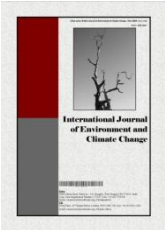

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Intercropping of Radish and Beetroot with Chilli under Prayagraj Agro-Climatic Conditions

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment entitled "Intercropping of Radish and Beetroot with Chilli under Prayagraj Agro-climatic conditions" was conducted from August, 2021 to February, 2022 at the Horticulture Research Farm, Department of Horticulture, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj. The experiment was laid out in Randomized Block Design (RBD) with three replications and 12 treatments. The experiment consisted of six cropping combinations *viz.*, sole chilli, sole radish, sole beetroot, chilli + radish, chilli+ beetroot, chilli + radish + beetroot. The highest yield (green chilli) was obtained from treatment T_1 (sole chilli @ 100 % RDN) (13.09 t ha^{-1}). Among the intercropping treatments, the highest chilli yield (12.62 t ha^{-1}) was obtained from treatment T_{10} (chilli @ 50% RDN + radish @ 50% RDN) whereas the lowest (9.45 t ha^{-1}) was found in treatment T_6 (chilli @ 75% RDN + radish @ 12.5% RDN + beetroot @ 12.5% RDN). Intercropping reduced chilli yield but total chilli with intercrop yield increased over sole chilli due to the contribution of companion crops. The highest chilli along with intercrop yield (150.71 t ha^{-1}), gross return (1101506 Rs. ha^{-1}), net return (817969 Rs. ha^{-1}) and benefit cost ratio (3.88) were obtained from treatment T_{12} (chilli @ 50% RDN + radish @ 25% RDN + beetroot @ 25% RDN). Considering the experimental findings, treatment T_{12} (chilli @ 50% RDN + radish @ 25% RDN + beetroot @ 25% RDN) found the most suitable combination for higher productivity and economic return under Prayagraj agro-climatic conditions.

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Keywords: Intercropping; chilli; radish; beetroot; RDN; yield.

1. INTRODUCTION

Intercropping is most typical practice which has a crucial role in increasing productivity and stability of yield. Intercropping has several advantages over sole culture of crops, like enhancement of efficient use of environmental factors (e.g., light, nutrient and soil moisture) and labour, reduces the adverse effect of varied biotic and abiotic stress, provides diversity of food, generates more income, offers insurance against failure, higher return and total productivity per unit area. Intercropping is taken into account advantageous in terms of economy of space, saving on tillage, use efficiency of nutrient and moisture in unused space. There'll be an intercrop competition during all stages of growth. Different intercropping combinations are also found in numerous agro-climatic zones available in India. Farmers generally prefer the intercropping system because intercropping can supply substantial yield advantages compared to sole cropping. These advantages are especially important because they're achieved not by means of expensive inputs but by the simple expedient of growing crops together. There's an advantage of stability in yield over different seasons. This is veritably important for poor farming people. The other form of advantage is the improved yield in a given season; the benefits of intercropping are risk decrease, effective use of accessible resources, economical use of labour, maximizing crop productivity, erosion management and food security. Many studies have indicated that intercropping with different vegetables was more productive and profitable than sole cropping, thanks to the complementary effects of intercrops [1]. Chilli (*Capsicum annum* L.) is one among the most important commercial vegetable crops in India. people like to consume chilli both in dried and green stage, for its colour, pungency and spicy taste. It's become a necessary ingredient in Indian meals and also has medicinal value too. Green chili is enriched in vitamin A, vitamin C and in flavonoid named 'rutin' which is of huge pharmaceutical need. chilli intercropping with different vegetables offers a major extent of using the land and other resources to the maximum ceiling. Chilli is generally grown at a wider distance of 60 cm × 45 cm, which makes it suitable for intercropping. Beetroot (*Beta vulgaris* L.) is a sugar-producing tuber crop. It is a best converter of alternative energy into stored energy and has capacity of sugar production at lower cost. It is a promising energy crop for ethanol production; also, it is an additional source of white sugar. In India it is famous as a salad crop. Beetroot nutrients include folate- a vitamin that helps keep your blood vessels healthy, and potassium to assist protect your heart. Beetroot provides a large range of possible health benefits like, reduction of blood pressure, helps in improving digestion and also reduces the risk of diabetes. Radish (*Raphanus sativus* L.) is one among the important vegetables cultivated all over India for its large edible tap roots. Radish is mainly consumed as salted vegetables and is also eaten as grated radish, garnish and salad. The combination of crispness and succulence, together with hot flavour, must makes radishes unique among the vegetables, and it is these qualities which add so much to a green salad. Radish is rich in various nutritive values, which is considered quite useful for patients suffering from piles, liver troubles, enlarged spleen, and jaundice. Different medicinal products made from radish are also used in curing liver and gall bladder problems. Roots are utilized in treating urinary issues and piles. The juice of newly harvested leaves is beneficial in diuretic and laxative purpose. The average yield of chilli and maximum utilization of land can be increased through the intercropping of chilli with beetroot and radish. It's thus important to estimate the performance and ease of the intercropping system among growers. The present study was conducted to estimate the performance of the intercropping system and to find out a suitable combination of chilli intercrop as well as to enhance the productivity and profitable return and to indicate that growing of chili as intercrops is more salutary than growing chilli alone in Prayagraj agro-climatic conditions.

2. MATERIALS AND METHODS

The experiment was conducted at Horticulture Research Farm, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology & Sciences, Prayagraj (U.P.) during August 2021 – February 2022. One cultivar of each crop was tried in Randomized Block Design (RBD) with three replications and twelve treatment combinations *viz.* T_1: Sole Chilli @ 100% RDN, T_2: Sole Radish @ 100% RDN, T_3: Sole Beetroot @ 100% RDN,

T_4: Chilli @ 100% RDN + Radish, T_5: Chilli @ 100% RDN + Beetroot, T_6: Chilli @ 100% RDN + Radish + Beetroot, T_7: Chilli @ 75% RDN + Radish @ 25% RDN, T_8: Chilli @ 75% RDN + Beetroot @ 25% RDN, T_9: Chilli @ 75% RDN + Radish @ 12.5% RDN + Beetroot @ 12.5% RDN, T_{10}: Chilli @ 50% RDN + Radish @ 50% RDN, T_{11}: Chilli @ 50% RDN + Beetroot @ 50% RDN, T_{12}: Chilli @ 50% RDN + Radish @ 25% RDN + Beetroot @ 25% RDN. Chilli cv. TMPH-449 (Trimurti plant science Pvt. Ltd.), Radish cv. Japanese White (I.A.R.I Regional Research Station, Katrain), Beetroot cv. Crimson Globe (I.A.R.I Regional Research Station, Katrain) these three varieties were used for the experiment. Farm Yard Manure 20 t/ha for chilli, 20 t/ha for radish and 25 t/ha for beetroot were applied at the time of field preparation. Nitrogen was supplied through the application of urea and DAP; phosphorus was supplied only through DAP, and potassium was supplied through MOP at various stages of crop growth. In each plot fertilizers were applied as per above-mentioned treatment combination and thoroughly mixed in the soil with the help of khurpi. Thirty days old healthy seedlings of chilli having 4-5 leaves with a height of 15-18 cm were selected and transplanted at the experimental plot and given light irrigation. At each observation, three plants from each plot were randomly selected for chilli and tagged, and for radish and beetroot, five plants of each plot were randomly selected at the time of harvesting. The observations were recorded from these plants. The data were subjected to analysis of variance and mean separation was assessed by critical difference (CD) at 5% probability. Data was analyzed using OPSTAT software.

3. RESULTS AND DISCUSSION

3.1 Effect of Intercrops on Green Chilli Yield and Quality on Application of Different level of RDN

It was clearly observed that the intercrops had significantly shown influence on growth and yield of chilli.

3.2 Growth, Yield and Quality Characters of Chilli

Growth, yield and quality characteristics of chilli were significantly differed in different treatments and are mentioned in Table 1. In terms of growth parameters, the maximum plant height of chilli (70.21 cm) was found in T_1 (Sole chilli @ 100% RDN) and the minimum plant height (58.98 cm) was recorded in T_6 (Chilli @ 100% + Radish + Beetroot). Kaur and Sharma, [2] reported that increasing the nitrogen level helped in increasing the plant height. Similarly the highest number of branches plant^{-1} (15.22), maximum leaf area at the time of harvesting (41.56 cm^2), lowest number of days taken for 50% flowering (28.67 days), minimum number of days taken to 1st harvest (47.7 days) was recorded in T_1 (Sole chilli @ 100% RDN) while the lowest number of branches plant^{-1} (13.33), minimum leaf area at the time of harvesting (32.85 cm^2), highest number of days taken for 50% flowering (36.33 days), maximum number of days taken to 1st harvest (57 days) was recorded in T_6 (Chilli @ 100% + Radish + Beetroot). When it comes to yield parameters, the maximum fruit length (8.22 cm) was recorded in T_1 (Sole chilli @ 100% RDN) while the minimum fruit length (7.94 cm) was recorded in T_6 (Chilli @ 100% + Radish + Beetroot). Correspondingly the maximum fruit girth (3.61 cm), the maximum average fruit weight (5.18 g), maximum number of fruit plant^{-1} (75.89), highest fruit yield plant^{-1} (392.76 g), maximum fruit yield hectare^{-1} (13.09 t) was recorded in T_1 (Sole chilli @ 100% RDN) while the minimum fruit girth (3.40 cm), the minimum average fruit weight (4.81 g), minimum number of fruit plant^{-1} (58.89), lowest fruit yield plant^{-1} (283.45 g), minimum fruit yield hectare^{-1} (9.45 t) was recorded in T_6 (Chilli @ 100% + Radish + Beetroot). Similarly, Begum et al., [3]; Ahmed et al. (2013) reported negative impact of intercropping on main crop. Likewise, the maximum TSS value (8.10 ºBrix) was observed in T_1 (Sole chilli @ 100% RDN) while the minimum TSS value (7.37 ºBrix) was observed in T_6 (Sole chilli @ 100% RDN + Radish + Beetroot). Intercrops significantly reduced the yield of main crop as compared to sole cropping. Similar results were recorded by Khatun et al., [4].

3.3 Yield and Quality Characters of Radish

Yield and quality characteristics of radish were significantly differed in different treatments and are mentioned in Table 2. In terms of yield parameters, the maximum root length (30.95 cm) was recorded in T_2 (Sole radish @ 100% RDN) and the minimum root length (23.80 cm) was recorded in T_6 (Sole chilli @ 100% RDN + Radish + Beetroot). Uniformly the maximum root

Table 1. Growth, yield and quality of chilli as influenced by chilli, radish and beetroot intercropping

Treatments	Plant height (cm)	No. of branches plant^{-1}	Leaf area at harvest (cm^2)	Days taken for 50% flowering	Days taken to 1st harvest	Avg. fruit length (cm)	Avg. fruit girth (cm)	Avg. fruit weight (g)	Avg. no of fruit plant^{-1}	Avg. fruit yield plant^{-1} (g)	Avg. yield hectare^{-1} (t)	TSS (ºBrix)
T_1	70.21	15.22	41.56	28.67	47.7	8.28	3.61	5.18	75.89	392.76	13.09	8.10
T_4	63.91	14.56	37.33	30.33	53.3	8.17	3.54	5.07	70.89	359.64	11.99	7.90
T_5	61.2	14.22	37.00	33.33	56.0	8.09	3.49	4.98	66.11	329.22	10.97	7.80
T_6	58.98	13.33	32.85	36.33	57.0	7.94	3.40	4.81	58.89	283.45	9.45	7.37
T_7	65.23	15.11	37.48	30.00	53.0	8.18	3.55	5.10	72.11	367.77	12.26	7.93
T_8	61.88	14.22	37.11	32.67	55.0	8.12	3.50	5.01	67.89	340.19	11.34	7.87
T_9	59.7	13.67	36.70	35.67	56.7	8.02	3.44	4.90	62.00	303.53	10.12	7.70
T_{10}	66.81	15.11	38.00	29.33	52.3	8.22	3.57	5.13	73.78	378.56	12.62	8.03
T_{11}	62.57	14.22	37.26	32.00	54.3	8.14	3.52	5.05	69.33	350.05	11.67	7.87
T_{12}	60.23	13.89	36.74	35.33	56.3	8.06	3.47	4.94	64.11	316.57	10.55	7.73
SE(d)±	1.59	0.48	0.65	2.24	2.18	0.02	0.01	0.02	0.46	2.39	0.08	0.17
CD $_{0.05}$	3.34	1.00	1.37	4.70	4.59	0.05	0.02	0.04	0.97	5.03	0.17	0.36

T_1- Sole Chilli @100% RDN, T_4- Chilli @100% RDN + Radish, T_5- Chilli @100% RDN + Beetroot, T_6- Chilli @100% RDN + Radish + Beetroot, T_7- Chilli @75% RDN + Radish @25% RDN, T_8- Chilli @75% RDN + Beetroot @25% RDN, T_9- Chilli @75% RDN + Radish @12.5% RDN + Beetroot @12.5% RDN, T_{10}- Chilli @50% RDN + Radish @50% RDN, T_{11}- Chilli @50% RDN + Beetroot @50% RDN, T_{12}- Chilli @ 50% RDN+ Radish @25% RDN+ Beetroot @25% RDN

Table 2. Yield and quality of radish as influenced by chilli, radish and beetroot intercropping

Treatments	Root length (cm)	Root Girth (cm)	Root weight without leaves plant^{-1} (g)	Root weight with leaves plant^{-1} (g)	Root yield with leaves hectare^{-1} (t)	TSS (ºBrix)
T_2	30.95	14.96	226.67	342.12	128.30	4.13
T_4	27.31	13.66	220.03	331.92	103.26	3.67
T_6	23.80	13.19	213.75	320.61	99.74	3.53
T_7	28.68	13.99	220.81	333.75	103.83	3.77
T_9	25.66	13.48	215.28	325.25	101.19	3.57
T_{10}	29.99	14.61	223.06	336.90	104.81	3.97
T_{12}	26.30	13.57	218.35	328.61	102.23	3.60
SE(d)±	0.46	0.21	1.30	2.69	0.85	0.18
CD $_{0.05}$	1.00	0.46	2.87	5.92	1.86	0.39

T_2- Sole Radish @100% RDN, T_4- Chilli @100% RDN + Radish, T_6- Chilli @100% RDN + Radish + Beetroot, T_7- Chilli @75% RDN + Radish @25% RDN, T_9- Chilli @75% RDN + Radish @12.5% RDN + Beetroot @12.5% RDN, T_{10}- Chilli @50% RDN + Radish @50% RDN, T_{12}- Chilli @ 50% RDN+ Radish @25% RDN+ Beetroot @25% RDN

Table 3. Yield and quality of beetroot as influenced by chilli, radish and beetroot intercropping

Treatments	Root length (cm)	Root Girth (cm)	Root weight without leaves plant^{-1} (g)	Root weight with leaves plant^{-1} (g)	Root yield without leaves hectare^{-1} (t)	TSS (ºBrix)
T_3	12.71	24.04	166.36	256.01	49.91	8.33
T_5	11.38	21.41	157.50	241.14	38.50	7.83
T_6	9.75	19.29	151.32	228.91	36.99	7.67
T_8	11.96	22.35	159.71	245.29	39.04	7.87
T_9	10.39	20.78	152.94	233.22	37.39	7.80
T_{11}	12.50	23.21	162.34	252.07	39.68	7.97
T_{12}	11.17	21.25	155.17	236.87	37.93	7.83
SE(d)±	0.14	0.13	0.43	0.46	0.11	0.13
CD $_{0.05}$	0.30	0.29	0.95	1.02	0.24	0.28

T_3- Sole Beetroot @100% RDN, T_5- Chilli @100% RDN + Beetroot, T_6- Chilli @100% RDN + Radish + Beetroot, T_8- Chilli @75% RDN + Beetroot @25% RDN, T_9- Chilli @75% RDN + Radish @12.5% RDN + Beetroot @12.5% RDN, T_{11}- Chilli @50% RDN + Beetroot @50% RDN, T_{12}- Chilli @ 50% RDN+ Radish @25% RDN+ Beetroot @25% RDN

Table 4. Economics of intercropping of radish and beetroot with chilli per hectare

Treatments	Gross return (Rs. /ha)	Cost of cultivation (Rs. /ha)	Net return (Rs. /ha)	B:C Ratio
T_1	261845	187219	74626	1.40
T_2	641475	176467	465008	3.64
T_3	499080	188137	310943	2.65
T_4	756082	229499	526583	3.29
T_5	604489	240153	364336	2.52
T_6	1057583	282433	775150	3.74
T_7	764350	229949	534401	3.32
T_8	617193	240808	376386	2.56
T_9	1082153	282985	799168	3.82
T_{10}	776441	230398	546043	3.37
T_{11}	630202	241462	388740	2.61
T_{12}	1101506	283537	817969	3.88

T_1- Sole Chilli @100% RDN, T_2- Sole Radish @100% RDN, T_3- Sole Beetroot @100% RDN, T_4- Chilli @100% RDN + Radish, T_5- Chilli @100% RDN + Beetroot, T_6- Chilli @100% RDN + Radish + Beetroot, T_7- Chilli @75% RDN + Radish @25% RDN, T_8- Chilli @75% RDN + Beetroot @25% RDN, T_9- Chilli @75% RDN + Radish @12.5% RDN + Beetroot @12.5% RDN, T_{10}- Chilli @50% RDN + Radish @50% RDN, T_{11}- Chilli @50% RDN + Beetroot @50% RDN, T_{12}- Chilli @ 50% RDN+ Radish @25% RDN+ Beetroot @25% RDN

girth (14.96 cm), the maximum root weight without leaves (226.67 g), the maximum root weight with leaves (342.12 g), the maximum root yield with leaves hectare^{-1} (128.30 t) was recorded in T_2 (Sole Radish @ 100% RDN) while the minimum root girth (13.19 cm), the minimum root weight without leaves (213.75 g), the minimum root weight with leaves (320.61 g), the minimum root yield with leaves hectare^{-1} (99.74 t) was recorded in T_6 (Sole chilli @ 100% RDN + Radish + Beetroot). Likewise, the maximum TSS value (4.13 ºBrix) was observed in T_2 (Sole radish @ 100% RDN) while the minimum TSS value (3.53 ºBrix) was observed in T_6 (Sole chilli @ 100% RDN + Radish + Beetroot). Similar findings were obtained by Islam et al., [5]. Similarly, Soniya et al., [6] observed that increasing the levels of recommended doses of fertilizers helps in increasing the growth and yield of radish in tomato and radish intercropping combination.

3.4 Yield and Quality Characters of Beetroot

Yield and quality characteristics of beetroot were significantly differed in different treatments and are mentioned in Table 3. In terms of yield parameters, the maximum root length (12.71 cm) was recorded in T_3 (Sole beetroot @ 100% RDN) and the minimum root length (9.75 cm) was recorded in T_6 (Sole chilli @ 100% RDN + Radish + Beetroot). Uniformly the maximum root girth (24.04 cm), the maximum root weight without leaves (166.36 g), the maximum root weight with leaves (256.01 g), the maximum root yield without leaves hectare^{-1} (49.91 t) was recorded in T_3 (Sole beetroot @ 100% RDN) while the minimum root girth (19.29 cm), the minimum root weight without leaves (151.32 g), the minimum root weight with leaves (228.91 g), the minimum root yield without leaves hectare^{-1} (36.99 t) was recorded in T_6 (Sole chilli @ 100% RDN + Radish + Beetroot). Likewise, the maximum TSS value (8.33 ºBrix) was observed in T_3 (Sole beetroot @ 100% RDN) while the minimum TSS value (7.67 ºBrix) was observed in T_6 (Sole chilli @ 100% RDN + Radish + Beetroot). For growth, yield and quality parameters, sole cropping pattern of each crop showed best result compared to intercropping combination but when it comes to overall yield, intercropping showed maximum result. Romaneckas et al., [7] also observed that yield of sugar beetroot crop decreased in intercropping practice.

3.5 Cost Benefit Analysis

Considering all the economics of different treatment and intercropping combination in chilli, the net return (Rs. 817969/ha) was maximum in T_{12} (Chilli @ 50% RDN + Radish @ 25% RDN + Beetroot @ 25% RDN) followed by (Rs. 799168/ha) was observed in T_9 (Chilli @ 75% RDN + Radish @ 12.5% RDN + Beetroot @ 12.5% RDN) while the minimum net return (Rs. 74626/ha) was observed in T_1 (Sole Chilli @ 100% RDN) (Table 4). Although the cost of cultivation of sole chilli, sole radish and sole beetroot was comparatively lower as compared to intercropping combinations but due to the additional yield of the intercropping vegetables the profitability of intercropping was increased over sole cropping. Ijoyah and Dzer [8] reported that the more the combined yields the more the economic return of the intercropping compared to sole cropping. Innazent et al., [9] reported that chilli + amaranth intercropping system provided maximum biological return. The highest benefit cost ratio (BCR) (3.88) was recorded in T_{12} (Chilli @ 50% RDN+ Radish @25% RDN+ Beetroot @25% RDN) followed by (3.82) was recorded in T_9 (Chilli @75% RDN + Radish @12.5% RDN + Beetroot @12.5% RDN) while the minimum benefit cost ratio (1.40) was recorded in T_1 (Sole Chilli @ 100% RDN). Similarly, Patil et al., [10] observed that turmeric and chilli intercropping combination increased the economics without affecting the growth and yield of main crop turmeric. Kadir et al., [11] observed that chilli and groundnut intercropping systems increased yield, economic and nutritional value. Besides this, many researchers also indicated that intercropping practice gets a higher economic return than the sole cropping practice (Razzaque et al., 2007; Suresha et al., [12]; Alom et al., [13]; Bhuiyan et al., [14]; Farhad et al., [15]; Begum et al., [3], Khatun et al., [4]).

4. CONCLUSION

From the study it was concluded that intercropping practices of radish and beetroot with chilli at different nutrient levels showed more potential than sole cropping for increasing the productivity without hindering the yield of main crop chilli. Results showed that providing higher levels of nutrients helped in increasing the growth, yield and quality, which directly helped in increasing the economics. The highest economic return and the best B:C ratio was obtained in T_{12} (Chilli @ 50% RDN+ Radish @ 25% RDN+

Beetroot @ 25% RDN) due to addition of yield of two different intercrops. Hence the treatment T_{12} (Chilli @ 50% RDN+ Radish @ 25% RDN+ Beetroot @ 25% RDN) is best suited for the farmers under Prayagraj agro-climatic Conditions in terms of land use efficiency, yield and net return.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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