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Study of intercropping in tomato (*Lycopersicon esculentum* Mill.)

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Abstract
The present experiment was carried out during October, 2020 to March, 2021 in Research Field, Department of Horticulture, SHUATS, Prayagraj. The experiment was conducted in Randomized Block Design (RBD), with eight treatments replicated thrice of tomato intercropped with different crops. The treatments were T0- Sole Tomato, T1- Tomato + Carrot (3:2), T2- Tomato + Spinach (3:2), T3- Tomato + Coriander (3:2), T4- Tomato + Carrot + Spinach (3:1:1), T5- Tomato + Coriander + Carrot (3:1:1), T6- Tomato + Spinach + Coriander (3:1:1), T7- Tomato + Carrot + Spinach + Coriander (3:1:1:1). From the investigation, it was perceived that all the characters were significantly affected by intercropping. Results revealed that significantly best values in terms of growth and quality parameters *viz*., plant height (83.44 cm), number of primary branches (5.33), TSS (4.63 0Brix), titratable acidity (0.55%), ascorbic acid (24.24 mg/100g), were recorded in T2- Tomato + Spinach (3:2). But in terms of yield per plant (2.51 kg), yield per hectare (788.66 q), net return (Rs. 3, 17,239.51) and B:C ratio (3.966), treatment T7- Tomato + Carrot + Spinach + Coriander (3:1:1:1) performed the best.

Keywords: Tomato, intercropping, carrot, spinach, coriander

Introduction
Tomato (*Lycopersicon esculentum* Mill.) is one of the most widely grown vegetable in the world. It is a member of the Solanaceae family and is universally treated as "Protective food" because of its special nutritive value and widespread production. It covers a wider coverage in comparison to other vegetables in India occupying an area of 8.82 lakhs hectare with a production of 18.74 million metric tonnes per hectare (NHB 2013-14). The pleasant 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) [1]. The advantages of intercropping are risk minimization, effective use of available resources, efficient use of labour, increased crop productivity, erosion control and food security (Addo-quaye *et al*., 2011) [2]. Many studies have indicated that intercropping with different vegetables was more productive and profitable than sole cropping, because of the complementary effects of intercrops (Guvenc and Yildirim, 2006) [3]. Through intercropping more effective use of water, nutrients and solar energy, can significantly enhance crop productivity compared to the growth of sole crops (Yildirim and Guvenc, 2005) [4]. Tomato is a kind of vegetable crop commonly grown in facility. Excessive fertilizer application and continuous monocropping of tomato has resulted in soil acidification and salinization, hence decreasing tomato yield and fruit quality. Intercropping with some companion plants could increase tomato quality, suppress nematodes, and improve soil environment without decreasing tomato yield. The intercrops used alongside tomato during this experiment were carrot, spinach and coriander. The disease, non-availability of suitable management practices and gaps in our knowledge abo

Materials and Methods
The present investigation entitled "Study of intercropping in tomato (*Lycopersicon esculentum Mill.*)" was conducted at Research Field, Department of Horticulture, Naini Agricultural Institute (NAI), Sam Higginbottom University of Agriculture, Technology and Sciences, during rabi season of 2020-2021. The experiment was laid out in Randomized Block Design comprising of eight treatments with three replications. The seeds of tomato variety, Suraj (F1 hybrid) were sown in lines 10cm apart in nursery beds on 22nd October, 2020. Thirty old seedlings of tomato were transplanted on the experimental field laid out with each plot 2m x 2m in size on 22nd November, 2020.

The seedlings of the main crop (tomato) were planted 60cm x 45cm in three rows and the different intercrops were planted in lines between the main crop in 3:2, 3:1:1 and 3:1:1:1 row proportion. The parameters relating to growth, yield, quality and economic returns were measured to make a critical analysis of the crop as affected by different treatments. The technique of representative sample was adopted for recording the observations on various morphological characters in tomato. At every observation, three plants from each plot were randomly selected and tagged. The observations were recorded at various successive growth stages. The data recorded during the investigation were subjected to statistical analysis according to the method of analysis of variance (Panse and Sukhatme, 1967).

Results and Discussion

Gowth attributes

Plant height at harvest recorded significantly higher in treatments of tomato intercropped with spinach as compared to sole planting of tomato. The collected data (Table 1) showed that T2 recorded the maximum plant height (83.44 cm) followed by T7 (82 cm). This might be due to with the competition for growth resources (light, moisture, nutrient and space) with intercrops which increases the efficiency of crops for resource utilization. Similar findings were reported by Ravindra *et al*. 2017 [5]. The average maximum number of primary branches was also recorded in T2 (5.33) followed by T7 (4.88). It might also be associated with the competition for growth resources with intercrops while climatic factors and soil nutrients could also be effective for the outcome. The results are in agreement with the findings of Ravindra *et al* 2017 [5] and Amit Malaker *et al* 2016 [6].

Quality attributes

Tomato intercropped with spinach also recorded the highest values of quality attributes. The highest total soluble solids recorded was in T2 (4.63 0Brix) followed by T7 (4.38 0Brix), highest value of titratable acidity (0.55%) and ascorbic acid (24.24 mg/100g) also in T2. This might be due to the additional uptake of nutrients by the main crop and less uptake of nutrients by intercrops. The results support the findings by P. Naveen Kumar 2020 and T. Liu *et al*. 2014 [7].

Table 1: Effect of intercropping on growth and quality attributes of tomato

Treatments	Plant height (cm)	No. of primary branches	Total Soluble Solids (0Brix)	Titratable acidity (%)	Ascorbic acid (mg/100g)
T0: Sole Tomato	75.88	4.66	3.59	0.31	18.50
T1: Tomato+Carrot (3:2)	70.66	3.88	3.77	0.30	19.07
T2: Tomato+Spinach (3:2)	83.44	5.33	4.63	0.55	24.24
T3: Tomato+Coriander (3:2)	73.22	4.10	3.84	0.33	20.70
T4: Tomato+Carrot+Spinach (3:1:1)	76.77	4.55	3.60	0.33	21.26
T5: Tomato+Spinach+Coriander (3:1:1)	70.66	4.44	3.76	0.43	20.78
T6: Tomato+Coriander+Carrot (3:1:1)	78.55	4.10	3.85	0.47	20.35
T7: Tomato+Carrot+Spinach+Coriander (3:1:1:1)	82.00	4.88	4.38	0.50	23.32
SE.d. (+)	3.94	0.384	0.304	0.074	1.606
C.D. at 5%	8.532	0.832	0.658	0.16	3.479

Yield attributes

The collected data (Table 2) showed that tomato intercropped with all the intercrops gave significantly better yield than all the other treatments. The highest yield per plant was recorded in T7 (2.51 kg) followed by T2 (2.22 kg), and the highest yield per hectare recorded was also in T7 (788.66 q) followed by T2 (685 q). This is due to the complementary utilization of all-natural resources and the efficient use of all inputs in the system. This is in agreement with the findings of P. Naveen Kumar 2020.

Economics

The study revealed that in terms of economic returns and cost benefit ratio, tomato intercropped with all the intercrops gave the best outcome as laid out in Table 2. The treatment T7 recorded a net return of Rs 3,17,239.51 and B:C ratio of 3.966. This is because intercropping improves soil quality and increases P availability in the rhizosphere of plant species, thereby enhancing soil resource utilization, and increasing crop productivity. Similar findings were reported by *Hussain* (2003) and Yildirim and Guvenc (2005) [4].

Table 2: Effect of intercropping on yield attributes and economics of tomato

Treatments	Yield/plant (kg)	Yield/hectare (q)	Net return (Rs)	B:C ratio
T0: Sole Tomato	1.54	670.41	171885.8	2.785
T1: Tomato+Carrot (3:2)	1.72	598.16	216312.8	3.138
T2: Tomato+Spinach (3:2)	2.22	685.00	205372.7	3.053
T3: Tomato+Coriander (3:2)	1.70	616.25	175202	2.781
T4: Tomato+Carrot+Spinach (3:1:1)	1.64	610.41	269304.8	3.567
T5: Tomato+Spinach+Coriander (3:1:1)	1.14	592.25	247843.93	3.400
T6: Tomato+Coriander+Carrot (3:1:1)	1.67	670.58	196998.9	2.929
T7: Tomato+Carrot+Spinach+Coriander (3:1:1:1)	2.51	788.66	317239.51	3.966
S.Ed. (+)	0.341	50.549		
C.D. at 5%	0.738	109.467		

Conclusion

From the findings of this experiment, it can be concluded that results were significantly better in intercropped treatments. Tomato intercropped with spinach in 3:2 row proportion (T2) performed well with respect to growth and quality parameters, and tomato intercropped with all the intercrops in 3:1:1:1 row proportion (T7) gave the highest values and best results in terms of yield and economic returns. However, these findings

are based on only one season trial. Therefore, further evaluation trials are needed to substantiate the findings.

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