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Subhradeep Pramanik
M.Sc. (Hort.) Scholar, Department of Vegetable Science, College of Agriculture, IGKV, Raipur, Chhattisgarh, India

Dr. Jitendra Singh
Professor, Department of Vegetable Science, College of Agriculture, IGKV, Raipur, Chhattisgarh, India

Dr. Vijay Kumar
Professor, Department of Vegetable Science, College of Agriculture, IGKV, Raipur, Chhattisgarh, India

Dr. (Major) GK Shrivastava
Professor, Department of Agronomy, College of Agriculture, IGKV, Raipur, Chhattisgarh, India

Dr. RR Saxena
Professor, Department of Agricultural Statistics and Social Science (Language), College of Agriculture, IGKV, Raipur, Chhattisgarh, India

Correspondence
Subhradeep Pramanik
M.Sc. (Hort.) Scholar, Department of Vegetable Science, College of Agriculture, IGKV, Raipur, Chhattisgarh, India

Effect of intercropping on the growth, yield parameters and yield of tomato and vegetable intercrops in solid soilless culture under protected condition

Subhradeep Pramanik, Dr. Jitendra Singh, Dr. Vijay Kumar, Dr. (Major) GK Shrivastava, Dr. RR Saxena

Abstract
An investigation to study the effect of intercropping on the growth, yield parameters and yield of tomato and vegetable intercrops in solid soilless culture under protected condition 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. Among different intercropping systems, highest plant height was recorded in sole tomato closely followed by in 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}. Sole tomato 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 tomato + ginger intercropping system. Among different intercropping systems, highest value for total fruit yield acre^{-1} has been obtained with tomato + ginger intercropping systems. Among different growth and yield parameters of elephant foot yam intercropped with tomato *viz*., plant height, weight of corms plant^{-1}, total corm yield acre^{-1} and total corm yield hectare^{-1}, 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, sole turmeric and sole ginger performed better as compared to the colocasia, turmeric and ginger intercropped with tomato with respect to all the growth and yield parameters.

Keywords: solid soilless culture, intercropping, tomato and vegetable

1. 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) [6].

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) [1] 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) [2]. 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. 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. Tomato is one of the major vegetable crops grown under the protected condition.

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. 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.

2. Objective of the Study

The objective of the investigation was to study the growth and yield parameters of tomato and different intercrops under protected condition.

3. 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 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) [4].

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

4. Results and Discussions

4.1 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 3.

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.

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) [9].

Table 3: 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$^{c\ b}$	199.32$^{c\ b\ e}$	498.29$^{c\ b}$
Tomato+ turmeric	263^{a}	7.57$^{a\ b\ c\ e}$	58.66^{a}	94.27^{a}	120.58^{a}	7.02$^{d\ c}$	208.17$^{d\ c\ e}$	520.41$^{c\ d\ e}$
Tomato+ ginger	261^{a}	7.33$^{e\ b\ c}$	58.84^{a}	91.32^{a}	121.46^{a}	7.12$^{e\ c\ d}$	211.17$^{e\ c\ d}$	527.92$^{e\ c}$
C.D. (α=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

4.2 Effect of intercropping on growth, yield parameters and yield of 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. Results from this experiment are in consonance with the findings of Chattopadhyay *et al.* (2008).

Table 4: 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

4.3 Effect of intercropping on growth, yield parameters and yield of 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. This result is supported by the earlier findings of Sivan (1984) [7], who observed the similar type of results in colocasia based intercropping systems with okra, corn, longbean and cowpea.

Table 5: 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

4.4 Effect of intercropping on growth, yield parameters and yield of 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. These results are in accordance with the findings of Sivaraman and Palaniappan (1994) [8] in maize and turmeric intercropping system.

Table 6: 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

4.5 Effect of intercropping on growth, yield parameters and yield of 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. These results are in conformity with the experimental findings of Kumar *et al.* (2018) [5].

Table 7: 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

5. Summary and Conclusions

The findings of studies conducted on the effect of intercropping on the growth, yield parameters and yield of tomato and vegetable intercrops in solid soilless culture under protected condition clearly visualized that among different intercropping systems, highest plant height was recorded in sole tomato closely followed by in 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}. Sole tomato 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 tomato + ginger intercropping system. Among different intercropping systems, highest value for total fruit yield acre^{-1} has been obtained with tomato + ginger intercropping systems. Among different growth and yield parameters of elephant foot yam intercropped with tomato *viz*., plant height, weight of corms plant^{-1}, total corm yield acre^{-1} and total corm yield hectare^{-1}, 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, sole turmeric and sole ginger performed better as compared to the colocasia, turmeric and ginger intercropped with tomato with respect to all the growth and yield parameters.

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