ऊँचाई, प्रति पौधा कंद वनज, कुल कंद वनज प्रति एकड़ और प्रति हेक्टेयर कुल कंद उपज, जिमी कंद की अंतर्वर्तीय टमाटर के साथ अकेले जिमीकंद की तुलना में सार्थक पाया गया। जबकि टमाटर के साथ जिमीकंद वनज प्रति पौधा शूट्स की संख्या अकेले जिमीकंद के सांख्यिकीय रूप से बराबर थी। अकेले अरबी सभी वृद्धि उपज मानकों और उपज के लिए उच्चतम दर्ज है। जैसे पौध ऊँचाई, प्रति पौध कंद का वजन, प्रति एकड़ कंद की उपज एवं प्रति हे. कुल कंद उपज। अकेले हल्दी और अकेले अदरक टमाटर के साथ अंतर्वर्तीय फसल की तुलना में सभी वृद्धि एवं उपज मानकों के संबंध में बेहतर प्रदर्शन किया। इस शोध में अध्ययन की गई सभी अंतर्वर्तीय पद्यति की समग्र उत्पादकता क्षमता और दक्षता के आंकलन के लिए टमाटर समकक्ष उपज और एल.ई.आर. निर्धारित किये गये थे। उच्चतम टमाटर समकक्ष उपज टमाटर + जिमीकंद अंतर्वर्तीय फसल पद्यति में पाया गया तत्पश्चात टमाटर + अदरक अंतर्वर्तीय फसल में रहा। टमाटर + हल्दी में उच्चतम एल.ई.आर. दर्ज लिया गया उसके बाद टमाटर + अदरक अंतर्वर्तीय फसल में दर्ज की गयी।

विभिन्न अंतर्वर्तीय फसल पद्यति के विश्लेषण से पता चलता है कि टमाटर + जिमीकंद अंतर्वर्तीय फसल एकड़ उच्चतम शुद्ध मुनाफा होता है। टमाटर + जिमीकंद और टमाटर + अदरक विभिन्न अंतर्वर्तीय फसल पद्यति के बीच लागत अनुपात के आधार पर सबसे अधिक लाभकारी पाया गया।

इन शोध निष्कर्षों के आधार पर यह निष्कर्ष निकाला जा सकता है कि जिमीकंद और अदरक सबसे अच्छे अंतर्वर्तीय फसल साबित होते हैं। टमाटर + जिमीकंद और टमाटर + अदरक अंतर्वर्तीय पद्यति भी सिफारिश खाद्य एवं पोषण सुरक्षा के लिए संरक्षित स्थिति के तहत ठोस मिट्टी रहित में सब्जी आधारित अंतर्वर्तीय फसल पद्यति के लिए अधिक वांछित वृद्धि और मौद्रिक प्राप्त हो सके।

CHAPTER - I

INTRODUCTION

Globally, population burst and industrialization are resulting in declining availability of per capita land, for which arable lands are under pressure to produce enough food for human consumption, especially in developing countries. Scientific crop management practices may be a solution to combat such circumstances, which help in increasing crop production and productivity per unit area per unit time. Intercropping is the most suitable measure to stabilize the crop production especially in case of vegetable production. Farmers generally prefer the intercropping system because it produces higher total crop yield per unit area, provides insurance against total crop failure, and also reduces incidences of pests and diseases (Lyocks et al., 2013).

Due to rapid urbanization and industrialization, land uses in India portray a grim picture. The same situation prevails in Chhattisgarh too. Per capita arable land availability in India has declined from 0.34 hectare (1961) to 0.121 hectare (2014) (Anonymous, 2015) and in Chhattisgarh, the figure is 0.26 hectare. The pressure of inequality of land distribution on environment is excessive. Moreover, barren and uncultivated area is on the higher percent, which leads to the dumping and accumulation of wastes, hence, creating an additional pressure on environment. In most urban and industrial areas, soil is less available for crop growing, or in some areas, there is scarcity of fertile cultivable arable lands due to their unfavorable geographical or topographical conditions (Beibel, 1960). In Chhattisgarh, the soil is deficient in mineral nutrients like calcium, magnesium, nitrogen, phosphorus and potassium which are concentrated in the lower parts of the soil layer and the main pressure for horticulture is the inadequate availability of soil in the state. Pressure on horticulture also arises from the excessive usage of insecticides and fertilizers. In addition to this, drought and intermittent dry spells, flooding and wet spells, heat waves, cold waves and hail storms are common in the state. Due to some unforeseeable extreme events, the farmers suffer loss in the field. Since, erratic climatic condition is affecting the production through traditional methods, early adapters like progressive farmers are shifting to the practice of raising high

value vegetables under protected cultivation. The advent of protected cultivation technology in India materialized during the early nineties, post globalization. In India, the area under protected cultivation is presently around 25,000 ha, while the greenhouse vegetable cultivation area is about 2,000 ha (Sabir and Singh, 2013). Faced with constraints of land holdings, rapid urbanization, declining crop production, declining biodiversity and ever increasing population, demand for food, especially vegetables has increased manifold and protected cultivation has offered a new dimension to produce more in a limited area. It is utmost necessary to improve the productivity of vegetable crops by adopting intensive cultivation, soilless culture (solid and liquid) under poly house condition. Adopting poly house cultivation, the productivity of vegetable crops can be increased by 3-5 times as compared to open environment. Besides productivity, the better quality of produce is also obtained under poly house cultivation. Tomato is one of the major vegetable crops grown under the protected condition.

Tomato (*Solanum lycopersicum* L.), grown throughout the world in both open and protected condition because of its wider adaptability, high yielding potential and suitability for variety of uses in fresh as well as processed food industries. The crop is native to Central and South America (Vavilov, 1951). It is a tropical day neutral and mainly self-pollinated plant. In world, it ranks second in importance after potato, but tops the list of processed vegetables (Chaudhary, 1996). Tomatoes are major contributors of antioxidants such as carotenoids (especially, lycopene and β -carotene), phenolics, ascorbic acid (vitamin C) and small amounts of vitamin E in daily diets (Rai *et al.*, 2012). Globally, the area under tomato is around 4.8 million hectares with a production of 162.52 million tonnes, while in India; tomato is grown across all agro-ecological zones and occupies an area of about 801 thousand hectares with an annual production of 22.33 million tonnes, respectively (Anonymous, 2017). In Chhattisgarh, tomato is being cultivated in an area 0.05 million hectares with the production of 0.95 million tonnes (Anonymous, 2017). Chhattisgarh accounts for 4% of the total production of tomato in the country. The major tomato producing belts in the state are Raigarh, Durg, Jashpur, Surguja, Jagdalpur, Bemetara, Balodabazar, Kabirdham, Raipur, Kondagaon,

Mungeli, Balod, Bilaspur, Surajpur & Rajnandgaon. January and February are the peak period of harvest of tomato in Chhattisgarh.

Many times, it is observed that crops (*e.g.* tomato) those are cultivated under the protected structures fail due to some inevitable reasons like sudden fall or increase in temperature, moisture stress etc. Poorly textured soil or shallow soil provides an unsatisfactory root environment because of limited aeration and slow drainage, which is also a reason for crop failure under the protected structures. These problems can be fixed only carefully controlling the factors responsible for the crop growth or by taking intercrops against the monoculture where it is not possible to control the growth and development factors and soilless culture (solid and liquid) may address the problems related to soil health under poly house condition. Farmers in the developing world have been growing two or more crops together on the same piece of land for many centuries. Proper management of the intercropping systems could play a determinant role in making a success of these systems.

Intercropping which is already established in the open field can also be evaluated in soilless culture under protected cultivation to address the tomato crop failure issues. Crops like elephant foot yam, colocasia, turmeric and ginger can be successfully grown as intercrop. Elephant foot yam corm has high carbohydrate content (about 18% starch) and rich in vitamin 'A', minerals and protein. As ayurvedic medicine, it is used against piles, jaundice, diabetes, dyspepsia and appetites, colocasia is good source of thiamin, riboflavin, iron, phosphorus and zinc and a very good source of vitamin B6, vitamin C, niacin, potassium, copper and manganese, ginger is used in culinary purpose and preparation of ginger preserve, candy, soft drinks, pickles and alcoholic beverages, dried ginger and preparation of ginger oil, oleoresin, dehydrated and bleached ginger and turmeric is used as condiment, dye, drug and cosmetic in addition to its use in religious ceremonies. These crops are commonly cultivated in open field for consumption as food or food adjuncts and/or seed material. Inadequacy of quality planting material is the major bottle-neck in production of these crops in the growing states. Production of seed materials in open field is challenging due to viral diseases and devastating sucking pests. To avoid these adverse conditions found in open field, some form of soilless culture

under protected cultivation may be justified. These crops may be assessed for their suitability in the intercropping system with tomato.

Therefore, the present investigation entitled “Studies on Vegetable Based Intercropping System in Solid Soilless Media under Protected Condition” was conducted during *kharif*, 2017 under the Naturally Ventilated Polyhouse at Centre of Excellence on Protected Cultivation and Precision Farming, Department of Vegetable Science, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh with the following objectives:

1. To identify suitable intercrops (rhizomatous crops and aroids) for tomato in solid soilless culture.
2. To study the growth and yield parameters of different intercrops and tomato under protected condition.
3. To study the economics of different treatments.

CHAPTER II

REVIEW OF LITERATURE

The current experimental approach for the “Studies on Vegetable Based Intercropping System in Solid Soilless Media under Protected Condition” includes identification of production potentials of crops *viz.*, elephant foot yam, colocasia, turmeric, and ginger used in the present investigation and evaluation of their performance in the tomato based intercropping systems. The research information pertaining to the experimental topic is very few. No systematic research work has been carried out on this aspect with regards on a broad basis. However, the relevant literatures available on various aspects of the present study were critically reviewed and are discussed under the following heads:

2.1 Vegetable Based Intercropping System under Protected Condition

Filho *et al.* (2011) conducted an experiment on agronomic efficiency of intercropping tomato and lettuce under greenhouse conditions. Intercropped tomato and lettuce were evaluated during two seasons and compared to their sole cropping. They found that in the first cropping season, intercropping established by transplanting lettuce during the interval between 30 days before up to 20 DAT tomato yielded land use efficiency (LUE) indices of 1.63 to 2.22. In the second period, intercropping established with the transplanting of lettuce up to 30 days before tomato yielded LUE indices of 1.57 to 2.05. The productivity of the tomato fruits were not influenced by having lettuce intercropped with it, but lettuce production was lowered when tomato was intercropped with it. There was an effect of cropping season on the extent of the agronomic advantage of intercropping over sole cropping.

Demir and Polat (2011) determined the effects of intercropping system of broccoli-crispy salad on the yield, quality characteristics, and land equivalent ratio (LER) by comparing alone broccoli and crispy salad cultivation under greenhouse conditions in the autumn of 2006 and 2007. According to results of this study, the highest values in investigated criteria were found in mono cropping. The highest total yield of broccoli was obtained with 1.67 and 2.46 kg m⁻² in mono cropping, respectively in the autumn of 2006 and 2007. Similarly, the highest total yield of

crispy salad was established with 5.93 and 3.36 kg m⁻² in mono cropping, respectively in the autumn 2006 and 2007. LER was found to be greater than 1 in broccoli and crispy salad combination for both periods. The highest value of LER was determined to be 1.64% in autumn 2007 period.

Cheng *et al.* (2014) studied growth, yield and quality of spring tomato and physico-chemical properties of medium in a tomato/garlic intercropping system under plastic tunnel organic medium cultivation. Intercropping reduced the total spring tomato yield but produced a higher net income than did monoculture. The net income of the intercropping mode (\$22886 ha⁻¹) was 12.3% higher than that of the monoculture mode (\$20378 ha⁻¹), despite the slightly negative impact of intercropping on the tomato yield due to competition for water, space and nutrition.

Tringovska *et al.* (2015) assessed the effect of companion plants as marigold (*Tagetes patula* L.), basil (*Ocimum basilicum* L.), lettuce (*Lactuca sativa* L.) and white mustard (*Sinapis alba* L.) on (i) greenhouse tomato yield and fruit quality; (ii) root-knot nematodes infestation and (iii) energy effectiveness of tomato production. The experiment was carried out during three consecutive years (2011–2013) in an unheated greenhouse. The researchers reported that white mustard caused significant decrease in early and total yield of tomatoes as well as decreased the average fruit weight. Marigold, basil and lettuce did not decrease significantly the tomato productivity. The use of white mustard significantly decreased the early yield by 34% and total yield by 17%. The percentage of early yield in marketable yield in the treatment with white mustard was significantly lower than that in the other treatments.

Jett *et al.* (2015) studied on tomatoes intercropped with lettuce (*Lactuca sativa* L.) and basil (*Ocimum basilicum* L.) within a high tunnel during a nine-month season in 2002 and 2003. The relative yield total (RYT), a measure of intercropping productivity, was 1.40 – 1.83 indicating that it would require 40 to 83% more land for separate monoculture plantings of tomatoes, lettuce and basil to produce a yield equivalent to the intercropping planting within the high tunnel.

2.2 Tomato Based Intercropping Systems in Field Condition

Schultz *et al.* (1982) conducted an experiment on intercropping of cucumbers and tomatoes in Southern Michigan, U.S.A. The land equivalent ratio (LER) was 1.14, that is, 14% more land would be needed to produce the same yield from two monocultures as from a unit area of intercrop. The intercrop advantage was statistically significant. They also reported that the relative yield totals averaged greater than 1, an indication that more than 1 ha of monocultures would be required to equal the production of 1 ha of polyculture. More importantly, depending on prices, polycultures can provide a greater dollar value per ha than monoculture.

Olasantan (1985) carried out a field trial on tomato intercropped with okra and found that fruit yield of improved cultivars of tomato were significantly reduced but yield of local cultivar of tomato was unaffected. Although the yield of okra cultivar V2 when grown with any of tomato cultivars was less than that of sole crop but aggregate yield of both crops in combination was more than sole crop. Tomato, when grown with okra the relative total yield increased to about 1.42 and 1.39.

Singh (1993) carried out a field trial at Ranchi to study feasibility of intercropping rainy season 'Pusa Sawani' okra with Contender French bean, local cowpea, Early Kunwari cauliflower, Muktakeshi brinjal and Arka Abha tomato. Intercropping of cowpea gave 60 per cent reduced yield of okra, but the okra-equivalent yield increased to a maximum of 34.98 tonnes/ha raising the productivity by 31–53 per cent in comparison with other intercropping combinations as well as pure crop of okra (16.31 tonnes/ha). The least equivalent yield (12.19 tonnes/ha) was given by the okra + French bean intercropping system.

Nihoul (1994) examined the effects of intercropping on the distribution of pests in a cropping system composed of rows of sweet peppers alternatively with rows of tomatoes in a 80 m² glasshouse. Maximum significant deviation in pest density was recorded among the rows of the vegetable species which favoured peak pest eruption. This impression was probably due to negative effects caused by the other plant species on the dispersion of the pest. Such intercropping seems to locally

limit pest outbreaks, and thus may reduce the amount of biological auxiliaries or pesticides needed to control them in comparison with monoculture.

Singh (1995) conducted a field trial at Ranchi on okra based intercropping system and found that application of increased doses of N from 40 to 200 kg ha⁻¹ produced significantly higher yield and size of fruit in base crop okra but the plant height improved up to 160kg N ha⁻¹ level. While in contrary, companion crop tomato also showed yield improvement up to 160 kg N ha⁻¹. The application of 160 kg N ha⁻¹ gave increased mean okra equivalent yield in okra + tomato i.e. 15.26, 7.29 and 1.33 % over 40,80 and 120 kg N levels respectively.

Jing Quan Yu (1999) executed an experiment for the studies on allelopathic suppression of *Pseudomonas solanacearum* infection of tomato (*Lycopersicon esculentum*) in a tomato-chinese chive (*Allium tuberosum*) intercropping system. The occurrence of bacterial wilt of tomato was delayed and suppressed by Chinese chive plants and there was no detrimental effect on the growth of tomato plants. *P. solanacearum* population declined faster in the soil grown with tomato alone than that in the soil grown with both tomato and Chinese chive. On the other hand, *P. solanacearum* population in bare soil was greater than that grown with Chinese chive. Root exudates of Chinese chive gathered with a unceasingly trapping system were inhibitory to multiplication of *P. solanacearum*.

Adeniyi (2001) carried out field studies to establish the effect of planting patterns on growth and yield of tomato-cowpea in intercropping. The planting pattern acted on vegetative growth and yields of both tomato and cowpea significantly was observed by the researchers. Growth and yields of cowpea were significantly lowered down in all the crop combinations especially when paired rows of tomato were intercropped with a row of cowpeas (TC 2: 1). Decreasing the proportion of tomatoes in the cropping patterns improved performance of cowpea. Cowpea rendered best when a row of tomato was switched with paired rows of cowpea (TC 1:2). Growth and yield of tomato in the 2:1 planting pattern were greater than those in the 1:1 and 1:2 patterns. The yield advantage in terms of relative yield total (RYT) had limits from 2.0 to 22.0% among the treatments. The

maximum RYT value of 1.22 was observed when paired rows of tomato were intercropped with a row of cowpea.

Singh (2001) performed field experiments for two consecutive years at Bihar (India) observed that intercropping of okra either with tomato or cowpea did not substantially affect the performance of main crop (okra). The researcher also observed higher okra-equivalent yield and net returns with tomato intercropping (370 q and Rs. 45847 ha⁻¹, respectively).

Hussain (2003) studied the outcome of intercropping on growth, yield and economics of vegetables in summer and winter vegetables. Tomato was intercropped with okra, potato, corn, chili and eggplant. All the polycultures generally yielded more than monoculture. In the intercropping system all the crop combinations lowered plant height, root weight, root volume, and root: shoot ratio in comparison to sole tomato. Concerning the yield parameters, tomato+ okra recorded maximum yield (27.61t ha⁻¹). Intercropping combination like tomato+ potato recorded minimum yield (12.75 t ha⁻¹). On other hand tomato+ okra recorded highest harvest index value (78.10%) succeeded by tomato + eggplant (61.1%). Minimum harvest index value (49.8%) was obtained with sole crop of tomato (49.8%). The best companion of tomato was okra and their combination gave maximum net income of Rs. 134241ha⁻¹ due to maximum yield (27.61 t ha⁻¹) as compared to that in sole crop (20.34 t ha⁻¹) and high market price of both vegetables. Tomato + corn combination yielded highest net income of Rs. 12579, credited to high yields of tomato in intercropping and stability of corn yield in two years. The highest net income was also due to market price of tomato and corn. The minimum income (Rs.59486 ha⁻¹) has been observed from intercropping tomato with potato due to great reduction in yield of both vegetables and huge cost of cultivation.

Md. Ariful Islam (2011) conducted a field experiment to examine the effect of intercropping on the management of whitefly (*Bemisia tabaci* Genn.) in tomato (*Lycopersicon esculentum* L.). Tomato (*Lycopersicon esculentum* Lin.) + garlic (*Allium sativum*), tomato + radhuni (*Trachyspermum roxburghianum*), tomato + mouri (*Foeniculum vulgare*), tomato + methi (*Trigonella foenium-graecum*), tomato + radish (*Raphanus sativum*), tomato + coriander (*Coriandrum sativum*)

and Sole tomato (control) were the crop combinations. The author reported that maximum healthy tomato yield (16.00 t ha^{-1}), minimum infested tomato yield (1.00 t ha^{-1}), maximum total tomato yield (17.00 t ha^{-1}), minimum relative yield (1.80 t ha^{-1}), maximum tomato equivalent yield (17.69 t ha^{-1}) and maximum gross return (Tk. 621600.00 ha^{-1}) were recorded in tomato + garlic intercropping system. The researcher observed that the treatment combination of tomato + garlic was the best treatment followed by tomato + methi, tomato + radhuni, tomato + mouri, tomato + radish and tomato + coriander where sole treatment (control) gave the lowest performance in terms of gross return.

2.3 Suitability of Different Intercrops in Intercropping System

Sivaraman & Palaniappan (1994) intercropped maize and onion with turmeric in two proportions (50 and 100 per cent of the recommended population levels). Turmeric yields were reduced from 9 to 25 per cent when intercropped with maize. Turmeric yield reductions due to intercropping were associated with reduction in number of tillers, mother rhizome, primary and secondary rhizomes. Maize yields were higher with intercropping than with sole cropping. The researchers reported that though yield of turmeric was reduced by intercropping, turmeric - maize and onion intercropping resulted in 17 to 34 per cent greater land use efficiency for the 9 months growing season than in the sole cropping systems.

Chattopadhyay *et al.* (2008) carried out a trial in order to find out a suitable vegetable as an intercrop in elephant foot yam (EFY), consisting of five treatments (Sole EFY; EFY + okra; EFY + cucumber; EFY + amaranth and EFY + vegetable cowpea) under irrigated condition for three consecutive years (2005-07) at Bidhan Chandra Krishi Viswavidyalaya, West Bengal. Results showed that growth parameters viz., height of pseudostem, pseudostem girth and canopy spread were superior when elephant foot yam was grown as a pure crop succeeded by vegetable cowpea grown as an intercrop. Intercrops influenced sprouting of main crop as compared to sole crop of elephant foot yam. Sprouting enhancement of elephant foot yam by 10 days was noticed when cowpea was grown as an intercrop. Though, the longest period (50 days) of realization of 50% emergence of shoots was achieved when elephant foot yam was grown as a sole crop. The mean corm

yield of elephant foot yam was found to be maximum (61.27 t ha^{-1}) when grown as a sole crop followed by cowpea intercropping (57.28 t ha^{-1}). The researchers also found that different intercrops lowered the main crop (EFY) yield considerably as compared to sole crop. Amongst the intercrops, the maximum elephant foot yam yield equivalent (9.80) was obtained from cowpea. The highest net return (Rs. 2, 15,400/-) and the income per rupee investment (1.80) were obtained from elephant foot yam + cowpea intercropping closely followed by sole crop of elephant foot yam (Rs. 1, 96,350/- and 1.78, respectively). The results clearly showed that vegetable cowpea can be profitably intercropped with elephant foot yam.

Lyocks *et al.* (2013) conducted field experiment during the cropping seasons of 2009 and 2010 in Zaria, Nigeria to determine the most suitable maize population that would provide an appropriate advantageous shade to ginger without significantly affecting its yield or the yield of maize adversely. The results obtained by the researchers showed that the ginger growth parameters did not show any significant ($P \leq 0.05$) differences in the means among treatments in the trails. They reported that intercropping ginger with 24074 maize plants per hectare produced ginger rhizome yield of 10.84 tonnes per hectare which was significantly ($P \leq 0.05$) comparable with highest rhizomes yields of 14.08 tonnes per hectare obtained in sole ginger crop ($P \leq 0.05$). The 24,074 plants per hectare maize population density also produced the highest maize grain yield (3.98 tonnes per hectare) among the intercropped treatments.

Sangwan (2014) conducted research to study the physiological behaviour and yield evaluation of colocasia under agri-horti-silviculture system at new orchard of Department of Fruit Science, Punjab Agricultural University, Ludhiana. Net photosynthesis, stomatal conductance and transpiration in colocasia were higher in pear-kinnow combination than in highly shaded area of poplar ones. Results revealed that colocasia was better in performance under partial shade in yield and yield contributing parameters, and decreased as canopy advanced in age. These parameters showed inverse relationship with canopy age and *vice versa* with more yield reduction under sixth year old canopy followed by preceding years and control. The transpiration (E) rate of colocasia was lowest under shade conditions irrespective of the crop used in the experiment leading to more water use efficiency

in the shade conditions than in open. It is suggested that to minimize resource competition and improve physiological processes of crops, canopy management is essential to ensure better yield under pear-based agri-horti-silviculture system.

Naik (2015) conducted a research to investigate the effect of intercropping of vegetables in banana (*Musa* spp.). There were seven treatment *i.e.*; T1-Banana+Colocasia, T2-Banana+Elephant foot yam, T3-Banana+Arrow root, T4-Banana+Ginger, T5-Banana+Mango Ginger, T6-Banana+Turmeric, T7-Control (No Intercropping). From the experiment it was found that banana alone gave an yield of 29.63 t/ha. Whereas arrow root intercropped with banana gave the highest yield of 16.4 t/ha and banana 28.88t/ha and followed by elephant foot yam 13.5 t/ha and banana 29.75t/ha but the minimum yield was with ginger where a yield of 6.2 t/ha and banana 28.56 was obtained. Banana & Arrow Root intercropping yielded gross return of Rs.843200/ with a net profit of Rs. 3,98,750/- as compared to gross return of Rs.810900/ and net profit of Rs. 3,66,450/- with banana +turmeric and a gross return of Rs.4,44,450 and net profit of Rs. 1,95,750/- in control. Maximum B:C ratio of 2.38 was obtained in Banana + Arrow Root intercropping as compared to 2.29 with Banana+Turmeric & minimum in control *i.e.*; 1.78. From the above findings it can be concluded that banana cultivation can be commercially followed with Banana + Arrow Root intercropping profitably without decreasing the returns from banana cultivation alone.

Pundir (2016) conducted a research to study the effect of intercropping on yield and quality of ginger (*Zingiber officinale* Rosc.) in cv. Himgiri at Vegetable Research Farm of Department of Vegetable Science, Dr. YSPUHF, Nauni, Solan (HP) during 2015. From the present investigation it can be concluded that the higher yield of ginger cv. Himgiri was obtained when intercropped with Colocasia (163.49qha⁻¹) and Turmeric (158.73q ha⁻¹) at planting ratio 4:1 and Okra at planting ratio 4:1 (132.93q ha⁻¹), 3:2(123.82q ha⁻¹) and 2:2 (118.09q ha⁻¹) resulting in the net return ranging from Rs. 5,18,520 - 6,18,584(B:C 2.02 - 2.51) with increased returns of Rs. 46,750 - 1,46,814 (9.91 - 31.11%) over sole ginger crop (129.52q ha⁻¹) with net return of Rs. 4,71,770 (B:C 1.54), along with low incidence of rhizome rot(12.15 - 13.12%) and improved quality. Therefore, Ginger intercropped with dense shade providing crops Colocasia and Turmeric at planting

ratio 4:1 and lesser shade providing crop Okra at planting ratio 3:2 was found most remunerative.

Kumar *et al.* (2018) conducted an experiment which consisted of 4 treatments, where one with sole ginger as mono crop and in the remaining spinach, cauliflower and bitter gourd were included as intercrops with the ginger. The researchers found that sole crop of ginger recorded the highest performance for all the growth characters, yield attributes and yield. Ginger + spinach (mixed cropping) + cauliflower+ bitter gourd performed best in terms of the gross yield, net returns and B: C ratios.

2.4 Growth and Yield Attributes and Yield of Vegetable Crops under Intercropping Systems

Schultz *et al.* (1982) conducted an experiment in intercropping cucumbers and tomatoes in Southern Michigan, U.S.A. The land equivalent ratio (LER) was 1.14, that is, 14% more land would be needed to produce the same yield from two monocultures as from a unit area of intercrop. The intercrop advantage was statistically significant. They also reported that the relative yield totals averaged greater than 1, an indication that more than 1 ha of monocultures would be required to equal the production of 1 ha of polyculture.

Sharma *et al.* (1988) carried out a two years intercropping experiment on cabbage at IARI, New Delhi and observed that cultivation of broad bean between cabbage rows resulted highest head yield of cabbage (37.5 t/ha) followed by the same with pea but radish (cv. Pusa Himani) or turnip (cv. Purple Top White Globe) adversely affected the yield of cabbage.

Ahmed (1995) carried out a intercropping study in the farmers field at Farming System Research Site, Palima ,Tangail, Bangladesh during rabi season of 1987-88 and found that among different intercropping combinations cabbage + batisak (palak) produced higher yield after tomato + cabbage combination.

Meng and Zhou (1996) carried out an intercropping trial and found that when spring cabbage was intercropped with wheat, the cabbage plants were shaded by wheat which ultimately affected the growth and yield (25.7% less) of cabbage as

compared to monoculture. Intercrop cabbage produced more rosette leaves and fewer head leaves and led to lower photosynthetic rate, lower dry matter accumulation and less distribution of the same to heading leaves.

Patil et al. (2004) conducted a field study at Regional Fruit Research Station, Ganeshkhind, Pune during the *kharif* seasons of 1993-94, 1994-95 and 1995-96 on a cabbage based intercropping system and observed that cabbage + radish recorded highest yield of marketable heads (338.01q/ha) followed by cabbage + palak (247.49q/ha) intercropping system. Highest LER (1.57) and B: C ratio (2.45) was also recorded from cabbage+ radish intercropping system.

Cheng et al. (2014) studied growth, yield and quality of spring tomato and physicochemical properties of medium in a tomato/garlic intercropping system under plastic tunnel organic medium cultivation. They observed that no significant difference exists between the intercropping tomato and monoculture tomato in yield per plot, fruit number per plot, yield per plant, fruit number per plant and average single fruit weight. Intercropping garlic showed beneficial effects on tomato nutritional quality and also significantly increased the contents of titratable acid, vitamin C and dry matter of tomato fruit, but the treatment had no significant influence on the other nutritional quality indexes such as solid matter, soluble protein and soluble sugar.

Jett et al. (2015) reported intercropping systems for tomatoes within a high tunnel. Tomatoes were intercropped with lettuce (*Lactuca sativa* L.) and basil (*Ocimum basilicum* L.) within a high tunnel during a nine-month season in 2002 and 2003. They found that intercropped tomatoes exhibited no significant reduction in yield or average fruit size when intercropped with lettuce relative to monoculture tomatoes. Relay intercropping also did not significantly lower marketable yield or average fruit size of tomatoes within a high tunnel in 2003. Yield of relay planted tomatoes was \approx 15% higher than monoculture tomatoes. Over 70% of all marketable fruit was graded as US No. 1 with both monoculture and intercropped treatments. Thus, intercropping did not significantly lower fruit quality. Relay intercropping did not delay time to first harvest or reduce marketable lettuce yields relative to monoculture lettuce. The average weight of

intercropped lettuce is 7 oz ft⁻² (2478 g m⁻²). The intercrop value can then be divided by the average yield of a lettuce crop grown in a monoculture system. The average yield value for monoculture lettuce was 11 oz ft⁻² (3441 g m⁻²). Thus, the relative yield for lettuce is 0.52. The same procedure can be applied to the average yield of tomatoes resulting in a relative yield of 0.88. The result is a Land Equivalency Ratio or Relative Yield Total of 1.40 for the intercropping combination. Intercropping lettuce with tomatoes is 40% more efficient than growing the two crops individually. The combined RYT of both tomato crops and the lettuce/basil was 1.83, indicating that intercropping was ≈ 80% more efficient within a high tunnel relative to monoculture production of each crop.

2.5 Effect of Intercropping on Economics

Schultz *et al.* (1982) carried out an experiment in intercropping cucumbers and tomatoes in Southern Michigan, U.S.A. The mechanism affecting price (e.g. market conditions, cucumber grade distribution), to the extent that the per hectare dollar value of a tomato monoculture is equal to the per hectare dollar value of a cucumber monoculture, the polyculture is more likely to show an advantage. For our data, if the ratio between tomato and cucumber monoculture are between 0.91 and 1.17, the polyculture will give a better return.

Nandal (1982) carried out a field trial on cabbage based intercropping with different short duration vegetable crops and found that cabbage intercropped with radish gave higher income only when nitrogen level of 175kg ha⁻¹ was applied. Besides intercrops like spinach, beet and fenugreek also recorded better returns over cabbage pure crop whereas turnip as intercrop with cabbage was not found useful.

Quayyam *et al.* (1988) conducted a two years trial on cabbage based intercropping model where cabbage, spinach, leaf amaranth, tomatoes and onions were intercropped in different combinations. After perusal of the data it was found that profitability was highest when cabbage was intercropped with tomatoes.

Varghese *et al.* (1990) studied on intercropping of cabbage cv. Pride of India with some short duration vegetable and spice crops like beet root, radish, fenugreek, coriander, palak and sorrel. The cabbage yield was depressed in all cases

except with sorrel. However, cabbage+ radish and cabbage+ palak intercropping system recorded 33.25% and 25.22% more money returns respectively than control.

Singh (1993) conducted a field trial at Ranchi during 1987-88 to study feasibility of intercropping rainy season 'Pusa Sawani' okra with Contender French bean, local cowpea, Early Kunwari cauliflower, Muktakeshi brinjal and Arka Abha tomato. They found that okra+ cowpea combination recorded the highest land-equivalent ratio (1.3) followed by okra +cauliflower (1.2).They also found that cowpea intercropping also produced a significantly higher net return (Rs. 36824). Pure tomato gave the highest net profit followed by okra + cowpea intercropping. In okra based intercropping system, it was found that okra + cowpea intercropping system recorded a significantly higher net return (Rs. 36,824 ha⁻¹ as compared to other intercropping system and also okra as pure crop (Rs. 26,389 ha⁻¹). But pure cropping of tomato gave highest net profit (401%) followed by okra + cowpea (361%) as compared to other intercropping system as well as pure.

Ahmed (1995) carried out a intercropping study in the farmers field at Farming System Research Site, Palima,Tangail Bangladesh during rabi season of 1987-88 and found thatamong different intercropping combinations tomato + cabbage system recorded highest gross return (Tk103923 ha⁻¹),net return (Tk 80666 ha⁻¹) and benefit : cost ratio (4.47)followed by cabbage + batisak (palak) system.

Rahangdale *et al.* (1995) carried out a cabbage based intercropping trial with some short duration vegetable and spice crops like spinach, fenugreek , sorrel, coriander and radish and found that among different intercrops radish caused maximum reduction in growth and yield parameters of cabbage but recorded highest return (Rs 29692.20 ha⁻¹ compared to Rs.20485.20 ha⁻¹ in control).

Singh (1997) while conducting a field trial at Central Horticultural Experiment Station, Ranchi, to assess the production potential and economics of vegetables intercropped with cabbage, found that growing cabbage with fenugreek recorded highest monetary return (Rs. 71778 ha⁻¹) followed by that is with coriander (Rs. 71580 ha⁻¹) whereas sole crop of cabbage gave return of Rs. 61333 ha⁻¹.

Regarding net profit, it was highest (538.6%) in cabbage + coriander intercropping system followed by cabbage+ fenugreek (536.3%) system.

Rana *et al.* (1999) carried out a field experiment at IARI, New Delhi to assess the production potential, energetic and competition function of potato and linseed. Net return was highest (Rs 12800ha⁻¹) when every fourth row of potato interspaced 60 cm was replaced with 3 rows of linseed interspaced 20 cm. On the other hand net return/rupee (1.6) investment was maximum in sole linseed followed by 3:3 planting pattern (Rs 0.70).

Hussain (2003) studied the effect of intercropping on growth, yield and economic dynamics of vegetables in summer and winter vegetables. In summer, tomato was intercropped with okra, potato, com, chili and eggplant. Regarding competitive functions tomato + okra recorded maximum value for LER (2.41), followed by tomato + corn (1.81) intercropping system. Intercropping combination like tomato + eggplant recorded lowest LER value (1.20). The best companion of tomato was okra and their combination gave maximum net income of Rs. 134241ha⁻¹ due to maximum yield (27.61 t ha⁻¹) as compared to that in sole crop (20.34 t ha⁻¹) and high market price of both vegetables. Tomato + corn combination resulted highest net income of Rs. 12579 due to high yields of tomato in intercropping and stability of corn yield in both years. The maximum net income was also due to market price of tomato and corn. The least income (Rs.59486 ha⁻¹) has been recorded from intercropping tomato with potato due to high reduction in yield of both vegetables and high cost of production.

Ramamoorthy *et al.* (2004) conducted a field trial at Coimbatore, Tamil Nadu during *kharif* and *rabi* seasons of 2000-2003 under rainfed conditions to study the performance of pigeon pea and finger millet in intercropping system. They found that raising of short duration pigeon pea (var. VBN-1) as an intercrop with short duration finger millet (var. CO- 11) recorded highest net return (Rs 15,287.00) and B:C ratio (4.38).

Cheng *et al.* (2014) studied growth, yield and quality of spring tomato and physicochemical properties of medium in a tomato/garlic intercropping system under plastic tunnel organic medium cultivation. The net income of the

intercropping mode ($\$22886 \text{ ha}^{-1}$) was 12.3% higher than that of the monoculture mode ($\$20378 \text{ ha}^{-1}$), despite the slightly negative impact of intercropping on the tomato yield due to competition for water, space and nutrition. The increased net income in the intercropping mode was mainly composed of the additional harvest of garlic bolts and bulbs.

CHAPTER-III

MATERIALS AND METHODS

This chapter deals with the description of the material used and various techniques or methods adopted throughout the course of investigation “Studies on vegetable based intercropping system in solid soilless media under protected condition”. The study was conducted during *Kharif* (July-December), 2017 under Naturally Ventilated Polyhouse at Centre of Excellence on Protected Cultivation and Precision Farming, Department of Vegetable Science, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh.

3.1 Experimental Site

The experiment was carried out during the *kharif* 2017 under the Naturally Ventilated Polyhouse number 3 at Centre of Excellence on Protected Cultivation and Precision Farming, Department of Vegetable Science, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh.

3.2 Geographical Situation

Raipur was the place of investigation and is situated in the central part of the Chhattisgarh state at 21°16' N latitude, 81°36' E longitude and at an altitude of 289.56 m from mean sea level. The location comes under the seventh agro-climatic zone of India that is eastern plateau and hills.

3.3 Climate

Raipur is a sub-humid region. The average annual rainfall ranges between 1200-1400 mm, out of which about 85 percent is received from third week of June to mid-September and occasional very little during winter and summer seasons. The pattern of rainfall, particularly during June to September months has great variation from year to year, May is the hottest month (46°C) and December is the coolest (6°C) month of the year. The average maximum temperature is 42.8°C and minimum temperature recorded 10.1°C respectively. According to meteorological

observation during the crop season of this investigation April is the hottest and December is the coolest month.

The meteorological observations recorded during the crop growth period by the meteorological observatory, IGKV, Raipur are presented in Appendix A and Fig 3.1 and Appendix B and Fig 3.2.

Fig.3.1: Metrological observations during crop growth period in outside environment condition

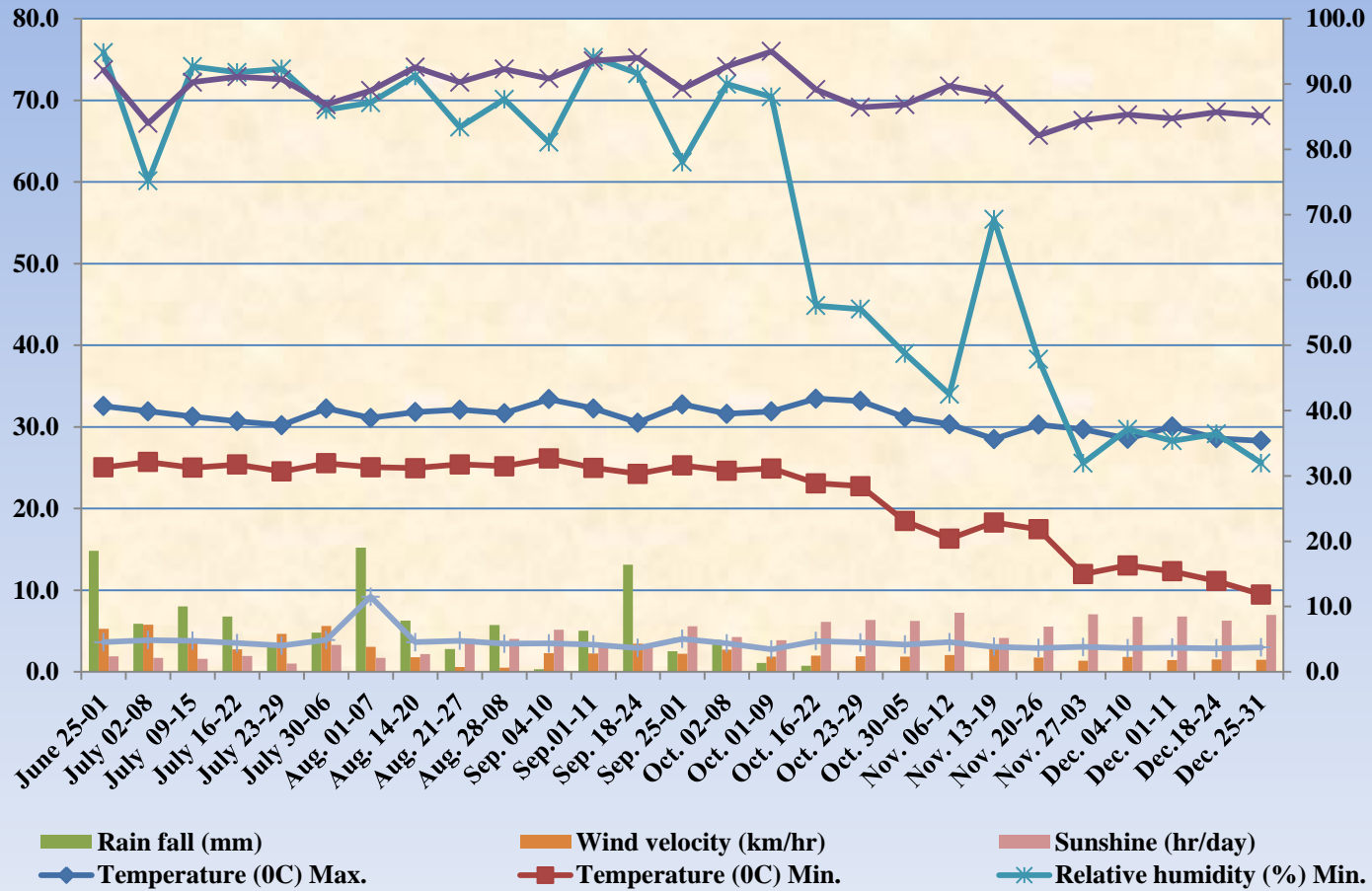
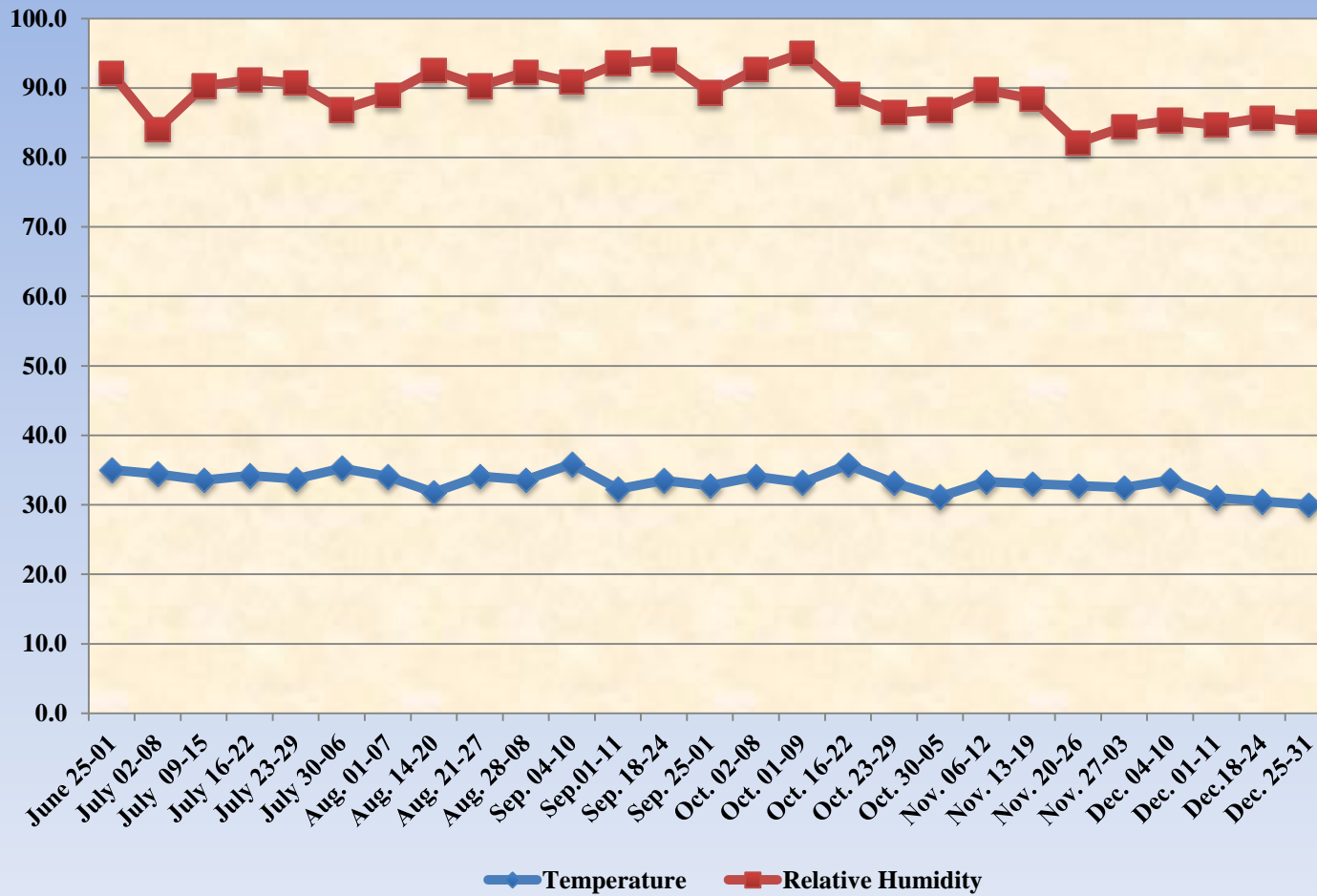


Fig.3.2: Meteorological data on temperature and relative humidity inside the naturally ventilated polyhouse



3.4 Experimental Details

The details of the experiment, treatments and layout of the experiment are given in Table 3.1, Table 3.2 and Fig. 3.3 and Fig. 3.4 respectively. Each replication consisted of eight troughs. Each 9 m trough in each plot consisted of ten plants and total eighty plants in each plot of sole crop in case of sole tomato, sole elephant foot yam, sole colocasia, sole turmeric and sole ginger. In case of intercropped plot, each line consisted of ten tomato plants and nine intercrop plants and total one fifty two plants in each plot.

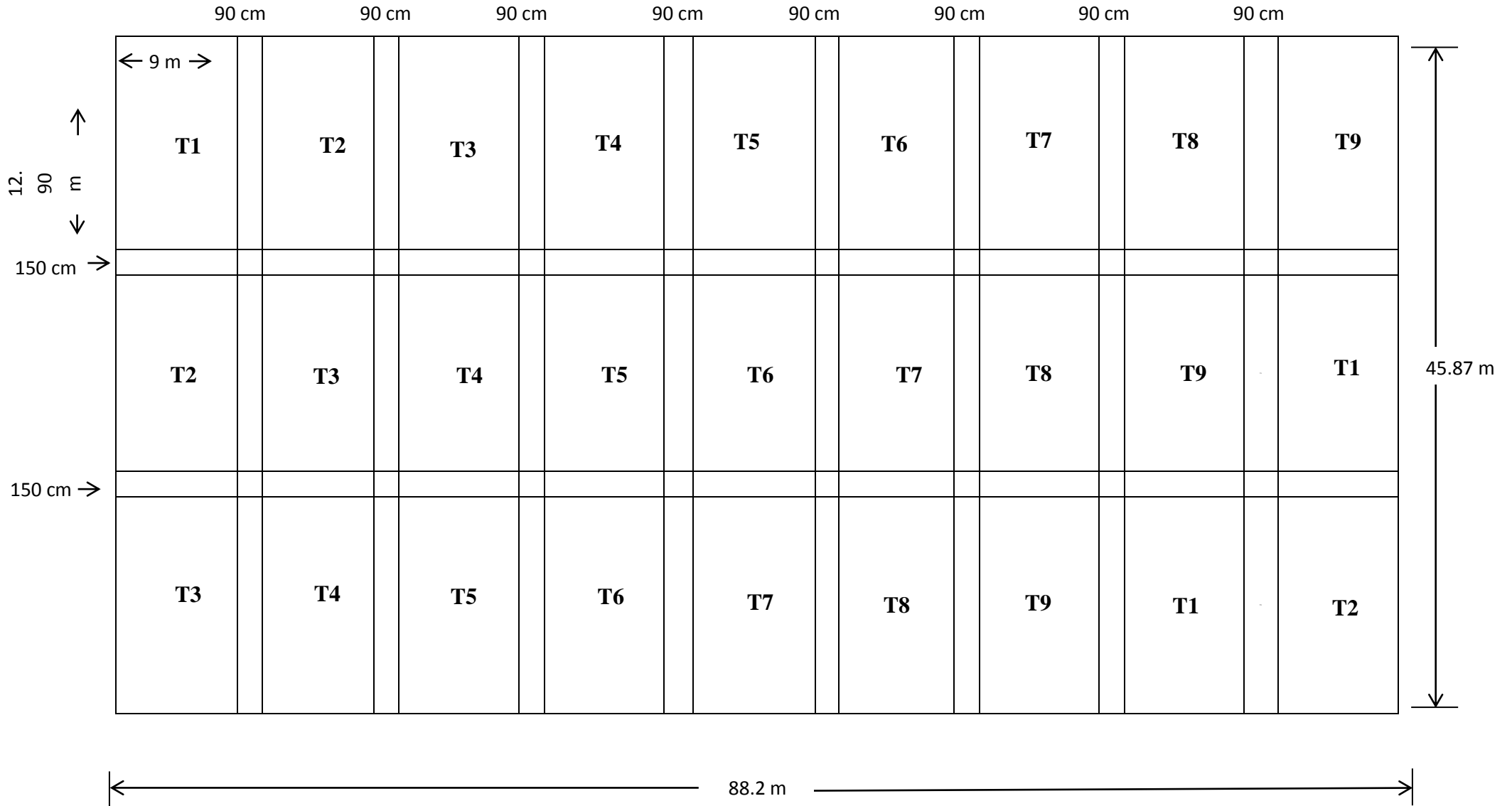
Table 3.1: Experimental details

| Particulars | Details |
|---------------------|--|
| Main crop | : Tomato |
| Intercrops | : Elephant Foot Yam, Colocasia, Turmeric , Ginger |
| Experimental Design | : Completely Randomized Design |
| Replication | : 03 |
| Spacing | : Trough to Trough- 150 cm Plant to Plant-90 cm (For Sole crops) Intercrops were planted within plant to plant spacing of tomato |

Table 3.2: Treatment details

| Notation | Treatment |
|----------------|------------------------------------|
| T ₁ | Sole Tomato (Yuvraj) |
| T ₂ | Sole Elephant Foot Yam (Gajendra) |
| T ₃ | Sole Colocasia (Kawardha Kochai 1) |
| T ₄ | Sole Turmeric (Suranjana) |
| T ₅ | Sole Ginger (Suprabha) |
| T ₆ | Tomato + Elephant Foot Yam |
| T ₇ | Tomato+ Colocasia |
| T ₈ | Tomato +Turmeric |
| T ₉ | Tomato + Ginger |

Fig.3.3: Layout plan



T1-Sole tomato;**T2**-Sole elephant foot yam;**T3**-Sole colocasia;**T4**- Sole turmeric;**T5**-Sole ginger;**T6**-Tomato + EFY;**T7**-Tomato + colocasia;**T8**-Tomato + turmeric;**T9**-Tomato + ginger

3.5 Characteristics of the Media

The major properties of coir pith are its high water holding capacity that is 6-8 times than its weight with excellent moisture retention even after drying. It has slow degradation due to high lignocellulosic bonding and it stores and releases nutrients over extended periods of time because of high porosity. It is 100% degradable, organic and a renewable resource and contains natural substances beneficial for plant growth.

3.6 Details of Cultural Practices

3.6.1 Description of naturally ventilated polyhouse used for the experiment

The preparation of field was done by cultivator followed by two cross-harrowing to pulverize the soil. To enrich the soil, well rotten FYM was applied after harrowing and well-mixed with the soil by planking. The field was levelled with planker. Finally ridge was made and lateral pipe of drip system is applied above the ridge and plastic mulch lay down before one week of transplanting.

3.6.2 Raising of planting material

The seeds of the indeterminate hybrid tomato Yuvraj were sown in plastic pro trays by using soilless media having coco peat inside the primary nursery of the centre on 5th May, 2017 to get healthy and disease free seedlings of tomato. The seedlings were ready for transplanting nearly after one month of sowing and were subsequently transplanted inside the naturally ventilated polyhouse equipped with drip irrigation system.

The propagules of the intercrops *viz.*, elephant foot yam (Gajendra), colocasia (Kawardha Kochai 1), turmeric (Suranjana) and ginger (Suprabha) were also sprouted in the secondary nursery on sand layer mixed with cocopeat. Water sprinkled over the propagules as and when required. 500 g of tuber of elephant foot yam, 20-25 g of colocasia, ginger and turmeric were used as planting material. Before planting, the seed material was treated with Bavistin @ 1.0g /litre of water.

3.6.3 Transplanting

Eighteen days old healthy seedlings were transplanted under naturally ventilated polyhouse by adopting a spacing of 150 cm between rows and 90 cm between plant to plant on 15th July, 2017.

The planting materials of the intercrops were transplanted 2 weeks later in between the main crop, having a distance of 45 cm from the plant in a row on 23rd July, 2017.

3.6.4 Application of irrigation, manure and fertilizers

Water soluble fertilizers were given through foliar spray, as well as through automated drip irrigation during entire crop growth period, starting three weeks after transplanting at the interval of two fertigation per week for 28 weeks with several types of fertilizers. The quantity of water required for fertigation was about half litre per plant and it was applied manually. EC and pH of the fertilizer mixture solution was maintained at 1.23 - 1.25 mmhose per cm² and its pH at 5 for avoiding adverse effect. The amount of water required for drip irrigation for 1 acre is 200 litres.

3.6.5 Plant protection measures

Plant protection measures were applied to control pest and diseases during crop period in tomato under poly house. The details of the measures are as followed.

Table 3.3: The details of pest and diseases and chemicals sprayed in tomato and intercrops

| Sl. No. | Pest/disease | Casual organism | Chemical sprayed | Dosage |
|---------|----------------------|------------------------------|------------------|---------|
| 1. | White fly | <i>Bemisia tabaci</i> | Triazophos | 1 ml/L |
| 2. | Cercospora leaf Spot | <i>Cercospora capsici</i> | Mancozeb 75% WP | 2.5 g/L |
| 3. | Thrips | <i>Scirtothrips dorsalis</i> | Fipronil 5% SC | 2 ml/L |

3.6.6 Harvesting

The harvesting of the tomato crop was started on 27th September, 2017 and the intercrops were harvested from 25th December to 31st December 2017.

3.7 Observations Recorded

Observations were recorded on single plant basis from five randomly selected competitive plants per plot of each crop for all the treatments separately.

3.7.1 Tomato

3.7.1.1 Plant height (cm)

The height of five randomly selected tomato plants was recorded in centimeter from the ground level to the shoot tip of the main stem at the time of maturation and the average height (cm) per plant was measured.

3.7.1.2 Number of fruits cluster⁻¹

Number of fruits per cluster was counted before the first picking, three fruit bunches were chosen in each of tagged plant to calculate the average number of fruits per cluster.

3.7.1.3 Number of fruits plant⁻¹

The number of fruits per plant on each of the randomly selected five plants were counted from first picking to last picking and averaged.

3.7.1.4 Days to first fruit harvest

Days to fruit maturity was recorded as number of days from transplanting to when fruit of the treatment (plant) is suitable for consumption in each plot.

3.7.1.5 Average fruit weight (g)

Weight of five tomato fruits was recorded in gram from five randomly selected plants in each replication and then averaged.

3.7.1.6 Fruit yield plant⁻¹ (kg)

The weight of fruits of five selected tomato plants was recorded under full range of pickings was added and averaged by dividing with the number of plants to get total yield per plant.

3.7.1.7 Total fruit yield (q acre⁻¹)

The total yield of fruits of all the pickings from each plot was calculated in kilogram and converted to quintals per acre the help of the following formula:

$$\text{Fruit yield (q acre}^{-1}\text{)} = \frac{\text{Weight of fruit (kg plot}^{-1}\text{)} \quad 4046}{\text{Net plot area (sq.m.)} \quad 100} \times \text{-----}$$

3.7.1.8 Total fruit yield (q ha⁻¹)

The total yield of fruits of all the pickings from each plot was calculated in kilogram and converted to quintals per hectare with the help of the following formula:

$$\text{Fruit yield (q ha}^{-1}\text{)} = \frac{\text{Weight of fruit (kg plot}^{-1}\text{)} \quad 10000}{\text{Net plot area (sq.m.)} \quad 100} \times \text{-----}$$

3.7.2 Elephant Foot Yam

3.7.2.1 Plant height (cm)

Height of the elephant foot yam plants was measured with the help of meter scale from base of pseudostem to the top of the leaf at 180 days after planting. Average height was calculated and expressed in centimeters.

3.7.2.2 Number of shoots plant⁻¹

Number of shoots of each randomly selected elephant foot yam plants was counted at 180 days after planting and average was calculated and expressed in numbers.

3.7.2.3 Weight of corms plant⁻¹ (kg)

The observations on corm yield per plant were recorded at the time of harvesting with the help of physical balance and expressed in kilogram.

3.7.2.4 Corm yield plant⁻¹ (kg)

The corm yield per plant was recorded at the time of harvesting in kilograms.

3.7.2.5 Total corm yield (q acre⁻¹)

The total yield of corm from each plot was calculated in kilogram and converted to quintals per acre the help of the following formula:

$$\text{Corm yield (q acre}^{-1}\text{)} = \frac{\text{Weight of corm (kg plot}^{-1}\text{)} \quad 4046}{\text{Net plot area (sq.m.)} \quad 100} \times \text{-----}$$

3.7.2.6 Total corm yield (q ha⁻¹)

The total yield of corm from each plot was calculated in kilogram and converted to quintals per hectare the help of the following formula:

$$\text{Corm yield (q ha}^{-1}\text{)} = \frac{\text{Weight of corm (kg plot}^{-1}\text{)} \quad 10000}{\text{Net plot area (sq.m.)} \quad 100} \times \text{-----}$$

3.7.3 Colocasia

3.7.3.1 Plant height (cm)

The height of the plant of the five tagged colocasia plants was recorded from the ground level to the base of the highest leaf.

3.7.3.2 Number of tillers plant⁻¹

The numbers of the tillers per plant were recorded of the five randomly tagged plants and the mean value was calculated.

3.7.3.3 Number of cormels plant⁻¹

Numbers of cormels were counted from the five tagged plants after harvesting and the mean value was calculated as number of cormels per plant.

3.7.3.4 Weight of cormels plant⁻¹ (g)

Weight of corm of colocasia was recorded after harvesting from each treatment of the five randomly tagged plants and the average value was calculated.

3.7.3.5 Total tuber yield (q acre⁻¹)

The tuber yield including corm and cormels of all treatments in each replication was recorded on net plot basis and the total tuber yield in quintals per acre was calculated using the formula:

$$\text{Tuber yield (q ha}^{-1}\text{)} = \frac{\text{Weight of tuber (kg plot}^{-1}\text{)} \quad 4046}{\text{Net plot area (sq.m.)} \quad 100} \times \text{-----}$$

3.7.3.6 Total tuber yield (q ha⁻¹)

The tuber yield including corm and cormels of all treatments in each replication was recorded on net plot basis and the total tuber yield in quintals per hectare was calculated using the formula:

$$\text{Tuber yield (q ha}^{-1}\text{)} = \frac{\text{Weight of tuber (kg plot}^{-1}\text{)} \quad 10000}{\text{Net plot area (sq.m.)} \quad 100} \times \text{-----}$$

3.7.4 Turmeric

3.7.4.1 Plant height (cm)

The height of the plant of the five tagged turmeric plants was measured from the ground level to the main stem apex. The average was worked out to obtain the average height per plant.

3.7.4.2 Number of tillers plant⁻¹

The number of tillers of each plant was counted from the randomly selected plants in each plot at 180 days after planting. The average was worked out and expressed as number of tillers per plant.

3.7.4.3 Rhizome yield plant⁻¹ (g)

The fresh weights of rhizomes from five selected plants were recorded treatment wise through the electronic weight balance. The average weight of rhizomes per plant was calculated.

3.7.4.4 Total rhizome yield (q acre⁻¹)

The yield of fresh rhizomes per plot was recorded by taking the weight of the entire produce harvested from the plot and the data expressed in kilogram. The yield per acre of experimental plants was calculated in quintals per hectare by using the formula:

$$\text{Total rhizome yield (q acre}^{-1}\text{)} = \frac{\text{Weight of rhizomes (kg plot}^{-1}\text{)} \quad 4046}{\text{Net plot area (sq.m.)} \quad 100} \times \text{-----}$$

3.7.4.5 Total rhizome yield (q ha⁻¹)

The yield of fresh rhizomes per plot was recorded by taking the weight of the entire produce harvested from the plot and the data expressed in kilogram. The yield per hectare of experimental plants of turmeric was calculated in quintals per hectare by using the formula:

$$\text{Total rhizome yield (q ha}^{-1}\text{)} = \frac{\text{Weight of rhizomes (kg plot}^{-1}\text{)} \quad 10000}{\text{Net plot area (sq.m.)} \quad 100} \times \text{-----}$$

3.7.5 Ginger

3.7.5.1 Plant height (cm)

For collection of height data, five ginger plants were randomly tagged in each plot and their heights were measured from the ground level to the terminal leaf using a ruler at 180 days after planting. The data that was collected were computed and the average height of the plant was determined.

3.7.5.2 Number of tillers plant⁻¹

The number of tillers of each plant was counted from the randomly selected plants in each plot at 180 days after planting. The average value was worked out and expressed as number of tillers per plant.

3.7.5.3 Rhizome yield plant⁻¹ (g)

The fresh weights of the rhizomes from the five randomly selected plants were recorded at the time of harvesting and the average yield per plant was estimated in grams.

3.7.5.4 Total rhizome yield (q acre⁻¹)

The yield of fresh rhizomes per plot was recorded by taking the weight of the entire produce harvested from the plot and the data expressed in kilogram. The yield per acre of experimental plants was calculated in quintals per hectare by using the formula:

$$\text{Total rhizome yield (q acre}^{-1}\text{)} = \frac{\text{Weight of rhizomes (kg plot}^{-1}\text{)} \quad 4046}{\text{Net plot area (sq.m.)} \quad 100} \times \text{-----}$$

3.7.5.5 Total rhizome yield (q ha⁻¹)

The yield of fresh rhizomes per plot was recorded by taking the weight of the entire produce harvested from the plot and the data expressed in kilogram. The yield per hectare of experimental plants was calculated in quintals per hectare by using the formula:

$$\text{Total rhizome yield (q ha}^{-1}\text{)} = \frac{\text{Weight of rhizomes (kg plot}^{-1}\text{)} \quad 10000}{\text{Net plot area (sq.m.)} \quad 100} \times \text{-----}$$

3.8 Statistical Analysis

The data collected from polyhouse observation were subjected to statistical t-test and analysis of variance technique as described in “Statistical procedure for Agriculture Research” by Gomez and Gomez (1985).

3.8.1 T test: It was calculated by using following formula:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{s^2 \left[\frac{1}{n_1} + \frac{1}{n_2} \right]}}$$

Where,

\bar{x}_1 = mean of sample 1

\bar{x}_2 = mean of sample 2

n_1 = number of subjects in sample 1

n_2 = number of subjects in sample 2

s^2 = variance of sample

However, the degree of freedom is altered to compensate the heterogeneity of variances. The degree of freedom associated with this t is $\frac{1}{2} (n_1 + n_2) - 1$.

3.8.2 Analysis of variance

The growth parameters, yield parameters and yield of tomato in sole tomato and different intercropping systems were tabulated and subjected to the analysis of variance.

Table 3.4 Skeleton of ANOVA

| Source of variation | Degree of freedom | Sum of squares | Mean Squares | Computed <i>F</i> value | Tabular F (0.05) |
|---------------------|-------------------|----------------|----------------|-------------------------|-------------------------|
| Treatment | (t-1) | TrSS | TrMS = TrSS/df | | |
| Error | t(r-1) | ESS | EMS = ESS/df | | |
| Total | rt-1 | TSS | | | |

The following formulae were used for calculating the standard error and critical difference.

(a) $S.E.m \pm = \sqrt{EMS/r}$

(b) $C.D. = S.E.m \times \sqrt{2} \times t (p=0.01) \text{ at error d.f.}$

Where, r = Number of replication M.S. = Mean sum of square, t = Number of treatments, S.E.m \pm = Standard error of mean, d.f. = Degree of freedom EMS = Error mean squares, S.S. = Sum of square and C.D. = Critical difference.

3.9 Calculation of Tomato Equivalent Yield

The data collected from polyhouse observation on yield of different intercrops were converted to tomato equivalent yield by following formula:

$$\text{Tomato equivalent yield (q acre}^{-1}\text{)} = \frac{\text{Yield of intercrop (q acre}^{-1}\text{)} \times \text{Price of intercrop (Rs q}^{-1}\text{)}}{\text{Price of tomato (Rs acre}^{-1}\text{)}}$$

The same formula for calculating was used by Talukder *et al.* (2015) for calculating onion equivalent yield, by Kushwah *et al.* (2011) for calculating potato equivalent yield and by Ghosh *et al.* (2009) for calculating soybean equivalent yield.

3.10 Land Equivalent Ratio

It is defined as the summation of the ratio of the yields of the given crop in an intercrop system to its yield as a sole crop (Mead and Willey, 1980). It was calculated by the following formula:

$$LER = \sum y_{ij}/y_{ii}$$

Where,

Y_{ij} = yield of crop in intercropping system

Y_{ii} = yield of the crop in sole cropping system

3.11 Economics

Studies on economics of production was made by keeping a record on operations carried out, number of labors engaged, power and input utilized. The standard cost of cultivation was calculated as per rates fixed by government and IGKV. Gross returns per acre, net return per acre and benefit: cost ratios were worked out as per the following formula.

3.11.1. Total gross return (acre⁻¹)

$$\text{Gross return} = \text{Yield (q acre}^{-1}\text{)} \times \text{Price of yield (q acre}^{-1}\text{)}$$

3.11.2 Net return (acre⁻¹)

$$\text{Net return (acre}^{-1}\text{)} = \text{Gross return (₹acre}^{-1}\text{)} - \text{Cost of cultivation (₹ acre}^{-1}\text{)}$$

3.11.3 Benefit: cost ratio

$$\text{Benefit : Cost ratio} = \frac{\text{Gross return (acre}^{-1}\text{)}}{\text{Cost of cultivation (acre}^{-1}\text{)}}$$



Plate no. 3.1: Overview of the polyhouse



Plate no. 3.2: Tomato + Elephant foot yam intercropping system



Plate no. 3.3: Tomato + Colocasia intercropping system



Plate no. 3.4: Tomato + Turmeric intercropping system



Plate no. 3.5: Tomato + Ginger intercropping system



Plate no. 3.6: Harvesting of tomato



Plate no. 3.7: Harvested elephant foot yam corm



Plate no. 3.8: Harvested colocasia corm



Plate no. 3.9: Elephant foot yam in storage



Plate no. 3.10: Ginger in storage



Plate no. 3.11: Packing of colocasia before sending to market



Plate no. 3.12: Packing of turmeric before sending to market

CHAPTER- IV

RESULTS AND DISCUSSION

A polyhouse experiment entitled “Studies on Vegetable Based Intercropping System in Solid Soilless Media under Protected Condition” was conducted during *kharif* (July-December), 2017 under Naturally Ventilated Polyhouse at Centre of Excellence on Protected Cultivation and Precision Farming, Department of Vegetable Science, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh. The data has been recorded and analyzed on various parameters of crop growth, yield attributing characters, yield and economic parameters. The results and discussion of the experiment are briefly described in this chapter under the following heads:

4.1 Effect of Intercropping on Growth and Yield Parameters of Different Intercrops

4.1.1 Effect of intercropping on growth, yield parameters and yield of tomato

Data pertaining to the growth and yield parameters of tomato as affected by the different intercropping systems has been presented in the Table 4.1.

After perusal of the data, it was observed that the plant height did not vary significantly with the differences in treatment combinations. Though among different intercropping systems, highest plant height (269 cm) was recorded in sole tomato followed by 263 cm in tomato + turmeric, 261 cm in tomato + ginger, 256 cm in tomato + colocasia and 254 cm in tomato + elephant foot yam intercropping system. The plant heights of tomato in different intercropping system were *at par* with the plant height of sole tomato (269 cm).

Number of fruits cluster⁻¹ of tomato plant was highest in sole tomato which registered the value of 8.14 fruits cluster⁻¹ followed by tomato + turmeric (7.57), tomato + ginger (7.33) and tomato + elephant foot yam (7.26). The numbers of fruits cluster⁻¹ in was lowest in the tomato + colocasia intercropping system (7.11). There is highly significant difference in the number of fruits cluster⁻¹ between sole tomato and tomato + elephant foot yam, tomato + colocasia, tomato + ginger, while, for the same trait the performance of tomato + turmeric intercropping system was *at par* with sole tomato.

Results related to the number of fruits plant⁻¹ showed that, the sole tomato registered highest number of fruits plant⁻¹ (64.07) followed by tomato + turmeric intercropping system (58.66), tomato + ginger intercropping system (58.84) and tomato + colocasia intercropping system (56.81), while, the lowest number of fruits plant⁻¹ was observed in the tomato + elephant foot yam intercropping system (55.74 fruits plant⁻¹). It was observed that there was no significant difference regarding the parameter in sole tomato and other intercropping system.

After evaluation of data related to days to first fruit harvest it was observed that tomato + elephant foot yam took the highest duration for the first fruit harvest (97.93 days) followed by tomato + colocasia (96.24 days), tomato + turmeric (94.27 days) and tomato + ginger (91.32 days) as compared to the sole tomato which took 88.00 days for the first fruit harvest.

Analyzed data pertaining to the average fruit weight of tomato in different intercropping systems revealed that tomato + elephant foot yam intercropping system registered the lowest value (117.44 g). The value for average fruit weight in intercropping systems viz., tomato + colocasia (119.74 g), tomato + turmeric (120.58 g) and tomato + ginger (121.46 g) were statistically *at par* with the average fruit weight of sole tomato (127.92 g), which was highest among all the treatments.

From the results, it is apparent that intercropping had significantly affected fruit yield plant⁻¹ in tomato in different treatment combinations as compared to the sole crop. The highest fruit yield plant⁻¹ was observed in sole tomato (8.17 kg) followed by 7.12 kg in tomato + ginger intercropping system, 7.02 kg in tomato + turmeric intercropping system, 6.72 kg in tomato + colocasia intercropping system and 6.47 kg in tomato + elephant foot yam intercropping system. Significant difference was observed among sole tomato and other intercropping systems.

Maximum fruit yield of 242.31 q acre⁻¹ (605.76 q ha⁻¹) was obtained with sole cropping due to no competition from component crop and maximum resource utilization by tomato. Among different intercropping systems, highest value for total fruit yield of tomato has been obtained with tomato + ginger intercropping systems (211.17 q acre⁻¹ or 527.92 q ha⁻¹) while the lowest value of total fruit yield

of tomato was registered by the tomato + elephant foot yam intercropping system (191.69 q acre⁻¹ or 479.23 q ha⁻¹). Total fruit yield of 199.32 q acre⁻¹ (498.29 q ha⁻¹) and 208.17 q acre⁻¹ (520.41 q ha⁻¹) were reported under tomato + colocasia intercropping system and tomato + turmeric intercropping system, respectively. Analysis of the yield data showed that the total fruit yield acre⁻¹ registered by tomato + elephant foot yam, tomato + colocasia, tomato + turmeric and tomato + ginger intercropping system were significantly low than the sole crop.

Zero competition for the resources at early growth phases were the congenial factors which might have triggered the process of partitioning photosynthates from source to sink resulting in higher yield of main crop. The experimental results revealed that the inclusion of any of the intercrops reduced the yield of main crop. Similar negative effect of white mustard on greenhouse tomato productivity was observed by Tringovska *et al.* (2015) and Hartz *et al.* (2005). Some authors explained it with a competition between the two species for water, nutrients, light, etc. (Teasdale and Abdul-Baki, 1998).

Table 4.1: Effect of intercropping on growth, yield parameters and yield of tomato

| Particulars | Plant height (cm) | Number of fruits cluster ⁻¹ | Number of fruits plant ⁻¹ | Days to first fruit harvest | Average fruit weight (g) | Fruit yield plant ⁻¹ (kg) | Total fruit yield (q acre ⁻¹) | Total fruit yield (q ha ⁻¹) |
|--|-------------------|--|--------------------------------------|-----------------------------|--------------------------|--------------------------------------|---|---|
| Sole tomato | 269 ^a | 8.14 ^a | 64.07 ^a | 88.00 ^a | 127.92 ^a | 8.17 ^a | 242.31 ^a | 605.76 ^a |
| Tomato+ elephant foot yam | 254 ^a | 7.26 ^b | 55.47 ^a | 97.93 ^a | 117.44 ^a | 6.47 ^b | 191.69 ^b | 479.23 ^b |
| Tomato+ colocasia | 256 ^a | 7.11 ^{cb} | 56.81 ^a | 96.24 ^a | 119.74 ^a | 6.72 ^{cb} | 199.32 ^{cbe} | 498.29 ^{cb} |
| Tomato+ turmeric | 263 ^a | 7.57 ^{abce} | 58.66 ^a | 94.27 ^a | 120.58 ^a | 7.02 ^{dc} | 208.17 ^{dce} | 520.41 ^{cde} |
| Tomato+ ginger | 261 ^a | 7.33 ^{ebc} | 58.84 ^a | 91.32 ^a | 121.46 ^a | 7.12 ^{ecd} | 211.17 ^{ecd} | 527.92 ^{ec} |
| C.D. ($\alpha=0.05$) | 21.54 | 0.39 | 5.68 | 7.39 | 7.47 | 0.29 | 8.62 | 21.65 |
| p-value | 0.572 | 0.01** | 0.058 | 0.081 | 0.089 | 0.001*** | 0.001*** | 0.001*** |

**=Significant at 0.01

***=Significant at 0.001

N.B.=Treatments sharing the same superscript are not significantly different, while treatments with different superscript are different.

4.1.2 Effect of intercropping on growth, yield parameters and yield of elephant foot yam

After perusal of data pertaining to growth and yield parameters of elephant foot yam, as presented in Table 4.2, it was observed that sole elephant foot yam registered pseudostem height of 85.97 cm, 1.26 shoots plant⁻¹, and 2.36 kg corm plant⁻¹, while it was 77.32 cm pseudostem height, 1.06 number of shoots and 1.68 kg corm plant⁻¹ in the intercropping system. 70.12 q acre⁻¹ (175.29 q ha⁻¹) yield were obtained in the sole elephant foot yam while, 50.05 q acre⁻¹ and (125.12 q ha⁻¹) yield were obtained in the elephant foot yam intercropped with tomato.

From the results, it is apparent that among different parameters *viz.*, plant height, weight of corms plant⁻¹, total corm yield in acre and total corm yield in hectare of elephant foot yam intercropped with tomato varied significantly as compared to the sole elephant foot yam, while, the number of shoots plant⁻¹ of the elephant foot yam intercropped with tomato was statistically *at par* with the sole elephant foot yam. Results from this experiment are in consonance with the findings of Chattopadhyay *et al.* (2008) and Sen *et al.* (1993).

Table 4.2: Effect of Intercropping on Sole Elephant Foot Yam and Tomato+ Elephant Foot Yam

| Characters | Sole elephant foot yam | Tomato+ elephant foot yam | t-value | p- value |
|--|------------------------|---------------------------|---------|----------|
| Plant height (cm) | 85.97 | 77.32 | 8.43 | 0.004* |
| Number of shoots plant ⁻¹ | 1.2 | 1.0 | 2.12 | 0.101 |
| Weight of corms plant ⁻¹ (kg) | 2.36 | 1.68 | 5.09 | 0.032* |
| Total corm yield (q acre ⁻¹) | 70.12 | 50.05 | 5.09 | 0.032* |
| Total corm yield (q ha ⁻¹) | 175.29 | 125.12 | 5.09 | 0.032* |

*-significant value

4.1.3 Effect of intercropping on growth, yield parameters and yield of colocasia

After evaluation of data presented in Table 4.3, it was observed that colocasia plants in the sole cropping registered 98.33 cm plant height, 8.2 number of tillers plant⁻¹, 22.93 numbers of cormels plant⁻¹ and 524.16 g of cormels plant⁻¹, while, colocasia plants intercropped with tomato registered 90.24 cm plant height, 6.2 number of tillers plant⁻¹, 17.20 numbers of cormels plant⁻¹ and 392.62 gm of cormels plant⁻¹. 15.53q acre⁻¹(38.82q ha⁻¹) yield were obtained in the sole colocasia while, 11.63 q acre⁻¹(29.08 q ha⁻¹) yield were obtained in the colocasia intercropped with tomato.

Analysis of the data (Table 4.3) showed significant difference with respect to different parameters of sole colocasia *viz.*, plant height, number of cormels plant⁻¹, weight of cormels plant⁻¹, total tuber yield acre⁻¹ and total tuber yield ha⁻¹. This result is supported by the earlier findings of Sivan (1984), who observed the similar type of results in colocasia based intercropping systems with okra, corn, longbean and cowpea.

Table 4.3: Effect of intercropping on sole colocasia and tomato+ colocasia

| Characters | Sole colocasia | Tomato+ colocasia | t-value | p-value |
|---|----------------|-------------------|---------|---------|
| Plant height (cm) | 98.33 | 90.24 | 5.14 | 0.006* |
| Number of tillers plant ⁻¹ | 8.00 | 6.00 | 5.22 | 0.007* |
| Number of cormels plant ⁻¹ | 22.93 | 17.20 | 4.79 | 0.018* |
| Weight of cormels plant ⁻¹ (g) | 524.16 | 392.62 | 9.46 | 0.001* |
| Total tuber yield (qacre ⁻¹) | 15.53 | 11.63 | 9.46 | 0.001* |
| Total tuber yield (q ha ⁻¹) | 38.82 | 29.08 | 9.46 | 0.001* |

*-significant value

4.1.4 Effect of intercropping on growth, yield parameters and yield of turmeric

From the assessment of the data from Table 4.4, it is evident that higher values for all the growth and yield parameters were recorded in sole turmeric as compared to the turmeric crop intercropped with tomato. Sole turmeric registered 66.38 cm plant height, 3.8 numbers of tillers plant⁻¹, 439.83 g rhizome plant⁻¹, 13.03 q acre⁻¹ (32.57qha⁻¹) of total rhizome yield, while, the turmeric intercropped with tomato registered 52.89 cm plant height, 2.8 number of tillers plant⁻¹, 389.09 g rhizome plant⁻¹, 11.53 q acre⁻¹ (28.82 qha⁻¹) of total rhizome yield. There was significant variation for all the parameters of turmeric intercropped with tomato as compared to the sole crop.

The cause might be due to less competition for nutrients which resulted in flourishing of more photosynthetically active leaf area which in turn led to greater translocation of assimilates from source to sink which ultimately increased the yield of sole turmeric. These results are in accordance with the findings of Sivaraman and Palaniappan (1994) in maize and turmeric intercropping system.

Table 4.4: Effect of intercropping on sole turmeric and tomato+ turmeric

| Characters | Sole turmeric | Tomato+ turmeric | t-value | p- value |
|---|---------------|------------------|---------|----------|
| Plant height (cm) | 66.38 | 52.89 | 6.00 | 0.004* |
| Number of tillers plant ⁻¹ | 3.80 | 2.80 | 6.12 | 0.003* |
| Rhizome yield plant ⁻¹ (g) | 439.83 | 389.09 | 6.26 | 0.003* |
| Total rhizome yield (q acre ⁻¹) | 13.03 | 11.53 | 6.26 | 0.003* |
| Total rhizome yield (q ha ⁻¹) | 32.57 | 28.82 | 6.26 | 0.003* |

*-significant value

4.1.5 Effect of intercropping on growth, yield parameters and yield of ginger

The perusal of data (Table 4.5) pertaining to the growth and yield parameters of ginger as sole crop and intercropped with tomato, it is indicative that sole ginger performed better as compared to the ginger intercropped with tomato with respect to all the growth and yield parameters. 82.63 cm plant height, 22.66 number of tillers plant⁻¹, 405.58 g rhizome plant⁻¹, 12.02 q acre⁻¹(30.04 qha⁻¹) rhizome yield were recorded in sole ginger, while, 66.20 cm plant height, 14.66 number of tillers plant⁻¹, 324.86 g rhizome plant⁻¹, 9.63 q acre⁻¹(24.06 qha⁻¹) rhizome yield were recorded in turmeric intercropped with tomato. All the parameters for growth and yield varied significantly in tomato + ginger intercropping system as compared to the sole ginger. These results are in conformity with the experimental findings of Kumar *et al.* (2018).

Table 4.5: Effect of intercropping on sole ginger and tomato+ ginger

| Characters | Sole ginger | Tomato+ ginger | t-value | p- value |
|---|-------------|----------------|---------|----------|
| Plant height (cm) | 82.63 | 66.20 | 16.73 | 0.0008* |
| Number of tillers plant ⁻¹ | 22.00 | 14.00 | 13.67 | 0.003* |
| Rhizome yield plant ⁻¹ (g) | 405.58 | 324.86 | 17.13 | 0.0002* |
| Total rhizome yield (q acre ⁻¹) | 12.02 | 9.63 | 17.13 | 0.0002* |
| Total rhizome yield (q ha ⁻¹) | 30.04 | 24.06 | 17.13 | 0.0002* |

*-significant value

4.2 Comparison of Different Intercropping Systems on the Basis of Tomato Equivalent Yield and Land Equivalent Ratio

4.2.1. Comparison of different intercropping systems on the basis of tomato equivalent yield

Tomato equivalent yield is the best tool to determine the overall productivity potential of all the intercropping systems studied in this experiment. All the intercrop yields were converted to tomato yield on the basis of price. The data related to tomato equivalent yield has been presented in Table 4.6. After evaluation of data it is indicative that, all the intercropping systems showed higher equivalent yield than sole tomato except tomato + colocasia intercropping system.

Tomato + elephant foot yam intercropping system recorded the maximum tomato equivalent yield (258.42 q acre⁻¹) followed by tomato + ginger (243.25 q acre⁻¹) and tomato + turmeric (238.91 q acre⁻¹). The tomato + colocasia registered tomato equivalent yield of 218.70 q acre⁻¹, which was the lowest tomato equivalent yield among different intercropping systems as compared to the sole tomato.

Though the price of the elephant foot yam (20 rupees per kg) was low, maximum values for tomato equivalent yield in tomato + elephant foot yam intercropping system was obtained due to higher yield of component crops *viz.*, tomato and elephant foot yam. Higher values of tomato equivalent yield was also obtained in tomato + ginger and tomato + turmeric intercropping systems due to higher selling price per kilogram of the intercrop produce *viz.*, 50 rupees per kilogram and 40 rupees per kilogram for ginger and tomato, respectively. Lower selling price per kilogram of colocasia corms (25 rupees per kilogram) was the reason for the lowest tomato equivalent yield in tomato + colocasia intercropping system.

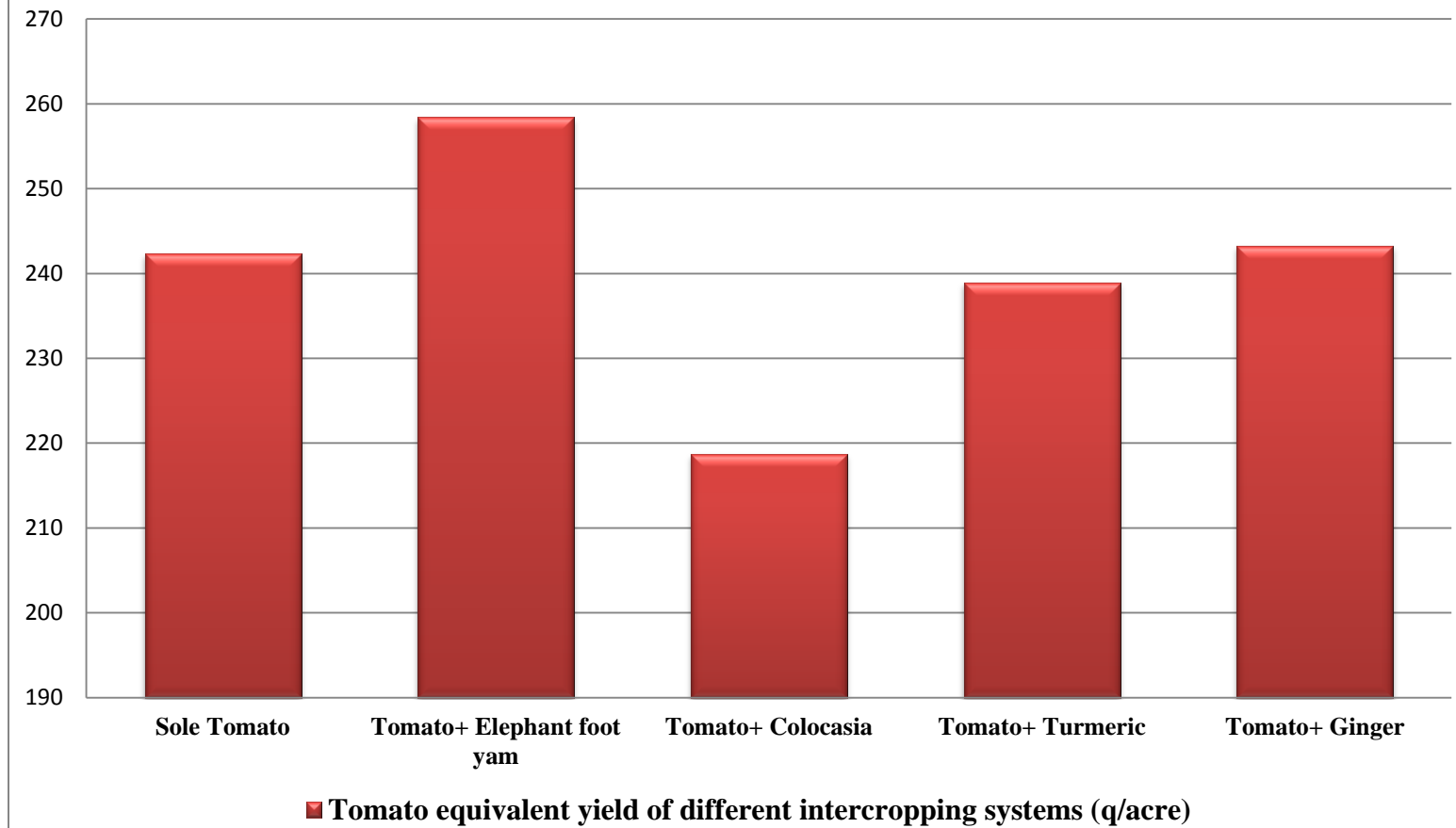
These results are in accordance with findings of Kushwah *et al.* (2011), who found highest potato equivalent yield (506.25qha⁻¹) was recorded in green-gram-radish-potato crop sequence, followed by soy-bean-garlic, green-gram-potato-wheat and soybean-potato crop sequences, Manorama and Lal (2010) who found that potato + French bean at 75:50 population recorded significantly higher potato equivalent yield, (PEY) and Singh *et al.* (2004) who found highest values of maize equivalent yield

were associated with maize + cowpea which were significantly superior to maize + okra and sole maize.

Table 4.6: Tomato equivalent yield of different intercropping systems

| Treatment combinations | Tomato Yield (q acre⁻¹) | Intercrop yield (q acre⁻¹) | Tomato equivalent yield of different intercrops (q acre⁻¹) | Tomato equivalent yield of different intercropping systems (q acre⁻¹) |
|-------------------------------|---|--|--|---|
| Sole Tomato | 242.31 | - | - | 242.31 |
| Tomato+ Elephant foot yam | 191.69 | 50.05 | 66.73 | 258.42 |
| Tomato+ Colocasia | 199.32 | 11.63 | 19.38 | 218.70 |
| Tomato+ Turmeric | 208.17 | 11.53 | 30.74 | 238.91 |
| Tomato+ Ginger | 211.17 | 9.63 | 32.08 | 243.25 |

Fig. 4.1:
Tomato equivalent yield of different intercropping systems (q acre⁻¹)



4.2.2. Comparison of different intercropping systems on the basis of land equivalent ratio (LER)

The efficiency of different intercropping systems in this study was evaluated by determining the resultant LER. The land equivalent ratio (LER) is the relative area of a sole crop required to produce the yield achieved in intercropping. If LER value is equal to one, it indicates that there is no yield advantage but when LER is more than one, there is yield advantage. The data pertaining to land equivalent ratio of tomato based intercropping experiment has been presented in Table 4.7. The data on LER of different intercropping systems indicated that LER values were greater than one in all the intercropping treatments as compared to the sole tomato where the LER value is equal to 1. Among different intercropping systems, the range of yield advantage over sole cropping of tomato was between 50 % and 74 %, with the highest in tomato + turmeric (74 %) intercropping system followed by tomato + ginger (67 %), tomato + colocasia (57 %) and tomato + elephant foot yam (50 %) intercropping system. Efficient utilization of natural resources *viz.*, space, light, etc. through symbiotic relationship between tomato and turmeric might resulted in highest value of LER in tomato + turmeric intercropping system.

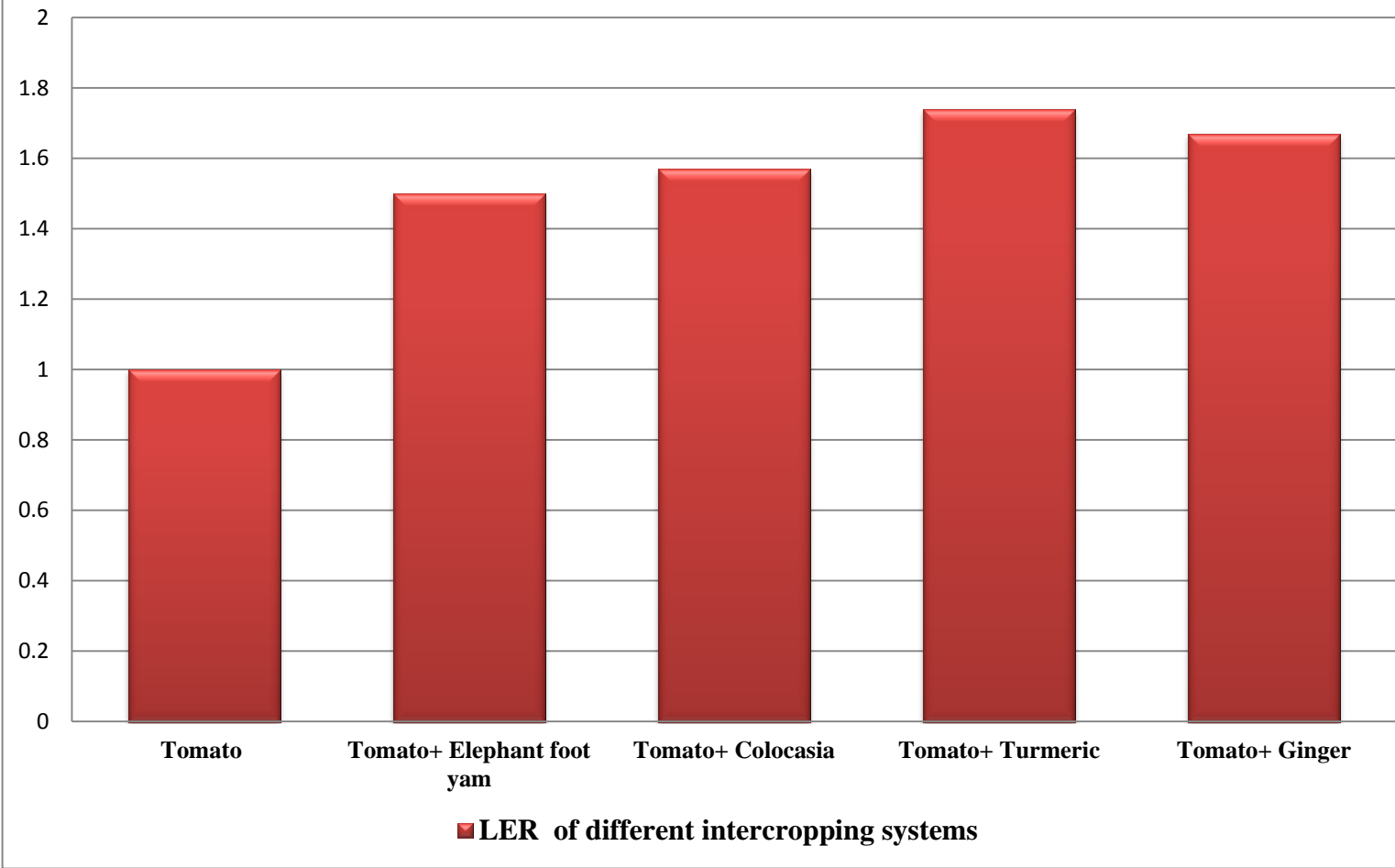
The data pertaining to land equivalent ratio of tomato based intercropping experiment has been presented in Table 4.11. The data on LER of different intercropping systems indicated that LER values were greater than one in all the intercropping treatments as compared to the sole tomato where the LER value is equal to 1. Among different intercropping systems, the range of yield advantage over sole cropping of tomato was between 50 % and 74 %, with the highest in tomato + turmeric (74 %) intercropping system followed by tomato + ginger (67 %), tomato + colocasia (57 %) and tomato + elephant foot yam (50 %) intercropping system. Efficient utilization of natural resources *viz.*, space, light, etc through symbiotic relationship between tomato and turmeric might resulted in highest value of LER in tomato + turmeric intercropping system.

These results were supported by the findings of Demir and Polat (2011) who observed the similar type of results in broccoli-crispy salad intercropping systems under greenhouse conditions.

Table 4.7: Land equivalent ratio (LER) of different intercropping systems

| Treatment combinations | LER of tomato | LER of different intercrops | LER of different intercropping systems |
|-------------------------------|----------------------|------------------------------------|---|
| Sole tomato | 1.00 | - | 1.00 |
| Tomato + elephant foot yam | 0.79 | 0.71 | 1.50 |
| Tomato + colocasia | 0.82 | 0.74 | 1.57 |
| Tomato + turmeric | 0.85 | 0.88 | 1.74 |
| Tomato + ginger | 0.87 | 0.80 | 1.67 |

Fig.4.2: LER of different intercropping systems



4.3 Economic Analysis of Different Intercropping Systems

4.3.1 Cost of cultivation of different intercropping system

The economic benefits of any intercropping system are influenced by the net returns which determine the commercial feasibility of different intercropping systems. The economics of cost and returns of different intercropping systems have been presented in Appendix K,L,M,N and O, for sole tomato, tomato + elephant foot yam, tomato + colocasia, tomato + turmeric and tomato + ginger, respectively.

4.3.2 Comparison of different intercropping systems on the basis of net returns

Analysis of data related to net returns per acre, presented in table 4.12, 4.13, 4.14, 4.15 and 4.16, it was revealed that tomato + elephant foot yam intercropping system had the highest net returns per acre (1,96,390 rupees acre⁻¹) followed by tomato + ginger (1,73,812 rupees acre⁻¹), while net returns from tomato + turmeric intercropping system (1,68,393 rupees acre⁻¹) and tomato+ colocasia intercropping system (1,39,554 rupees acre⁻¹) as compared to the sole tomato crop (1,76,815 rupees acre⁻¹).

These results are in conformity with the findings of Manorama and Lal (2010) who found that potato + French bean at 75:50 population registered higher net returns (Rs 69,090) over sole potato, Kumar *et al.* (2005) who found similar results in maize + cowpea intercropping system and Adeniyi (2001) in tomato-okra intercropping system.

4.3.3 Comparison of different intercropping systems on the basis of benefit: cost ratio

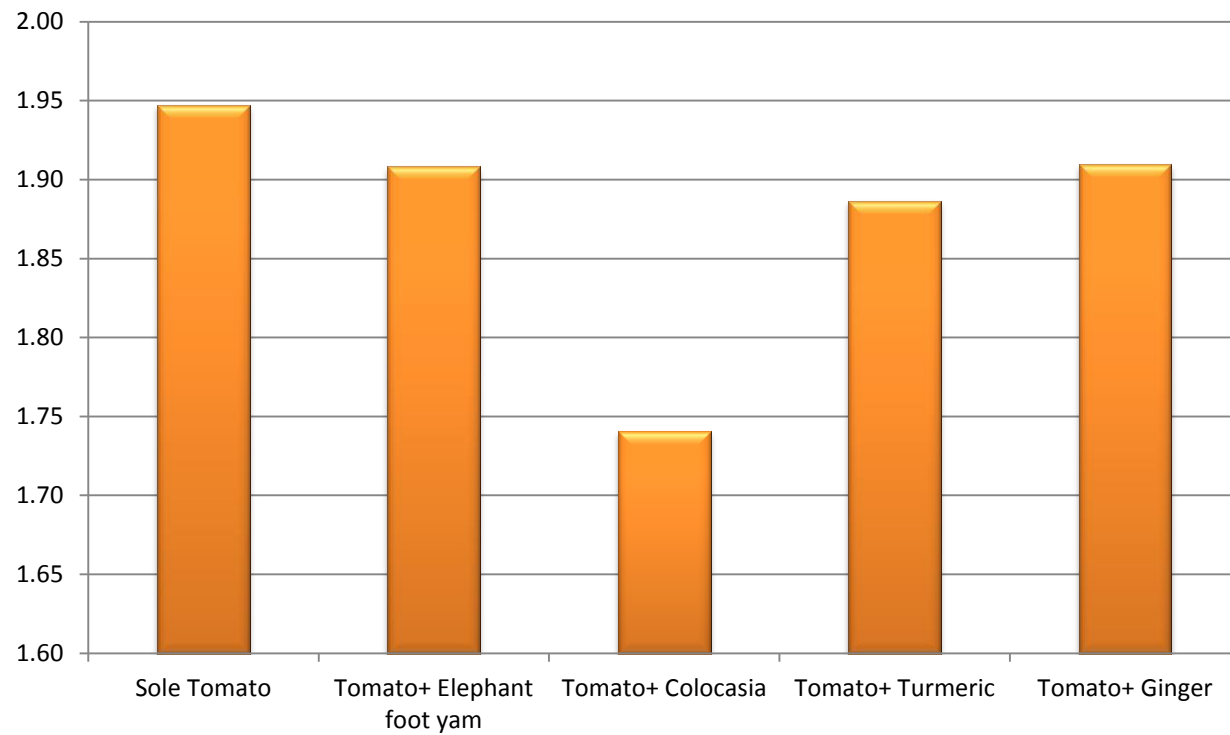
After perusal of the data, presented in Table 4.8, it was found that among different combinations, tomato + elephant foot yam and tomato + ginger intercropping system were found most remunerative, which might be due to highyield of elephant foot yam in tomato + elephant foot yam intercropping system and higher selling price of ginger and comparatively higher yield of tomato with ginger than most of the intercropping systems. Tomato + elephant foot yam and tomato + ginger intercropping systems registered benefit cost ratio of 1.91. Due to comparatively lower selling price of

intercrop produces and less yield of the intercrop, the benefit cost ratio of other intercropping system was low *viz.*, tomato+ turmeric (1.89) and tomato+ colocasia (1.74) in comparison with sole tomato (1.95). Similar results were reported by Kushwah *et al.* (2011) who found maximum receipt per rupee invested under soybean-onion crop sequence, followed by soybean-wheat and green-gram-radish-potato crop sequences and Yamgar *et al.* (2006) in turmeric based intercropping system.

Table 4.8: Benefit cost ratio of different intercropping system

| Treatment combinations | Benefit: cost ratio |
|-------------------------------|----------------------------|
| Sole Tomato | 1.95 |
| Tomato+ Elephant foot yam | 1.91 |
| Tomato+ Colocasia | 1.74 |
| Tomato+ Turmeric | 1.89 |
| Tomato+ Ginger | 1.91 |

Fig:3.3 Benefit cost ratio



■ Benefit cost ratio

CHAPTER- V

SUMMARY AND CONCLUSIONS

A polyhouse experiment entitled “Studies on Vegetable Based Intercropping System in Solid Soilless Media under Protected Condition” was carried out during *kharif* (July-December), 2017 under Naturally Ventilated Polyhouse at Centre of Excellence on Protected Cultivation and Precision Farming, Department of Vegetable Science, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh.

The experiment was laid out in completely randomized design with three replications. There were nine treatment combinations *viz.*, sole tomato (Yuvraj), sole elephant foot yam (Gajendra), sole colocasia (Kawardha Kochai 1), sole turmeric (Suranjana), sole ginger (Suprava), tomato + elephant foot yam, tomato + colocasia, tomato + turmeric and tomato + ginger. Effect of intercropping on the growth and yield parameters, tomato equivalent yield, LER (land equivalent ratio) and economics of those above said treatments were studied, assessed and analyzed. The salient findings of the present investigation and the conclusion drawn are summarized as under:

5.1 Growth, Yield Parameters and Yield of Tomato and Different Intercrops

5.1.1 Tomato

Among different intercropping systems, highest plant height (269 cm) was recorded in sole tomato closely followed by in tomato + turmeric (263 cm), tomato + ginger (261 cm), tomato + colocasia (256 cm) and tomato + elephant foot yam (254 cm) intercropping system. Sole tomato registered the highest number of fruits cluster⁻¹ (8.14) and highest number of fruits of fruits plant⁻¹ (64.07) and tomato + colocasia intercropping system registered the lowest number of fruits cluster⁻¹ (7.11), while, tomato + turmeric, tomato + ginger and tomato + elephant foot yam intercropping system registered the value of 7.57, 7.33 and 7.26 number of fruits cluster⁻¹, respectively. Among different intercropping systems, tomato + ginger registered highest number of fruits plant⁻¹ (58.84) closely followed by tomato + turmeric intercropping system (58.66 fruits plant⁻¹), tomato + colocasia intercropping system (56.81 fruits plant⁻¹) and tomato + elephant foot yam

intercropping system (55.74 fruits plant⁻¹). Tomato + elephant foot yam intercropping system took the highest duration for the first fruit harvest (97.93 days) followed by tomato + colocasia (96.24 days), tomato + turmeric (94.27 days) and tomato + ginger (91.32 days) as compared to the sole tomato which registered the shortest duration of 88.00 days for the first fruit harvest. Tomato + elephant foot yam intercropping system registered the lowest average fruit weight of 117.44 g. The average fruit weight of tomato + colocasia (119.74 g), tomato + turmeric (120.58 g) and tomato + ginger (121.46 g) were statistically *at par* with the average fruit weight of sole tomato (127.92 g). The highest fruit yield plant⁻¹ was observed in sole tomato (8.17 kg) followed by 7.12 kg in tomato + ginger intercropping system, 7.02 kg in tomato + turmeric intercropping system, 6.72 kg in tomato + colocasia intercropping system and 6.47 kg in tomato + elephant foot yam intercropping system. Maximum fruit yield acre⁻¹ was obtained with sole cropping (242.31 q acre⁻¹). Among different intercropping systems, highest value for total fruit yield acre⁻¹ has been obtained with tomato + ginger intercropping systems (211.17 q acre⁻¹) followed by tomato + turmeric (208.17 q acre⁻¹), tomato + colocasia (199.32 q acre⁻¹) and tomato + elephant foot yam intercropping system (191.69 q acre⁻¹). Similarly, the highest fruit yield per hectare was obtained in sole tomato followed by tomato + ginger (527.92 q ha⁻¹), tomato + turmeric (520.41 q ha⁻¹), tomato + colocasia (498.29 q ha⁻¹) and tomato + elephant foot yam (479.23 q ha⁻¹) intercropping system.

5.1.2 Elephant foot yam

Sole elephant foot yam registered higher value for all the growth and yield parameters. Intercropping significantly affected the crop in tomato + elephant foot yam intercropping system. Sole elephant foot yam registered pseudostem height of 85.97 cm, 1.26 shoots plant⁻¹, 2.36 kg corm plant⁻¹ while it was 77.32 cm pseudostem height, 1.06 numbers of shoots and 1.68 kg corm plant⁻¹ in the intercropping system. Sole elephant foot yam gave yield of 70.12 q acre⁻¹ (175.29 q ha⁻¹), while, 50.05 q acre⁻¹ (125.12 q ha⁻¹) yields were obtained in the elephant foot yam intercropped with tomato.

5.1.3 Colocasia

Sole cropping registered 98.33 cm plant height, 8.2 numbers of tillers plant⁻¹, 22.93 numbers of cormels plant⁻¹ and 524.16 g of cormels plant⁻¹, while, colocasia plants intercropped with tomato registered 90.24 cm plant height, 6.2 numbers of tillers plant⁻¹, 17.20 numbers of cormels plant⁻¹ and 392.62 g of cormels plant⁻¹. 15.53 q acre⁻¹ (38.82 q ha⁻¹) yield was obtained in the sole colocasia, while, 11.63 q acre⁻¹ (29.08 q ha⁻¹) yield was obtained in the colocasia intercropped with tomato.

5.1.4 Turmeric

Sole turmeric registered the higher values for all the growth and yield parameters in comparison to the turmeric in tomato + turmeric intercropping system. Sole turmeric registered 66.38 cm plant height, 3.8 numbers of tillers plant⁻¹, 439.83 g rhizome plant⁻¹, 13.03 q acre⁻¹ (32.57 q ha⁻¹) of total rhizome yield, while, the turmeric intercropped with tomato registered 52.89 cm plant height, 2.8 number of tillers plant⁻¹, 389.09 g rhizome plant⁻¹, 11.53 q acre⁻¹ (28.82 q ha⁻¹) of total rhizome yield.

5.1.5 Ginger

Sole ginger performed better as compared to the ginger intercropped with tomato with respect to all the growth and yield parameters. Sole ginger recorded 82.63 cm plant height, 22.66 number of tillers plant⁻¹, 405.58 g rhizome plant⁻¹, 12.02 q acre⁻¹ (30.04 q ha⁻¹) rhizome yield, while, 66.20 cm plant height, 14.66 number of tillers plant⁻¹, 324.86 g rhizome plant⁻¹, 9.63 q acre⁻¹ (24.06 q ha⁻¹) rhizome yield, were recorded in turmeric intercropped with tomato.

5.2 Tomato Equivalent Yield and LER (Land Equivalent Yield) of Different Intercropping Systems

Highest tomato equivalent yield (258.42 q acre⁻¹) was obtained in tomato+ elephant foot yam intercropping system closely followed by tomato + ginger (243.25 q acre⁻¹), tomato + turmeric (238.91 q acre⁻¹), while, tomato + colocasia intercropping system registered lowest tomato equivalent yield of 218.70 q acre⁻¹.

LER values were greater than one in all the intercropping treatments as compared to the sole tomato where the LER value is equal to 1. Tomato + turmeric intercropping system registered the highest LER value of 1.74 followed by tomato + ginger (1.67) and tomato + colocasia (1.57). Tomato + elephant foot yam intercropping system registered the lowest LER value of 1.50. The range of yield advantage over sole cropping of tomato was between 50 % and 74 %, with the highest in tomato + turmeric (74 %) intercropping system followed by tomato + ginger (67 %), tomato + colocasia (57 %) and tomato + elephant foot yam (50 %) intercropping system.

5.3 Net Returns and Benefit: Cost Ratio

Among different intercropping systems, tomato + elephant foot yam intercropping system had the highest net returns per acre (1,96,390 rupees acre⁻¹) followed by tomato + ginger (1,73,812 rupees acre⁻¹), while net returns from tomato + turmeric intercropping system (1,68,393 rupees acre⁻¹) and tomato + colocasia intercropping system (1,39,554 rupees acre⁻¹) was less as compared to the sole tomato crop (1,76,815 rupees acre⁻¹).

Among different combinations, tomato + elephant foot yam and tomato + ginger intercropping system were found most remunerative with the benefit: cost ratio of 1.91 closely followed by tomato + turmeric (1.89). Sole tomato registered the benefit: cost ratio of 1.95. Tomato + colocasia intercropping system registered lowest benefit: cost ratio of 1.74.

5.4 Conclusions

The findings of studies conducted on “Studies on Vegetable Based Intercropping System in Solid Soilless Media under Protected Condition” clearly visualized that intercropping systems of tomato + elephant foot yam and tomato + ginger were remunerative over other systems of intercropping studied in this experiment. The highest tomato equivalent yield, 258.42 q acre⁻¹, was obtained in tomato + elephant foot yam intercropping system followed by tomato + ginger intercropping system which registered tomato equivalent yield of 243.25 q acre⁻¹.

In terms of yield advantage over sole cropping, tomato + turmeric intercropping system registered 74 % yield advantage and tomato + ginger intercropping system recorded 67 % yield advantage.

Tomato + elephant foot yam intercropping system recorded highest net returns of 1, 96,390 rupees acre⁻¹ followed by tomato + ginger intercropping system which registered the value of 1,73,812 rupees acre⁻¹.

Tomato + elephant foot yam and tomato + ginger intercropping system registered highest benefit: cost ratio of 1.91 followed by tomato + turmeric intercropping system which recorded the value of 1.89 compared to the 1.95 registered by the sole tomato.

So based on these findings, it may be concluded that elephant foot yam and ginger were found to be the best intercrops. The tomato + elephant foot yam and tomato + ginger intercropping system may be recommended for achieving the much desired increased yield and monetary return for vegetable based intercropping system in solid soilless media under protected condition for food and nutrition security.

5.5 Suggestions for Future Research Work:

On the basis of experience gained and results obtained after completion of present investigation, following suggestions are being made for further research work:

1. Multivarietal evaluation of ginger and elephant foot yam may be conducted.
2. Experiment on sequential cropping system including tomato, ginger, elephant foot yam and turmeric may be conducted.

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APPENDIX A: Weekly metrological observations during crop growth period in outside environment condition

| Week | Temperature (°C) | | Rain fall (mm) | Relative humidity (%) | | Wind velocity (km/hr) | Evaporation (mm/day) | Sunshine (hr/day) |
|------------|------------------|------|----------------|-----------------------|------|-----------------------|----------------------|-------------------|
| | Max. | Min. | | Max. | Min. | | | |
| June 25-01 | 32.6 | 25.0 | 18.5 | 92 | 76 | 6.6 | 3.6 | 2.4 |
| July 02-08 | 31.9 | 25.7 | 7.4 | 84 | 60 | 7.2 | 3.9 | 2.1 |
| July 09-15 | 31.3 | 25.0 | 10.0 | 90 | 74 | 4.6 | 3.8 | 2.0 |
| July 16-22 | 30.7 | 25.4 | 8.5 | 91 | 73 | 3.4 | 3.5 | 2.4 |
| July 23-29 | 30.2 | 24.5 | 3.8 | 91 | 74 | 5.8 | 3.2 | 1.3 |
| July 30-06 | 32.3 | 25.5 | 6.0 | 87 | 69 | 7.0 | 3.9 | 4.1 |
| Aug. 01-07 | 31.1 | 25.1 | 19.0 | 89 | 70 | 3.8 | 9.2 | 2.1 |
| Aug. 14-20 | 31.8 | 24.9 | 7.8 | 93 | 73 | 2.2 | 3.6 | 2.7 |
| Aug. 21-27 | 32.1 | 25.4 | 3.5 | 90 | 67 | 0.8 | 3.8 | 5.1 |
| Aug. 28-08 | 31.7 | 25.2 | 7.2 | 92 | 70 | 0.7 | 3.4 | 5.0 |
| Sep. 04-10 | 33.4 | 26.1 | 0.4 | 91 | 65 | 2.9 | 3.5 | 6.4 |
| Sep.01-11 | 32.3 | 25.0 | 6.3 | 94 | 75 | 2.8 | 3.4 | 4.2 |
| Sep. 18-24 | 30.5 | 24.3 | 16.4 | 94 | 73 | 4.3 | 2.9 | 3.8 |
| Sep. 25-01 | 32.8 | 25.3 | 3.1 | 89 | 62 | 2.8 | 4.0 | 7.0 |
| Oct. 02-08 | 31.6 | 24.6 | 4.9 | 93 | 72 | 3.4 | 3.5 | 5.3 |
| Oct. 01-09 | 31.9 | 24.9 | 1.4 | 95 | 70 | 2.3 | 2.7 | 4.8 |
| Oct. 16-22 | 33.5 | 23.1 | 0.9 | 89 | 45 | 2.5 | 3.8 | 7.7 |
| Oct. 23-29 | 33.2 | 22.7 | 0.0 | 86 | 44 | 2.4 | 3.6 | 7.9 |
| Oct. 30-05 | 31.2 | 18.5 | 0.0 | 87 | 39 | 2.3 | 3.3 | 7.8 |
| Nov. 06-12 | 30.3 | 16.3 | 0.0 | 90 | 34 | 2.6 | 3.6 | 9.0 |
| Nov. 13-19 | 28.5 | 18.3 | 0.1 | 88 | 55 | 3.7 | 3.1 | 5.2 |
| Nov. 20-26 | 30.3 | 17.5 | 0.0 | 82 | 38 | 2.2 | 2.9 | 6.9 |
| Nov. 27-03 | 29.7 | 12.0 | 0.0 | 84 | 26 | 1.7 | 3.1 | 8.8 |
| Dec. 04-10 | 28.5 | 13.0 | 0.0 | 85 | 30 | 2.3 | 2.9 | 8.4 |
| Dec. 01-11 | 30.0 | 12.3 | 0.0 | 85 | 28 | 1.8 | 3.0 | 8.5 |
| Dec.18-24 | 28.6 | 11.1 | 0.0 | 86 | 29 | 1.9 | 2.9 | 7.8 |
| Dec. 25-31 | 28.3 | 9.5 | 0.0 | 85 | 26 | 1.9 | 3.0 | 8.7 |

APPENDIX B: Weekly temperature and relative humidity observations during crop growth period in inside polyhouse

| Week | Temperature | Relative Humidity |
|-------------|--------------------|--------------------------|
| June 25-01 | 35.1 | 92 |
| July 02-08 | 34.4 | 84 |
| July 09-15 | 33.6 | 90 |
| July 16-22 | 34.2 | 91 |
| July 23-29 | 33.7 | 91 |
| July 30-06 | 35.3 | 87 |
| Aug. 01-07 | 34.1 | 89 |
| Aug. 14-20 | 31.8 | 93 |
| Aug. 21-27 | 34.1 | 90 |
| Aug. 28-08 | 33.6 | 92 |
| Sep. 04-10 | 35.9 | 91 |
| Sep.01-11 | 32.3 | 94 |
| Sep. 18-24 | 33.5 | 94 |
| Sep. 25-01 | 32.8 | 89 |
| Oct. 02-08 | 34.1 | 93 |
| Oct. 01-09 | 33.2 | 95 |
| Oct. 16-22 | 35.8 | 89 |
| Oct. 23-29 | 33.2 | 86 |
| Oct. 30-05 | 31.2 | 87 |
| Nov. 06-12 | 33.3 | 90 |
| Nov. 13-19 | 33.0 | 88 |
| Nov. 20-26 | 32.8 | 82 |
| Nov. 27-03 | 32.5 | 84 |
| Dec. 04-10 | 33.5 | 85 |
| Dec. 01-11 | 31.0 | 85 |
| Dec.18-24 | 30.5 | 86 |
| Dec. 25-31 | 30.1 | 85 |

APPENDIX C: ANOVA for plant height of tomato

| <i>Source of Variation</i> | <i>SS</i> | <i>df</i> | <i>MS</i> | <i>F</i> | <i>P-value</i> | <i>F crit</i> |
|----------------------------|-----------|-----------|-----------|----------|----------------|---------------|
| Between Groups | 423.6 | 4 | 105.9 | 0.762529 | 0.57294241 | 3.478049691 |
| Within Groups | 1388.8 | 10 | 138.88 | | | |
| Total | 1812.4 | 14 | | | | |

APPENDIX D: ANOVA for number of fruits per cluster of tomato

| <i>Source of Variation</i> | <i>SS</i> | <i>df</i> | <i>MS</i> | <i>F</i> | <i>P-value</i> | <i>F crit</i> |
|----------------------------|-----------|-----------|-----------|----------|----------------|---------------|
| Between Groups | 1.933686 | 4 | 0.4834216 | 10.45774 | 0.00134611 | 3.478049691 |
| Within Groups | 0.462262 | 10 | 0.0462262 | | | |
| Total | 2.395948 | 14 | | | | |

APPENDIX E: ANOVA number of fruits per plant of tomato

| <i>Source of Variation</i> | <i>SS</i> | <i>df</i> | <i>MS</i> | <i>F</i> | <i>P-value</i> | <i>F crit</i> |
|----------------------------|-----------|-----------|-------------|----------|----------------|---------------|
| Between Groups | 128.3025 | 4 | 32.07562667 | 3.281602 | 0.05801773 | 3.478049691 |
| Within Groups | 97.74382 | 10 | 9.774381667 | | | |
| Total | 226.0463 | 14 | | | | |

APPENDIX F: ANOVA for days to first fruit harvest of tomato

| <i>Source of Variation</i> | <i>SS</i> | <i>df</i> | <i>MS</i> | <i>F</i> | <i>P-value</i> | <i>F crit</i> |
|----------------------------|-----------|-----------|-------------|----------|----------------|---------------|
| Between Groups | 188.2751 | 4 | 47.06877667 | 2.849215 | 0.08167916 | 3.478049691 |
| Within Groups | 165.1991 | 10 | 16.51990833 | | | |
| Total | 353.4742 | 14 | | | | |

APPENDIX G: ANOVA for average fruit weight of tomato

| <i>Source of Variation</i> | <i>SS</i> | <i>df</i> | <i>MS</i> | <i>F</i> | <i>P-value</i> | <i>F crit</i> |
|----------------------------|-----------|-----------|-------------|----------|----------------|---------------|
| Between Groups | 184.9465 | 4 | 46.23661491 | 2.741454 | 0.08924204 | 3.478049691 |
| Within Groups | 168.6573 | 10 | 16.86572928 | | | |
| Total | 353.6038 | 14 | | | | |

APPENDIX H: ANOVA fruit yield per plant of tomato

| <i>Source of Variation</i> | <i>SS</i> | <i>df</i> | <i>MS</i> | <i>F</i> | <i>P-value</i> | <i>F crit</i> |
|----------------------------|-----------|-----------|-------------|----------|----------------|---------------|
| Between Groups | 5.113485 | 4 | 1.278371349 | 51.20216 | 0.000000 | 3.478049691 |
| Within Groups | 0.249671 | 10 | 0.024967136 | | | |
| Total | 5.363157 | 14 | | | | |

APPENDIX I: ANOVA for total fruit yield per acre

| <i>Source of Variation</i> | <i>SS</i> | <i>df</i> | <i>MS</i> | <i>F</i> | <i>P-value</i> | <i>F crit</i> |
|----------------------------|-----------|-----------|-------------|----------|----------------|---------------|
| Between Groups | 4488.707 | 4 | 1122.176756 | 51.20191 | 0.000000 | 3.478049691 |
| Within Groups | 219.167 | 10 | 21.91669922 | | | |
| Total | 4707.874 | 14 | | | | |

APPENDIX J: ANOVA for total fruit yield per hectare

| <i>Source of Variation</i> | <i>SS</i> | <i>df</i> | <i>MS</i> | <i>F</i> | <i>P-value</i> | <i>F crit</i> |
|----------------------------|-----------|-----------|-------------|----------|----------------|---------------|
| Between Groups | 28054.45 | 4 | 7013.6117 | 51.20216 | 0.000000 | 3.478049691 |
| Within Groups | 1369.788 | 10 | 136.9788186 | | | |
| Total | 29424.23 | 14 | | | | |

APPENDIX K: Cost of cultivation of tomato

| Sl.no. | Particulars | Cost | | |
|--------|---|------------------|-------------|----------|
| I. | Variable costs | | | |
| A. | Material costs | Requirement/acre | Rate (₹) | Cost (₹) |
| | a. Planting material | 2962 | 2/ seedling | 5925 |
| | b. Manures+ Fertilizers | - | - | 18000 |
| | c. Plant protection chemicals | - | - | 4500 |
| | d. Cocopeat cost | 7200 kg | 15/kg | 27000 |
| | e. Electricity cost | 6 months | 3000 | 18000 |
| B. | Labour cost | | | |
| | a. Hired labour | 10 persons | 281 | 2810 |
| | b. Machine labour | 4 hrs | 100 /hr | 400 |
| | Total | | | 76635 |
| II. | Fixed costs | | | |
| | a. Depreciation of drip machine+ sprayer+ polyhouse | - | 110000 | 110000 |
| | b. Rental Value of land | | 15 | 15 |
| | Total | | | 110015 |
| III. | Total cost of cultivation (I+II) | - | - | 186650 |
| IV. | Average yield of the produce (q/acre) | - | - | 242.31 |
| V. | Market price of the produce (rupees/q) | - | - | 1500 |
| VI. | Gross returns | - | - | 363465 |
| VII. | Net returns | - | - | 176815 |
| VIII. | Returns from rupee of investment | - | - | 1.95 |

APPENDIX L: Cost of cultivation of tomato+ elephant foot yam intercropping system

| Sl.no. | Particulars | Cost | | |
|--------|---|---------------------------------|-------------------------|----------|
| I. | Variable costs | | | |
| A. | Material costs | Requirement/acre | Rate (₹) | Cost (₹) |
| | a. Planting material | 1481kg EFY+2962 tomato seedling | 20/kg of EFY;2/seedling | 35545 |
| | b. Manures+ Fertilizers | - | - | 18000 |
| | c. Plant protection chemicals | - | - | 4500 |
| | d. Cocopeat cost | 7200 kg | 15/kg | 27000 |
| | e. Electricity cost | 6 months | 3000 | 18000 |
| B. | Labour cost | | | |
| | a. Hired labour | 10 persons | 281 | 2810 |
| | b. Machine labour | 4 hrs | 100 /hr | 400 |
| | Total | | | 106256 |
| II. | Fixed costs | | | |
| | a. Depreciation of drip machine+ sprayer+ polyhouse | | 110000 | 110000 |
| | b. Rental Value of land | | 15 | 15 |
| | Total | | | 110015 |
| III. | Total cost of cultivation (I+II) | | | 216270 |
| IV. | Average yield of tomato (q/acre) | | | 191.69 |
| V. | Average yield of elephant foot yam (q/acre) | | | 50.05 |
| VI. | Gross returns | | | |
| | a. Gross returns from tomato | | | 287535 |
| | b. Gross returns from elephant foot yam | | | 125125 |
| | Total | | | 412660 |
| VII. | Net returns | | | 196390 |
| VIII. | Returns from rupee of investment | | | 1.91 |

APPENDIX M: Cost of cultivation of tomato+ colocasia intercropping system

| Sl.no. | Particulars | Cost | | |
|--------|---|--|--------------------------------|----------|
| I. | Variable costs | | | |
| A. | Material costs | Requirement/acre | Rate (₹) | Cost (₹) |
| | a. Planting material | 74.05 kg colocasia+2962 numbers of tomato seedling | 25/kg of colocasia ;2/seedling | 7776 |
| | b. Manures+ Fertilizers | - | - | 18000 |
| | c. Plant protection chemicals | - | - | 4500 |
| | d. Cocopeat cost | 7200 kg | 15/kg | 27000 |
| | e. Electricity cost | 6 months | 3000 | 18000 |
| B. | Labour cost | | | |
| | a. Hired labour | 10 persons | 281 | 2810 |
| | b. Machine labour | 4 hrs | 100 /hr | 400 |
| | Total | | | 78486 |
| II. | Fixed costs | | | |
| | a. Depreciation of drip machine+ sprayer+ polyhouse | | 110000 | 110000 |
| | b. Rental Value of land | | 15 | 15 |
| | Total | | | 110015 |
| III. | Total cost of cultivation (I+II) | | | 188501 |
| IV. | Average yield of tomato (q/acre) | | | 199.32 |
| V. | Average yield of elephant foot yam (q/acre) | | | 11.63 |
| VI. | Gross returns | | | |
| | a. Gross returns from tomato | | | 298980 |
| | b. Gross returns from elephant foot yam | | | 29075 |
| | Total | | | 328055 |
| VII. | Net returns | | | 139554 |
| VIII. | Returns from rupee of investment | | | 1.74 |

APPENDIX N: Cost of cultivation of tomato+ turmeric intercropping system

| Sl.no. | Particulars | Cost | | |
|--------|---|---|-------------------------------|----------|
| I. | Variable costs | | | |
| A. | Material costs | Requirement/acre | Rate (₹) | Cost (₹) |
| | a. Planting material | 74.05 kg turmeric+2962 numbers of tomato seedling | 45/kg of turmeric ;2/seedling | 9258 |
| | b. Manures+ Fertilizers | - | - | 18000 |
| | c. Plant protection chemicals | - | - | 4500 |
| | d. Cocopeat cost | 7200 kg | 15/kg | 27000 |
| | e. Electricity cost | 6 months | 3000 | 18000 |
| B. | Labour cost | | | |
| | a. Hired labour | 10 persons | 281 | 2810 |
| | b. Machine labour | 4 hrs | 100 /hr | 400 |
| | Total | | | 79968 |
| II. | Fixed costs | | | |
| | a. Depreciation of drip machine+ sprayer+ polyhouse | | 110000 | 110000 |
| | b. Rental Value of land | | 15 | 15 |
| | Total | | | 110015 |
| III. | Total cost of cultivation (I+II) | | | 189982 |
| IV. | Average yield of tomato (q/acre) | | | 208.17 |
| V. | Average yield of elephant foot yam (q/acre) | | | 11.53 |
| VI. | Gross returns | | | |
| | a. Gross returns from tomato | | | 312255 |
| | b. Gross returns from elephant foot yam | | | 46120 |
| | Total | | | 358375 |
| VII. | Net returns | | | 168393 |
| VIII. | Returns from rupee of investment | | | 1.89 |

APPENDIX O: Cost of cultivation of tomato+ ginger intercropping system

| Sl.no. | Particulars | Cost | | |
|--------|---|---|-----------------------------|----------|
| I. | Variable costs | | | |
| A. | Material costs | Requirement/acre | Rate (₹) | Cost (₹) |
| | a. Planting material | 74.05 kg ginger+2962 numbers of tomato seedling | 60/kg of ginger ;2/seedling | 10369 |
| | b. Manures+ Fertilizers | - | - | 18000 |
| | c. Plant protection chemicals | - | - | 4500 |
| | d. Cocopeat cost | 7200 kg | 15/kg | 27000 |
| | e. Electricity cost | 6 months | 3000 | 18000 |
| B. | Labour cost | | | |
| | a. Hired labour | 10 persons | 281 | 2810 |
| | b. Machine labour | 4 hrs | 100 /hr | 400 |
| | Total | | | 81079 |
| II. | Fixed costs | | | |
| | a. Depreciation of drip machine+ sprayer+ polyhouse | | 110000 | 110000 |
| | b. Rental Value of land | | 15 | 15 |
| | Total | | | 110015 |
| III. | Total cost of cultivation (I+II) | | | 191093 |
| IV. | Average yield of tomato (q/acre) | | | 211.17 |
| V. | Average yield of elephant foot yam (q/acre) | | | 9.63 |
| VI. | Gross returns | | | |
| | a. Gross returns from tomato | | | 316755 |
| | b. Gross returns from elephant foot yam | | | 48150 |
| | Total | | | 364905 |
| VII. | Net returns | | | 173812 |
| VIII. | Returns from rupee of investment | | | 1.91 |

RESUME

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