Effect of nitrogen fertilization and summer season vegetables as intercrops on growth and yield of broccoli (*Brassica oleracea* L. var. *italica)*

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Abstract: - In developing countries like India, cultivation of vegetables out of their normal growing season in suitable intercropping system will help the farmers to fetch the higher market price from early produce. However, the optimum production of main crop and intercrop demands special care of essential plant nutrients such as nitrogen. Nitrogen management is a critical factor for production of broccoli (*Brassica oleracea* L. var. *italica*). Field trial was conducted in 2016-2017 at Vegetable Seed Production Farm, Punjab Agricultural University, Ludhiana to optimize the nitrogen dose in broccoli intercropping system. The experiment was replicated thrice in RCBD with three doses of nitrogen (125, 150 and 175 kg/ha) and four summer season vegetables (capsicum, chilli, cucumber and tomato) as intercrops. Nitrogen rates had significant effect on all the growth and yield parameters of broccoli. The maximum plant height (57.11 cm), number of leaves per plant (15.85), leaf size (394.87 cm^2), leaf area index (3.39), plant spread (64 cm), head weight (176.72 g), number of axillary sprouts per plant (9.01), weight of axillary sprouts per plant (130.50 g) and total yield (145.47 q/ha) obtained with nitrogen @ 175 kg/ha were statistically at par with nitrogen @ 150 kg/ha. The statistical differences were non-significant in intercropping systems but the sole crop of broccoli showed maximum values for growth and yield parameters. The highest benefit cost ratio (BCR: 3.74) and land equivalent ratio (LER: 1.67) were observed in broccoli + tomato followed by broccoli + chilli. Thus, on the basis of BCR and LER, tomato/chilli as intercrops can be successfully grown by the application of nitrogen @ 150 kg/ha or 175 kg/ha without their any adverse effect on growth and yield parameters of broccoli, under plains of Punjab.

Key-Words: - Broccoli, Nitrogen doses, Intercrops, Capsicum, Chilli, Cucumber, Tomato, BCR, LER

1 Introduction

India ranks second in the vegetable production in the world after China [1]. The vegetable requirement of India is evaluated as 225 million tones by 2020 [2], hence it necessitates the need to enhance the vegetable productivity. Presently, the increase in agricultural productivity through intensive practices has created some problems such as decline in soil fertility, environmental pollution and emergence of chemical resistant weeds and pests [3]. On the other hand, expanding population and industrialization have further elevated the shortage of arable land. Hence, effective land utilization to enhance the productivity is need of the hour. Diversification through intensive cropping for instance, increasing number of crops, has been proposed as the probable solution to all the above mentioned problems. In developing countries like India, intercropping plays a pivotal role in achieving the enhanced productivity with maintenance of soil health without additional resources [4 and 5].

Harsh climatic conditions in northern regions of India offers limited period to grow vegetables like capsicum, chilli, cucumber and tomato in open conditions throughout the year. Moreover, small farmers cannot afford the costly techniques like polyhouse, green house etc. to grow these vegetables in off season. So, to raise them earlier and fetch high returns, intercropping in frost tolerant vegetables with more spreading type growth such as broccoli, is found to be an appropriate solution. It has high nutritional value and due to presence of some cancer fighting substances like sulforaphane, it has gained momentum in its production and demand by health conscious customers.

However, the objective of maximum production of broccoli cannot be achieved in absence of essential plant nutrients [6]. The high yield of broccoli in intercropping system demands care of nutrient management especially nitrogen as it is highly responsive to varying nitrogen levels. Nitrogen improves food quality, enhances the yield [7], and increases the photosynthetic activity, leaf area, leaf area duration and net assimilation rate [8]. Although the role of nitrogen is reported frequently but nitrogen requirement of broccoli in intercropping system under Punjab conditions is not documented yet.

Therefore, due to lack of research particularly under field conditions, to show the effects of nitrogen, the present study was carried out to find the suitable nitrogen dose responsible for higher yields of main crop along with suitable summer season vegetable(s) as intercrop(s) in intercropping systems in plains of Punjab.

2 Materials and Methods

The experiment was conducted at Vegetable Seed Production Farm and biochemical analysis was done at Biochemistry Laboratory of the Department of Vegetable Science, Punjab Agricultural University, Ludhiana during 2016-2017. Ludhiana is situated between 30º54’N latitude and 75º48’E longitude at 247 m above mean sea level having semi-arid region and sub-tropical climate. Hot and dry summer from April to June, humid rainy season from July to September and cold winter from December to February prevail here. The monthly maximum and minimum temperature, relative humidity, rainfall and total evaporation during the crop growing period were recorded from the School of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana. The soil at experimental site had pH - 8.2, available N-125.22 kg/ha, available P-21.6 kg/ha and available K-146 kg/ha. The experiment was executed in Randomized Complete Block Design (RCBD). It was replicated thrice with three doses of nitrogen, viz., 125 kg/ha (N_1), 150 kg/ha (N_2) and 175 kg/ha (N_3) in broccoli as a main crop along with four intercrops, viz., chilli-CH-1, capsicum-Bharat, cucumber-Punjab Naveen and tomato-Punjab Upma. Broccoli was transplanted in mid-October whereas, the transplanting of intercrops was done in last week of October (Table 1) on ridges in 3×3 m^2 plot. The seedlings of chilli and capsicum were transplanted in between plants of broccoli in every row whereas, cucumber and tomato seedlings were transplanted in alternate rows in between the broccoli plants. No protection was given to the intercrops. The intercrops were protected only under the spreading growth of broccoli. Nitrogen in the form of urea was applied in three split doses i.e. at the time of transplanting, one month after transplanting and 60 days after transplanting. The other intercultural operations were followed according to Package of Practices for cultivation of vegetables, Punjab Agricultural University, Ludhiana [27].

Data was recorded from randomly selected five plants during the initial growth stage. The observations taken were plant height, number of leaves per plant, leaf size, leaf area index, plant spread, number of days taken to the first harvest, head diameter, weight of main head, number of axillary sprouts per plant, weight of sprouts per plant, total yield, benefit cost ratio (BCR) and land equivalent ratio (LER).

3 Results and Discussion

3.1 Effect of nitrogen doses and intercropping systems on growth parameters of broccoli

3.1.1 Plant height

The data exhibited in Table 2 showed that application of nitrogen doses had significant effect on plant height of broccoli. The highest plant height at harvest obtained in N_3 (57.11 cm) was statistically at par with N_2 (54.25 cm), whereas, N_1 recorded the minimum plant height (49.36 cm). So, these consequences showed that plant height increased with increasing dose of nitrogen. Similar positive trend was also observed in studies of [9, 10, 11, 12 and 13] with their genetic material in their set of conditions. The increase in plant height might be due to enhanced photosynthesis. Nitrogen being an important component of chlorophyll imparts green colour to the plants and thus, improves the photosynthesis which resulted into more production of photosynthates and ultimately increased the plant height [14].

Intercropping systems had non-significant effect on plant height of broccoli. Though the statistical differences were non-significant, the sole crop of broccoli showed maximum plant height (54.28 cm) followed by broccoli + chilli (53.95 cm). Similar result was also recorded with regard to plant height of sole broccoli as compared to the intercropping systems in study of [15] under their environmental conditions. The interaction effect was also non-significant.

3.1.2 Number of leaves per plant

Nitrogen had significant effect on number of leaves per plant (Table 2). Broccoli plants treated with N_3 had maximum number of leaves (15.85) and were statistically at par with N_2 (15.04). The minimum number of leaves was found in N_1 (13.17). In general, the number of leaves per plant increased with increase in nitrogen dose. The present findings are in consonance with the studies of [9, 12, 13 and 16] who also reported such increase in leaf number per plant with their genetic material in their climatic conditions. This increase in number of leaves could be due to beneficial effect of nitrogen which promotes the meristemic activity and hence, increase the number of tissues and organs (leaves) as reported by [17].

The effect of intercropping system was non-significant on number of leaves per plant of broccoli. Instead of its non-significant effect, sole crop of broccoli exhibited the highest number of leaves (15.43) followed by broccoli + tomato (14.70). This result is supported by the studies of [15, 18 and 19].

The interaction effect of nitrogen rates and intercropping systems was also non-significant for the number of leaves per plant.

3.1.3 Leaf area (cm^2)

Results given in Table 2 indicated that nitrogen doses had statistical differences with regard to broccoli leaf area. The highest value was achieved in N_3 (394.87 m^2) and was at par with N_2 (392.42 cm^2). The minimum leaf size was recorded in N_1 (373.43 cm^2). The present investigation is in congruence with the studies of [10, 13 and 16]. Nitrogen enhances the cytokinin production in the roots of the plants and hence, more cytokinin carried to the leaves, resulted in more cell division. Therefore, an obvious increase in leaf area was obtained and leaf expansion took place. So, leaf area increases with higher dose of nitrogen.

Non-significant differences were observed due to intercropping systems and interaction effect with regard to leaf area of broccoli.

3.1.4 Leaf area index (LAI)

The results in Table 2 indicated that LAI increased significantly with higher dose of nitrogen. N_3 recorded the maximum LAI (3.39) followed by N_2 (3.09). The minimum value for LAI was obtained in N_1 (2.65). This result is in agreement with the study of [20]. The enhanced leaf area index might be due to more leaf area. So, the higher rate of nitrogen linearly increased the LAI accounting to more photosynthates production and finally higher yield.

The interaction effect and intercropping systems had non-significant differences for leaf area index.

3.1.5 Plant spread (cm)

Table 2 indicated the significant variations in plant spread with nitrogen doses. Plant spread enhanced with increment in nitrogen rate. Maximum value of plant spread was recorded in N_3 (64 cm) and was statistically at par with N_2 (61.71 cm). The minimum value for plant spread was found in N_1 (54.53 cm). The present result is in accordance with the study of [9 and 12]. Plant spread is directly related to leaf size. More leaf area will ultimately results into more plant spread.

The combined effect of both treatments and effect of intercropping system was non-significant.

3.2 Effect of nitrogen doses and intercropping systems on yield parameters of broccoli

3.2.1 Head weight (g)

Results presented in Table 3 indicated that nitrogen rate had significant effect on head weight of the broccoli. The maximum head weight was found in N_3 (176.72 g) and was statistically at pat with N_2 (174.34 g). The lowest value of head weight was obtained in N_1 (149.05 g). The present finding is in consonance with the investigations of [9, 10, 21, 22 and 23]. The enhanced head weight might be due to more photosynthetic activity with higher nitrogen rate resulting into accumulation of photosynthates and hence, more head weight.

The intercropping systems showed non-significant effect on head weight. However, maximum head weight was recorded in sole crop of broccoli (167.32 g). The interaction effect was also non-significant.

3.2.2 Number of axillary sprouts per plant

The evaluated data in Table 3 showed that number of sprouts followed increasing trend with increment in nitrogen rate. The maximum number of sprouts was found in N_3 (9.01) followed by N_2 (7.90). The minimum number of axillary sprouts was recorded in N_1 (6.97). The present result is supported by findings of [11 and 21]. This beneficial effect of nitrogen could be due to the enhanced meristemic activity of plants and hence production of new tissues and organs (sprouts).

The intercropping system and the interaction had non-significant effect for number of axillary sprouts of broccoli.

3.2.3 Weight of axillary sprouts per plant (g)

Results shown in Table 3 exhibited the remarkable effect of nitrogen on weight of axillary sprouts. More the number of sprouts more will be their weight. So, higher nitrogen rate increased the weight of axillary sprouts. The maximum weight of sprouts per plant was obtained in N_3 (130.50 g) and was statistically at par with N_2 (129.29 g). The minimum weight of axillary sprouts was recorded in N_1 (117.50 g). This result is in agreement with the study of [24].

No significant variation was observed in intercropping systems and interaction effect for weight of axillary sprouts.

3.2.4 Total yield (q/ha)

Significant differences were observed in nitrogen rates for total yield of broccoli. The highest yield was recorded in N_3 (145.47 q/ha) and was statistically at par with N_2 (143.11 q/ha). The minimum value was obtained in N_1 (134.19 q/ha). [9, 10, 21, 25 and 26] also reported such increase in yield of broccoli plants with higher nitrogen rates at their place.

The interaction of intercropping systems and nitrogen doses and; intercropping systems showed no significant variation for total yield of broccoli.

3.3 Effect of nitrogen doses and intercropping systems on economics and land equivalent ratio of broccoli

3.3.1 Economics

The perusal of data given in Table 4 showed that among nitrogen doses, the highest net return (Rs. 1, 07,900.32/ha) and benefit cost ratio (2.87) was observed in N_3 followed by N_2 (Rs. 1,05,872.19/ha and 2.84, respectively).

Among the intercropping systems, broccoli + tomato was found the most remunerative treatment as it recorded the highest net return (Rs. 1, 73,124.95/ha) and benefit cost ratio (3.74) followed by broccoli + chilli treatment (Net return: Rs. 1,67,938.3/ha and benefit cost ratio: 3.49). Cucumber being temperature sensitive was found least remunerative as intercrop in broccoli with lowest net return (Rs. 1,02,302.2/ha) and benefit cost ratio (2.69).

3.3.2 Land equivalent ratio (LER)

LER is an important factor to determine the efficiency of intercropping system. If the value of LER is greater than one in intercropping system then it indicates the efficient use of land. The results in Table 4 indicated that broccoli + tomato intercropping system was found the most remunerative as it recorded the highest LER (1.67) followed by broccoli + chilli. The lowest LER (0.96) was observed in broccoli + cucumber due to mortality of cucumber seedlings in month of December. The results confirmed that tomato and chilli can be successfully grown as intercrops in broccoli.

4 Conclusion

The objective of the present study was to find optimum dose of nitrogen in summer vegetable based intercropping system of broccoli under Punjab conditions. According to the results, growth and yield parameters both increased with higher rate of nitrogen. Broccoli + tomato showed the highest net return, benefit cost ratio and land equivalent ratio. Intercropping systems showed non-significant effect on growth and yield of broccoli. Broccoli is highly responsive to the varying levels of nitrogen so further experimentation is required to refine the nitrogen dose for broccoli cultivation along with summer vegetable crops as intercrops in intercropping systems.

Table 1: Sowing and transplanting time of crops

Sr. no.	Crop	Sowing Time	Transplanting time
1.	Broccoli	15^{th} September, 2016	15^{th} October, 2016
2.	Capsicum	22^{nd} September, 2016	25^{th} October, 2016
3.	Chilli	22^{nd} September, 2016	22^{nd} October, 2016
4.	Cucumber	20^{th} September, 2016	25^{th} October, 2016
5.	Tomato	20^{th} September, 2016	25^{th} October, 2016

Table 2: Effect of nitrogen doses and intercropping systems on growth parameters of broccoli (*Brassica oleracea* L.var. *italica*)

Treatment	Plant height at harvest (cm)	No. of leaves per plant	Leaf size (cm^2)	Leaf area index	Plant spread (cm)
Nitrogen (kg/ha)					
N_1 (125 kg/ha)	49.36	13.17	373.43	2.65	54.53
N_2 (150 kg/ha)	54.25	15.04	392.42	3.09	61.71
N_3 (175 kg/ha)	57.11	15.85	394.87	3.39	64.00
CD (P=0.05)	4.17	0.91	15.51	0.20	3.71
Intercropping System					
Broccoli (Sole)	54.28	15.43	390.63	3.08	60.84
Broccoli + Capsicum	53.28	14.58	388.43	3.04	59.57
Broccoli + Chilli	53.95	14.20	388.27	3.01	59.99
Broccoli + Cucumber	53.40	14.52	388.31	3.04	59.97
Broccoli + Tomato	52.95	14.70	378.88	3.05	60.03
CD (P=0.05)	NS	NS	NS	NS	NS
Interaction Effect	NS	NS	NS	NS	NS

Table 3: Effect of nitrogen doses and intercropping systems on yield parameters of broccoli (*Brassica oleracea* L.var. *italica*)

Treatment	Head weight (g)	No. of axillary sprouts per plant	Weight of axillary sprouts per plant (g)	Total yield (q/ha)
Nitrogen (kg/ha)				
N_1 (125 kg/ha)	149.05	6.97	117.50	134.19
N_2 (150 kg/ha)	174.34	7.90	129.29	143.11
N_3 (175 kg/ha)	176.72	9.01	130.50	145.47
CD (P=0.05)	10.56	0.49	8.20	8.69
Intercropping System				
Broccoli (Sole)	167.32	8.38	127.20	144.86
Broccoli + Capsicum	166.39	7.58	124.69	140.57
Broccoli + Chilli	167.00	7.99	125.36	139.78
Broccoli + Cucumber	166.87	8.03	126.70	140.29
Broccoli + Tomato	165.94	7.82	124.87	139.12
CD (P=0.05)	NS	NS	NS	NS
Interaction Effect	NS	NS	NS	NS

Table 4: Effect of different doses of nitrogen and intercropping systems on economics and land equivalent ratio of broccoli (*Brassica oleracea* L.var. *italica*)

Treatment	Gross return (Rs/ha)	Cost of cultivation (Rs/ha)	Net return (Rs/ha)	Benefit cost ratio	Land equivalent ratio		
Nitrogen (kg/ha)							
N_1 (125 kg/ha)	1,34,190	36,905.93	97,284.07	2.63	-	-	-
N_2 (150 kg/ha)	1,43,110	37,237.81	1,05,872.19	2.84	-	-	-
N_3 (175 kg/ha)	1,45,470	37,569.68	1,07,900.32	2.87	-	-	-
Intercropping System					**LER (Broccoli)**	**LER (Intercrops)**	**Total LER**
Broccoli (Sole)	1,44,860	37,237.80	1,07,622.2	2.8	-	-	-
Broccoli + Capsicum	2,13,629	48,133.8	1,65,495.2	3.43	0.97	0.60	1.57
Broccoli + Chilli	2,15,926	47,987.7	1,67,938.3	3.49	0.96	0.69	1.65
Broccoli + Cucumber	1,40,290	37,987.81	1,02,302.2	2.69	0.96	-	0.96
Broccoli + Tomato	2,19,403	46,278.05	1,73,124.95	3.74	0.96	0.71	1.67

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