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Productivity potential and efficiency and economic feasibility of tomato based intercropping systems in solid soilless media under protected condition

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Abstract
An investigation for the evaluation of tomato based intercropping system was conducted during *Kharif* (July-December), 2017 under naturally ventilated polyhouse at Centre of Excellence on Protected Cultivation and Precision Farming, I.G.K.V., Raipur, Chhattisgarh. Elephant foot yam, colocasia, turmeric and ginger were selected as intercrops. The experiment was laid out in completely randomized design with three replications. 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. Among different systems studied, 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. Tomato + elephant foot yam and tomato + ginger intercropping system were found most remunerative on the basis of benefit: cost ratio. Elephant foot yam and ginger were found to be the best intercrops and may be recommended for achieving the much desired yield and monetary return for vegetable based intercropping system in solid soilless media under protected condition for food and nutrition security.

Keywords: Tomato equivalent yield, LER, protected cultivation and precision farming

1. Introduction

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. 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) [2] 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) [3]. 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) [8].

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 and 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. It is utmost necessary to improve the productivity of vegetable crops by adopting intensive cultivation, soilless culture (solid and liquid) under poly house condition. Tomato is one of the major vegetable crops grown under the protected condition.

Often it is observed that poly house tomato fail due to some inevitable reasons like sudden fall or increase in biotic and abiotic stress. 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 and development 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. 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. 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. The objectives of the investigation were:

i) To study the productivity potential and efficiency of all the intercropping systems studied in this experiment and
ii) Economic analysis of different intercropping systems.

2. Materials & Methods

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

The seeds of the indeterminate hybrid tomato Yuvraj were sown in plastic Protrays 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. 500gm of tuber of elephant foot yam, 20-25gm of Colocasia, ginger and turmeric were used as planting material. Before planting, the seed material was treated with Bavistin @ 1.0g /litre of water.

Eighteen days old healthy seedlings were transplanted under naturally ventilated poly house 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.

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 1.23-1.25mm hose per $cm^2$and its pH at 5 for avoiding adverse effect. The amount of water required for drip irrigation for 1 acre is 200litre.

Plant protection measures were applied to control pest and diseases during crop period in tomato under poly house. The details of the measures are given in table 3.

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

2.1 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:

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

The same formula for calculating was used by Talukder *et al.* (2015) [12] for calculating onion equivalent yield, by Kushwah *et al*. (2011) [7] for calculating potato equivalent yield and by Ghosh *et al.* (2009) [5] for calculating soybean equivalent yield.

2.2 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) [10]. It was calculated by the following formula:

$$\text{LER} = \Sigma \text{ yij/yii}$$

Where,
Yij = yield of crop in intercropping system
Yii = yield of the crop in sole cropping system

2.3 Net return ($acre^{-1}$)

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

2.4 Benefit: cost ratio

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

3. Results and Discussions

3.1 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. 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) [7], 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) [9] who found that potato + French bean at 75:50 population recorded significantly higher potato equivalent yield, (PEY) and Singh *et al.* (2004) [4] who found highest values of maize equivalent yield were associated with maize + cowpea which were significantly superior to maize + okra and sole maize.

3.2 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 5. 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) [4] who observed the similar type of results in broccoli-crispy salad intercropping systems under greenhouse conditions.

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

Analysis of data related to net returns per acre, 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 in conformity with the findings of Manorama and Lal (2010) [9] who found that potato + French bean at 75:50 population registered higher net returns (Rs 69,090) over sole potato, Kumar *et al.* (2005) [6] who found similar results in maize + cowpea intercropping system and Adeniyi (2001) [1] in tomato-okra intercropping system.

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

After perusal of the data, presented in Table 6, 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 high yield 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) [7] 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) [13] in turmeric based intercropping system.

Table 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 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

Table 3: Details of plant protection measures

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

Table 4: 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

Table 5: 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

Table 6: 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

Table 7: Cost of cultivation of tomato

S. 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 + poly house	-	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

Table 8: Cost of cultivation of tomato + elephant foot yam intercropping system

S. 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 + poly house		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

Table 9: Cost of cultivation of Tomato + Colocasia intercropping system

S. 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	4hrs	100/hr	400
Total				78486
II.	Fixed costs			
	a. Depreciation of drip machine+ sprayer+ poly house		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

Table 10: Cost of cultivation of tomato + turmeric intercropping system

S. 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	4hrs	100/hr	400
Total				79968
II.	Fixed costs			
	a. Depreciation of drip machine + sprayer + poly house		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

Table 11: Cost of cultivation of tomato+ ginger intercropping system

S. 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	4hrs	100 /hr	400
Total				81079
II.	Fixed costs			
	a. Depreciation of drip machine+ sprayer+ poly house		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

4. Conclusions

The findings of studies conducted on evaluation of tomato based intercropping system 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.

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