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Sustainable Production of Bell Pepper in West Bengal

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***Abstract*:** An experiment was carried at Horticultural Research Station, Bidhan Chandra Krishi Viswavidyalaya, Mondouri, Nadia, during rabi seasons of 2017-18 and 2018-2019 to study effect of intercropping on of bell pepper. Most of the growth and yield attributes were significantly influenced by intercropping system. Maximum plant height (88.06 cm) was recorded from sole capsicum followed by capsicum+ French bean treatment (85.79 cm) and lowest value was observed in capsicum + spinach intercropping system (79.10 cm). Capsicum+ French bean recorded significantly maximum capsicum equivalent yield (31.16 tons ha^{-1}). Capsicum +French bean model recorded maximum TSS, ascorbic acid and beta carotene content of capsicum i.e. 6.27^0 Brix, 181.15 mg $100g^{-1}$ and 1.90 mg $100g^{-1}$, respectively. The total and reducing sugar content of capsicum is triggered when, coriander crop grown as inter crop. Capsicum + coriander treatment recorded highest total (5.15 %) and reducing sugar (2.83 %) content. Capsicum grown with French bean valued maximum land equivalent ratio about 1.62 and minimum of 1.29 was recorded for spinach grown as intercrop in capsicum. Maximum B: C ratio (3.02) was obtained in capsicum+ French bean model .Inclusion of French bean in the interspaces of capsicum may be a viable option for sustainable production of bell pepper.

***Keywords*:** Bell pepper, Economics, Growth, Intercropping, Sustainable

Intercropping of bell pepper with different crops offers greater scope to utilize the land and other resources to maximum extend (Brintha et al 2012). Among the cropping system intercropping is the most suitable practice to stabilize the production (Kabiraj et al 2017) and two or many crops can be grown at a time from the same land having huge advantages over mono cropping (Islam et al 2021). Intercropping with vegetables is also profitable as it generates more income of the farm through increased production $unit^{-1}$ area from more number of crops in a season of a year (Dodiya et al 2018) as it provides complete and economical use of natural resources like soil, water, space, nutrients and sunlight through selection of crop combination of different duration and rooting pattern(Qinyu et al 2022). Intercropping also minimizes the cost of production attracting farmers towards intercropping cultivation (Choudhuri et al 2016). Sweet pepper, which is one of the capital earning vegetable crops for the farmers of gangetic plains of west Bengal. The soil and climatic condition of this region is mostly sandy loam in nature coupled with low organic matter and high rainfall. Cultivation of capsicum is gaining its importance among the vegetable growers of this region. But this vegetable suffers from lower productivity, frequent outbreak of pest and diseases. On the other hand capsicum is grown with wider spacing which offers ample scope for taking intercrops in between. Keeping all these present study was undertaken.

MATERIAL AND METHODS

This experiment was carried out at Horticultural Research Station, Bidhan Chandra Krishi Vishwavidyalaya, Mondouri, Nadia, during the year 2017-18 and 2018-2019. The location of the experimental site is 23.5^0 North latitude and 80^0 East longitudes with average altitude of 9.75 m above the MSL. The research work was conducted during rabi season in the randomized block design with nine (9) treatment combinations and replicated thrice, with capsicum variety Ayesha (Table 1). Seeds of capsicum were sown in plug-trays filled with coco-peat as a growing media and seedlings emerged after one week. The 30-35 days old capsicum seedlings were transplanted at the experimental plot, whereas for other intercrops direct seed sowing was done. Capsicum seedlings were transplanted at a spacing of 60 cm x 50 cm. Seeds of the intercrops i.e. spinach, radish, coriander and French bean were sown in between the rows of capsicum in 1:1 ratio i.e. in additive series and they were also transplanted in sole plot at spacing of 20 x 5 cm, 20 X 10 cm, 30 x 15 cm and 50 x 15 cm, respectively. Observations recorded are plant height (cm), plant main stem girth (cm), number of primary branches $plant^{-1}$, number of secondary branches $plant^{-1}$, number of leaves $plant^{-1}$, fruit length (cm), fruit diameter (cm), fruit yield $plant^{-1}$ (kg), fruit yield $plot^{-1}$ (kg) and total yield (tonnes ha^{-1}). Crops were raised and suitable measures and methods were adopted for fertilizer application, weed minimization, harvesting, disease and pest control following standard cultivation practices. Total soluble solids (TSS) content was estimated with the help of a digital refractometer (0 to 32°Brix). Ascorbic acid content of

capsicum fruits was determined (Ranganna 1986). Beta carotene content of fruit was analyzed as per the method suggested by Davies (1976).Total and reducing sugar content were estimated by the procedure proposed by Dubois et al (1956).

In association of crop yield, Capsicum Equivalent Yield (CEY) (Verma and Modgal 1983), Land Equivalent Ratio (LER) (Mead and Willey 1980) and Relative Crowding Coefficient (K) (Hall 1974) were measured.

Capsicum Equivalent Yield measured by the formula of

Yield of capsicum in intercrop + Yield of intercrop in a mixed stand x price of intercrop

Price of capsicum

LER = $\sum$ Yij/Yii,

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

Relative Crowding Coefficient (K) was measured by the formula of

$Kab = Y_{ab} X Z_{ba}$

(a and b are two crops in intercropping system)

$(Y_{aa}-Y_{ab}) x Z_{ab}$

Where, Yab= yield of crop a in mixed stand, Yaa= yield of crop a in pure stand, Zab= sown proportion of crop a (in mixed stand with b), Zba= sown proportion of crop b (in mixed stand with crop a. Mean values of each entry in each replication for all the traits were subjected to statistical analysis by using MS Office Excel software.

Economics of capsicum production under intercropping system was calculated by computing the market price of capsicum and their intercrops and net returns and benefit cost ratios were worked out for each treatment (Zivenge et al 2013).

Net returns = Gross returns – Total production cost.

Benefit: Cost = Gross returns / Total production cost

RESULTS AND DISCUSSION

Growth parameters: Intercropping had significantly affected most of the growth parameters of bell pepper (Table 1). Maximum plant height (88.06 cm) was recorded from sole capsicum followed by capsicum+ French bean treatment and minimum plant height (79.10 cm) was observed in capsicum + spinach intercropping system preceded by capsicum + radish intercropping combination. maximum values of plant height in capsicum + French bean plots might be due lesser competition between the components crops for biological resources. This result was in conformity with the findings of Magray et al (2021) and Suresha et al (2007) in capsicum and chilli based intercropping system respectively.

Maximum stem girth (0.73 cm) was in sole capsicum and was statistically at par with all other treatment. Same trend was also observed by Thapa (2015) in garlic based intercropping system, where stem girth was maximum in sole garlic followed by garlic + garden pea intercropping system. Significantly highest number of leaves plant^{-1}(58.07) was from sole capsicum treatment and among the intercropping system, higher number of leaves plant^{-1} was found in capsicum+ French bean treatment which is supported by Morsy et al (2009), followed by capsicum+ coriander and statistically at par with each other. Lowest number of leaves plant^{-1} (46.03) was recorded from capsicum + spinach treatment. Maximum number of both primary and secondary branches plant^{-1} observed when capsicum has been grown alone. Begum et al (2015) also observed sole cropping of chilli produced maximum number of branches plant^{-1} in chili based intercropping system. This might be due to minimum competition for space and growth resources compared to growing of two or more crops in intercropping.

Yield attributing characters: Intercropping influenced yield and yield attributing characters of capsicum (Table 2). Significantly maximum fruit length (8.95 cm), fruit diameter (6.96 cm) and fruit yield (27.58 t ha^{-1}) of capsicum was from sole capsicum treatment over all other treatments. Jan et al (2016) while carrying out a field trial at Sheri Kashmir University of Agricultural Sciences and Technology, Srinagar to evaluate the nodulation behavior and other growth and yield parameters of maize and cowpea in different ratio found the similar type of results. Capsicum grown alone has no competition from intercrops for nutrients, water, sunlight,

Table 1. Effect of intercropping on growth parameters of capsicum

Treatments	Plant height (cm)	Plant main stem girth (cm)	Number of leaves plant^{-1}	Number of primary branches plant^{-1}	Number of secondary branches plant^{-1}
T_1: Sole capsicum	88.06	0.73	58.07	1.84	5.00
T_2:Capsicum+ spinach	79.10	0.63	46.03	1.54	3.93
T_3:Capsicum+radish	81.01	0.65	48.80	1.45	3.48
T_4:Capsicum+Frenchbean	85.79	0.69	54.93	1.68	4.09
T5:Capsicum+Coriander	83.58	0.66	52.71	1.59	3.58
CD (p=0.05)	1.38	0.07	3.97	0.20	0.61

space etc. that leads to maximum utilization of all the available resources by capsicum alone, which accelerated higher crop production. Higher values of fruit length (8.53 cm) and diameter (6.59 cm) were observed from capsicum+ French bean treatment followed by capsicum + coriander model. Significantly lowest fruit length and diameter (7.35 cm and 5.83 cm respectively) were obtained from capsicum+ spinach treatment. Brintha et al (2012) also reported maximum fruit length and diameter in sole chilli plots. Different levels of nitrogen, phosphorus, particularly potassium, plays dynamic role and significantly influence the production and development of good quality and length of fruits. The model Capsicum+ French bean recorded highest yield (26.20 t ha^{-1}) in intercropping combinations, which is statistically at par with capsicum+ coriander treatment and significantly lowest fruit yield about 20.90 t ha^{-1} was observed from capsicum+ spinach treatment. Koocheki et al (2021) also observed maximum values for most of the yield attributing characters in sole capsicum plots.

Capsicum+ French bean intercropping system recorded significantly maximum capsicum equivalent yield ha^{-1} (31.16 t) and lowest was observed from capsicum + spinach treatment (23.81 t ha^{-1}), preceded by capsicum + coriander intercropping system which was statistically at par with capsicum+ radish treatment. The maximum values for capsicum equivalent yield in capsicum + French bean intercropping treatment might be due the inclusion of the legume crop like French bean which might have helped in more nitrogen fixation and hence increased the nitrogen availability to the main crop. Singh et al (2019) while evaluating the efficiency of maize + pea intercropping system at Khalsa College, Amritsar, India also found that maximum maize equivalent yield was obtained from maize + pea intercropping system. Magray et al (2021) also recorded similar results in capsicum and French bean association. Kumari et al (2018) observed maximum chilli equivalent yield in chilli + fenugreek intercropping system. This may be due to ameliorative effect legume crop like fenugreek and less competition among them for water, nutrient, light etc. due to higher values of biological parameters like land equivalent ratio, relative crowding coefficient, etc and high price of French bean.

Effect of intercropping on qualitative parameters of capsicum: Biochemical parameters like TSS, ascorbic acid, beta carotene and sugar content of capsicum were also affected by intercropping (Table 3). French bean grown as inter crop recorded maximum TSS value, ascorbic acid and beta carotene content of capsicum (6.27^0 Brix, 181.15 mg 100 g^{-1} and 1.90 mg 100g^{-1}, respectively). The capsicum + coriander treatment recorded highest total and reducing sugar about 5.15 and 2.83%, respectively. Lowest values of TSS (4.58^0 Brix), ascorbic acid (89.62 mg 100g^{-1}) and beta carotene content (0.59 g 100 g^{-1}) of capsicum were observed from capsicum+ radish treatment. Significantly, lowest values of total sugar (4.19 %) and reducing sugar (2.56 %) were recorded from capsicum crop grown alone.

The higher ascorbic acid content in capsicum and French bean intercropping might be attributed to increased

Table 2. Effect of intercropping on yield and yield attributing parameters of capsicum

Treatments	Fruit length (cm)	Fruit diameter (cm)	Yield (t ha^{-1})	Capsicum equivalent yield (t ha^{-1})
T_1	8.95	6.96	27.58	27.58
T_2	7.35	5.83	20.90	23.81
T_3	7.89	6.03	24.26	27.31
T_4	8.53	6.59	26.20	31.16
T_5	8.30	6.26	25.38	26.80
CD (p=0.05)	0.13	0.12	1.01	1.08

Table 3. Effect of intercropping on quality parameters of capsicum

Treatments	TSS (°Brix)	Ascorbic acid (mg/100g)	β carotene (mg 100g^{-1}	Total sugar (%)	Reducing sugar (%)
T_1	5.38	159.98	1.32	4.19	2.56
T_2	5.01	137.80	0.68	4.61	2.61
T3	4.58	89.62	0.59	4.53	2.59
T_4	6.27	181.15	1.90	4.81	2.67
T5	4.80	106.30	1.07	5.15	2.83
CD (p=0.05)	0.29	10.05	0.92	0.14	0.08

availability of nutrients in the soil that might lead to synthesis and accumulation of more photosynthates which could have mobilized the biosynthesis of ascorbic acid. Choudhuri (2011) also found that maximum ascorbic acid content was found in okra + cowpea intercropping system. Increase in β- carotene and total sugar content of capsicum fruits may be attributed to increased vegetative growth in capsicum + French bean intercropping system due to better biological attributes like higher LER, Relative crowding coefficient, etc., which increases the efficiency of photosynthesis for the manufacture of compounds such as polysaccharides, which, when analyzed, produce acetyl COA, lycopene and β- carotene dyes (Hussein 2013). Mana and Kazem (2014) explained that the intercropping system outweighs the qualities and quality of the product. Capsicum and coriander grown together that leads to accumulation of potash in capsicum at higher quantities as coriander is less user of potash and ultimately accumulated more reducing sugar in capsicum.

Competitive functions: The observation recorded on competitive functions showed that capsicum grown with French bean recorded maximum LER value of 1.62, which indicated that about 62% of land saving and also have yield advantages, when French bean grown along with capsicum intercropping system (Table 4). It might be due to efficient utilization of natural resources viz., space, light, etc. as well as component crop having different characteristics like nutrient requirements and shading effects. Thapa, (2015) also reached the same conclusion. Capsicum + spinach recorded lowest value of LER (1.29).

All the values of relative crowding coefficient showed greater than one, which indicated yield advantage over monocropping and better land utilization efficiency by the component crops. Capsicum grown with French bean recorded maximum relative crowding coefficient (RCC) (42.16) followed by capsicum + coriander (23.65) intercropping system. RCC value obtained for all the treatment combinations in this experiment is more than one, which assumed sustainable biomass production for all treatments. Capsicum grown with French bean recorded maximum values for relative crowding coefficient which might be due to beneficial effect of legume to capsicum that leads to production of higher quantity of capsicum and French bean. Meena et al (2008) also observed same phenomena in cluster bean + sesame intercropping system.

Table 4. Effect of intercropping on competitive function of capsicum

Treatments	Land equivalent ratio	Relative crowding coefficient		Product
		K_a	K_b	
T_1:Capsicum+ spinach	1.29	3.15	1.20	3.78
T_2:Capsicum+ radish	1.45	7.46	1.35	10.07
T_3:Capsicum+ french bean	1.62	19.25	2.19	42.16
T_4:Capsicum+ coriander	1.57	11.65	2.03	23.65
T_5:Sole capsicum	1	-	-	-
T_6:Sole spinach	1	-	-	-
T_7:Sole radish	1	-	-	-
T_8:Sole french bean	1	-		-
T_9:Sole coriander	1	-	-	-

K_a – Relative crowding coefficient of capsicum, Kb- Relative crowding coefficient of intercrops

Table 5. Economics of capsicum based intercropping system

Treatments	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio
T_1:Capsicum+ spinach	131063.00	309530.00	178467.00	2.36
T_2:Capsicum+ radish	132220.00	355030.00	222810.00	2.69
T_3:Capsicum+ French bean	130050.00	405080.00	271030.00	3.11
T_4:Capsicum+ coriander	120052.00	348400.00	228348.00	2.90
T_5:Sole capsicum	123120.00	358540.00	235420.00	2.91
T_6:Sole spinach	42575.00	71170.00	28595.00	1.67
T_7:Sole radish	43075.50	74060.00	30985.00	1.72
T_8:Sole French bean	45065.00	91700.00	46635.00	2.03
T_9:Sole coriander	20075.00	28015.00	7940.00	1.40

Economics: The capsicum + French bean combination was most remunerative as it recorded highest B : C ratio (3.11) followed by sole cropping of capsicum (Table 5). Among the intercropping systems, capsicum + spinach combination was recorded least economical (2.36). Among different combinations, capsicum grown with French bean was most remunerative which is due to maximum capsicum equivalent yield than all other treatments. But due to comparatively higher cost of cultivation and comparatively lower capsicum equivalent yield than most of the treatments capsicum grown with spinach was least remunerative Thapa (2015) also observed that the intercropping system garlic + garden pea combination was the most economical.

CONCLUSION

Most of the growth and yield attributes were significantly influenced due to intercropping system and economic analysis showed that capsicum+ French bean model recorded highest benefit-cost ratio. Hence, it may be concluded that inclusion of French bean with capsicum can be a profitable for a sustainable production system for the farmers of Gangetic plains of West Bengal.

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