J. Farm Sci., 35(1): (85-89) 2022

RESEARCH PAPER

Evaluation of sweet corn (*Zea mays convar. Saccharata* L.) based intercropping systems with vegetable legumes during winter season

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(Received: October, 2021 ; Accepted: January, 2022)

Abstract : A field experiment was conducted at Main Agricultural Research Station, UAS, Dharwad during *rabi* 2020-21 to study the intercropping of sweet corn with vegetable legumes. It was laid out in randomized complete block design with 10 treatments replicated thrice. The treatments consisted of sweet corn intercropping with field bean, green pea and french bean at 1:1 and 2:2 row proportion compared with their sole cropping for their productivity and profitability. Sole sweet corn recorded significantly higher cob yield with husk (162.2 q ha^{-1}) and without husk (131.3 q ha^{-1}) compared to its' yield in intercropping systems in 2:2 row proportion. Among intercropping systems, sweet corn + field bean (151.9 and 121.0 q ha^{-1} respectively) and sweet corn + green pea (149.2 and 118.5 q ha^{-1} respectively) at 1:1 row proportion recorded significantly higher sweet corn yield with and without husk compared to 2:2 row proportion and also recorded higher growth and yield attributes of both component crops. Further higher sweet corn equivalent yield (239.84 q ha^{-1}), gross return (₹ 4,05,400 ha^{-1}), net return (₹ 3,26,900 ha^{-1}), and B:C ratio (5.17) were recorded in sweet corn + green pea in 1:1 row ratio, which was on par with sweet corn + field bean which had recorded higher LER and ATER in 1:1 row proportion. Therefore, sweet corn intercropped with green pea in 1:1 row ratio found remunerative.

Key words: Economics, Growth, Net return, Sweet corn

Introduction

Specialty corns *viz.*, sweet corn, popcorn, baby corn, and high oil corn *etc.* assume a tremendous market potential not only in India but also in international market. These specialty corns with their high market value are perfectly suitable to peri-urban agriculture. Thus they promise higher income to maize growers. Out of the various specialty corns, sweet corn (*Zea mays* convar. *Saccharata* L) has big market potential. It is introduced to India recently from USA. Hungary is the leading sweet corn producing country in the European union, having an area of 31,000 ha (Anon., 2006). Sweet corn also called sugar corn and pole corn. It is a hybridized variety of maize with a high sugar content (12%) and rich source of Vitamin C, niacin, beta-carotene dietary fiber, antioxidant elements like calcium, potassium *etc.* In India, sweet corn is grown on a very limited area by some farmers and other private sectors to meet domestic requirement. Unlike field corn varieties, which are harvested when the kernels are dry and mature (dent stage), sweet corn is picked when immature (milk stage) and prepared and eaten as a vegetable, rather than a grain. Since the process of maturation involves converting sugar to starch, sweet corn stores poorly and must be eaten fresh, canned, or frozen before the kernels become tough and starchy. It is one of the seven major types of corn, the others being dent corn, flint corn, pod corn, popcorn, and flour corn.

Legumes are essential because they play a key role in the vegetarian diet that is prevalent in India. Malnutrition among the most vulnerable members of our society is being caused by a lack of pulses in the country. Combining pulses with cereal-based diets, according to nutritionists, is one of the most effective measure to fight protein deficiency. To fulfil the body's protein requirements, the ICMR recommends 55-80 g of pulses per capita per day. However, India's current per capita availability of pulses is 43.9 g. Therefore, growing pulses as intercrops in diverse existing crops or in several cropping systems can enlarge the area under pulses.

Legumes like Green pea (*Pisum sativum* L.) is grown in an area of 5.40 lakh hectares with the production of 54.22 lakh metric tonnes and the productivity is 10.04 tonnes per hectare (Anon., 2018) consumed as a vegetable. French bean (*Phaseolus vulgaris*) being fertilizer responsive cool season legume vegetable, grown for its tender pods, shelled green beans and dry beans (Rajmah beans). In India, the average production and productivity of french bean were 6.75 lakh tonnes and 27.94 t/ha, respectively. Where as in the world, the production and productivity were 242.21 lakh tonnes and 153.30 t/ha, respectively from an area of 15.80 lakh ha (Anon., 2018). Field bean (*Lablab purpureus* L.) commonly known as *dolichos*, *lubia* and *hyacinth* bean. It's a bushy, perennial herb and semi erect belongs to family Fabaceae. Karnataka recorded a production of 8,000 t from an area of about 85,000 ha (Anon., 2016).

Principal reasons for small farmers to adopt intercropping are because of flexibility, risk minimization, pests and disease control, profit maximization, balanced nutrition and soil conservation (Matusso *et al*., 2014). Because of limited horizontal expansion of space, intercropping could help enhance vegetable yield. Sweet corn, as a wider-spaced plant, allows some component crops to grow without incurring a financial loss, while sacrificing a lower sweet corn yield in exchange for

increased production in terms of land and time. Because of meagre research in this sector the intercropping of legumes with sweet corn was selected to study the feasibility and economics of this intercropping system.

Material and methods

A field experiment was conducted to study the intercropping of sweet corn with vegetable legumes at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad (Karnataka) during *rabi* 2020-21 in black clay textural soil with medium in available nitrogen (298 kg ha^{-1}N), phosphorus (30 kg $ha^{-1}P_2O_5$) and potassium (287 kg ha^{-1} K_2O), respectively. The total rainfall during *rabi* season of sweet corn cropping period (November – February) was 37.8 mm. The experiment was laid out in Randomized complete block design (RCBD) with three replications having ten treatment combinations of sweet corn, field bean green pea and french bean in sole, 1:1 and in 2:2 row proportions. Sweet corn hybrid used was 'Sugar 75' which was released by Syngenta pvt.ltd. The intercropped varieties were *Hebbalavre*, *AP3* and *Vaishali* of field bean, green pea and french bean respectively. The sweet corn Seeds were sown at a spacing of 60 cm x 20 cm with seed rate of 10 kg ha^{-1} and intercrops were sown at 30 x 10 cm spacing. The row proportion followed was 1:1 and 2:2 for additive series of intercropping systems. The recommended quantity of FYM (7.5 t ha^{-1}) was applied two weeks before sowing of the crop. Recommended dose of fertilizers were applied for the sole crops of sweet corn (100:50:25 kg N, P_2O_5 and K_2O ha^{-1}, respectively) and intercrops field bean (25:50:25 kg N, P_2O_5 and K_2O ha^{-1}), green pea (38:60:50 kg N, P_2O_5 and K_2O ha^{-1}) and french bean (63:100:75 kg N, P_2O_5 and K_2O ha^{-1}). In the intercropping systems the fertilizers were applied to the component crops and were placed in furrows opened at 5 cm away from the crop row and covered with soil. For sweet corn crop, half of the recommended nitrogen and full doses of phosphorous and potash were placed below the seed in opened furrows at the time of sowing. Remaining nitrogen was top dressed at knee-high stage and second at tasselling stage. For component crops, full dose of nitrogen, phosphorous and potash was given as per the treatments. The other management operations were done as per recommended package of practices for both main and intercrops. Growth and yield components of sweet corn were recorded at 30 and,60 DAS, and at harvest stage and for intercrops these were recorded at 30DAS and at harvest of crops. The equivalent yield of sweet corn crop was calculated by following formula.

$$\text{SEY (q ha}^{-1}\text{)} = \text{Sweet corn yield} + \frac{\text{legume yield (q ha}^{-1}\text{)} \times \text{Price of legume (₹ q}^{-1}\text{)}}{\text{Sweet corn price (₹ q}^{-1}\text{)}}$$

Leaf area was computed by length and breadth method. It was multiplied by factor 0.75 and expressed in dm^2 by following procedure given by Saxena and Singh (1968) but for intercrops (field bean, green pea and french bean) leaf area was worked out by leaf area meter.Leaf area index of component crops worked out by dividing leaf area per plant (dm^2) by area occupied by per plant (dm^2) and this procedure given by Watson (1952). Light transmission ratio calculated by dividing Light intensity (foot candles) above the canopy (I_0) by Light intensity (foot candles) at ground level (I) and this procedure was given by Yoshida *et al.,* (1972). Harvest index for main crop and intercrops was worked out by dividing economic yield (kg ha^{-1}) of crops by biological yield (kg ha^{-1}) of respective crops. The benefit-cost ratio was calculated by dividing Gross returns (₹ ha^{-1}) by cost of cultivation (₹ ha^{-1}).

Results and discussion

Performance of sweet corn

Sole sweet corn recorded significantly higher fresh cob yield with husk (162.2 q ha^{-1}), without husk (131.3 q ha^{-1}) and green fodder yield (233.3 q ha^{-1}) compared to its' yield in intercropping systems at 2:2 row ratio (Table 1). It was on par with intercropping of sweet corn with all vegetable legumes at 1:1 ratio. The higher yield in sole cropping may be due to the competition free light, soil moisture, air, nutrients and better

Table 1. Growth and yield components and sweet corn equivalent yield as influenced by intercropping system

Tr. No.	Treatments	Plant height (cm)	TDMP (g $plant^{-1}$)	Leaf area index	Cob length (cm)	Cob diameter (cm)	Grain weight cob^{-1} (g)	Cob yield with husk (q ha^{-1})	Cob yield without husk (q ha^{-1})	SCEY (q ha^{-1})	Stover yield (q ha^{-1})
T_1	Sole sweet corn	194.3	188.50	5.52	22.00	10.85	214.73	162.2	131.3	162.20	41.16
T_2	Sole green pea									181.78	-
T_3	Sole field bean									150.31	-
T_4	Sole french bean									163.44	-
T_5	Sweet corn + field bean (1:1)	178.1	177.90	5.15	21.33	9.47	201.77	151.9	121.0	227.82	40.93
T_6	Sweet corn + green pea (1:1)	174.4	174.33	4.58	19.67	9.07	194.83	149.2	118.5	239.84	40.73
T_7	Sweet corn + french bean (1:1)	171.2	169.43	4.41	19.33	8.63	184.53	145.6	115.2	230.35	40.76
T_8	Sweet corn + field bean (2:2)	189.6	161.67	3.61	16.00	8.17	179.00	128.4	93.4	194.30	40.52
T_9	Sweet corn + green pea (2:2)	185.2	154.91	3.12	15.67	7.50	173.43	114.5	85.6	197.59	38.42
T_{10}	Sweet corn + french bean (2:2)	182.1	151.10	2.81	14.33	7.03	162.13	108.3	80.8	188.83	37.58
	S.Em. ±	3.9	7.63	0.37	0.93	0.39	10.14	5.5	6.28	9.73	7.48
	LSD (P = 0.05)	12.1	23.47	0.99	2.87	1.17	31.18	16.98	19.35	162.20	NS

TDMP: Total dry matter production SCEY: Sweet corn equivalent yield

agronomic practices which helped the crop to exhibit their full production potential. Crops having divergent growth habits can decrease the mutual competition for growth factors. Cowpea, green gram and black gram, because of short duration, grow complementary with maize crop and fit capably as intercrops in maize. As these crops have divergent growth pattern and rooting habit, there is a healthy competition between them. Since maize is a broadly spaced crop, inter-row space could profitably be utilized by legumes (Shridhar and Salakinkop, 2021). Singh and Singh (1993) observed the growth and yield are generally decreased when two or more crops grown together in intercropping system compared to respective sole cropping, but the combined yield was higher either of sole crops as a result of higher total productivity and returns, it indicates better compatibility between the component crops with suitable cropping geometry Higher yield attributes *viz.*, cob length (22.0 cm), cob girth (10.85 cm), fresh grain weight per cob (214.73 g) and cob weight (313.0 g cob $^{-1}$) contributed towards increased yield in sole sweet corn. Further improved growth parameters *viz.*, leaf area plant^{-1} (76.5, and 66.20 dm^2 at 60 DAS and at harvest respectively), leaf area index (6.65 and 5.53 at 60 DAS and harvest stage, respectively) and total dry matter production (114.67 and 188.50 g plant^{-1}at 60 DAS and at harvest respectively) (Table 1)have contributed better yield and yield attributes in sole crop than intercrop. There was more light transmission in sole sweet corn (55.79 and 39.50% at 30 and 60 DAS, respectively) than in intercrops. The increased light transmission ratio could have helped towards higher photosynthesis, dry matter accumulation and translocation to reproductive parts. Manpreet *et al.* (2016) also reported higher plant height, cobs per plant and grains per cobin sole maize compared to maize in intercropping with rajmasha. Marer (2007) also reported higher plant height, leaf area plant^{-1}, grain weight per plant and test weight in sole maize. Shridhar and Salakinkop (2019) also found that sole maize recorded significantly higher leaf area plant^{-1}, cob girth, grain weight per cob, kernel yield and stover yield compared to its intercropping systems.

Among intercropping systems, sweet corn at 1:1 row ratio with field bean recorded higher fresh cob yield with husk (151.9 q ha^{-1}) and without husk (121.0 q ha^{-1}) and higher green fodder yield (219.4 q ha^{-1}) compared to their 2:2 row proportion. The higher cob yield and green fodder yield was mainly due to complimentary relationship between the component crops and optimum spacing leads to lesser competition for the resources. However, yield attributes *viz*., cob length (21.33 cm), cob girth (9.47 cm), number of grains cob^{-1} (518.1), fresh grain weight per cob (201.77 g) and cob weight (301.67 g cob^{-1}). Further the growth parameters *viz*., leaf area plant^{-1} (70.7 and 61.72 dm^2 plant^{-1}), leaf area index (5.24 and 5.15 at 60 DAS and harvest stage, respectively) and total dry matter production (110.80 and 177.90 g plant-1 at 60 DAS and harvest stage, respectively,) were higher in sweet corn + field bean at 1:1 row proportion than in 2:2 row ratio due to complementary relationship between the crops and lower competition for available resources at field level. At 1:1 row ratio increased light transmission ratio could have helped towards higher photosynthesis, dry matter accumulation and translocation to reproductive parts. Jha *et al*. (2015) stated that 1:1 row proportion of maize with legumes (soybean, rice bean and cowpea) recorded significantly higher stover yield of maize as compared to 1:2 row proportion. Padhi *et al*. (2006) revealed that the higher parameters like cobs plant^{-1} grains cob^{-1} (and maize yield was observed in maize + soybean intercropping at 1:1 row ratio. Vinayak (2019) reported significantly higher yield attributing characters in maize + field bean at 1:1 row proportion.

Performance of intercrops

Sole crops of field bean recorded higher fresh pod yield and fresh haulm yield (96.20 and 82.67 q ha^{-1} respectively), green pea (83.10 and 84.70 q ha^{-1} respectively) and french bean (87.17 and 78.80 q ha^{-1} respectively) compared to their yield in intercropping systems (Table 2). Higher fresh pod and haulm yield in sole intercrop were mainly due to higher plant population and lower interspecific competition for growth resources (Padhi., 2001). Further contribution by yield attributing characters especially number of pods per plant (17.01, 22.47 and 16.87 in green pea, field bean and french bean respectively) which was higher in sole cropping compared to intercropping system.

Further, there was improved growth parameters at 30 DAS and at harvest such as plant height of field bean (16.43 and 75.33 cm, respectively) green pea (22.70 and 46.80 cm, respectively) and french bean (28.20 and 42.53 cm respectively) leaf area per plant of field bean (19.07 and 137.40 dm^2 plant^{-1}

Table 2. Growth and yield components of vegetable legumes at harvest as influenced by intercropping system

Tr. No.	Treatments	Plant height (cm)	Leaf area (dm^2 plant^{-1})	Leaf area index	No. of pods plant^{-1}	Fresh pod yield (q ha^{-1})	Fresh haulm yield (q ha^{-1})	Harvest index
T_2	Sole green pea	46.80	49.13	1.64	17.01	83.10	84.70	49.6
T_6	Sweet corn + green pea (1:1)	42.08	40.63	1.35	15.44	41.43	46.33	47.3
T_9	Sweet corn + green pea (2:2)	43.93	44.77	1.49	14.58	37.97	38.67	49.5
T_3	Sole field bean	75.53	137.40	4.58	22.47	96.20	82.67	53.8
T_5	Sweet corn + field bean (1:1)	71.44	108.90	3.63	20.00	48.57	46.00	51.2
T_8	Sweet corn + field bean (2:2)	73.23	122.70	4.09	17.33	42.20	38.00	52.9
T_4	Sole french bean	42.53	61.77	1.44	16.87	87.17	78.80	52.6
T_7	Sweet corn + french bean (1:1)	36.66	54.00	1.27	14.67	45.20	41.47	52.1
T_{10}	Sweet corn + french bean (2:2)	38.97	57.70	1.36	11.67	42.93	40.43	51.6
	S.Em. ±	1.87	6.29	0.19	1.07	3.27	4.55	1.64
	LSD (P = 0.05)	5.60	18.8	0.59	3.20	9.80	13.6	NS

Table 3. Economics of sweet corn and vegetable legumes under sole and intercropping systems

Tr. No.	Treatments	Cost of cultivation (000, ₹ ha^{-1})	Net returns (000, ₹ ha^{-1})	B:C ratio
T_1	Sole sweet corn	67.86	215.0	4.17
T_2	Sole green pea	50.12	249.2	5.97
T_3	Sole field bean	50.23	198.5	4.95
T_4	Sole french bean	77.12	192.2	3.49
T_5	Sweet corn + field bean (1:1)	77.03	309.4	5.02
T_6	Sweet corn + green pea (1:1)	78.47	326.9	5.17
T_7	Sweet corn + french bean (1:1)	84.65	304.9	4.60
T_8	Sweet corn + field bean (2:2)	77.03	252.7	4.28
T_9	Sweet corn + green pea (2:2)	78.47	256.0	4.26
T_{10}	Sweet corn + french bean (2:2)	84.65	235.6	3.78
	S.Em. ±	-	15.8	0.19
	C.D. at 5 %	-	46.7	0.60

respectively) green pea (21.97 and 49.13 dm^2 plant^{-1} respectively) french bean (19.73 and 61.77 dm^2 plant^{-1} respectively) in sole crop as compared to intercropping systems.

Among the intercropping systems sweet corn + vegetable legumes at 1:1 row ratio recorded higher fresh pod yield and fresh haulm of intercrops, (field bean (48.57 q ha^{-1}, 46.00 q ha^{-1}, respectively), green pea (41.43 q ha^{-1}, 46.33 q ha^{-1} respectively) and french bean (45.20 q ha^{-1}, 41.47 q ha^{-1} respectively) (Table 2) due to optimum spacing and lesser competition for resources. However, yield attributing characters such as pods per plant (15.44, 20.00, 14.67 in green pea, field bean, and french bean respectively,) was highest in 1:1 row ratio than 2:2 row ratios. There was more light transmission ratio in sweet corn intercropped with vegetable legumes at 1:1 row ratio compared to 2:2 row ratio. Increased light transmission ratio could have helped towards more photosynthesis, dry matter accumulation and translocation to reproductive parts.

Maximum yield loss of intercrops was in 2:2 row ratio due to reduction in spacing and spatial competition for growth factors for prolonged period and their susceptibility to shading effect could have affected performance of legumes (Shridhar., 2019). Minimum yield reduction of intercrops was in 1:1 row ratio might be due to its better spacing and plant population, effective utilization of resources and lesser shading effect. Similar results were obtained by Padhi *et al*. (2006) and Parvender *et al*. (2010) in black gram yield with maize at 1:1 row ratio.

Economic analysis

Significantly higher gross and net returns and B:C ratio were recorded in 1:1 row ratio of sweet corn + green pea (₹ 4,05,400 ha^{-1} and ₹ 3,26,900 ha^{-1}). which were on par with sweet corn + field bean (₹ 3,86,400ha^{-1} and ₹ 3,09,400 ha^{-1}), sweet corn + french bean (₹ 3,89,600 ha^{-1} and ₹ 3,04,900 ha^{-1}) at 1:1 row ratio. The increased gross and net returns were mainly due to better performance of component crops which have higher equivalent yield and higher market price of sweet corn (₹1600 q^{-1}), field bean (₹ 2500 q^{-1}), green pea (₹ 3500 q^{-1}) and french bean (3000 q^{-1}). On other hand significantly lower gross and net returns were recorded in sole field bean (₹ 2,48,800 ha^{-1} and ₹ 1,98,500 ha^{-1}respectively) than other treatments. The results are corroborated with the findings of Artika *et al.,* 2017 who reported significantly higher gross returns (₹ 1,41,593 ha^{-1}), net returns (₹ 1,21,719 ha^{-1}) and B-C ratio (7.12) under clusterbean + cowpea (2:2) intercropping systems. Manpreet *et al.* (2016) revealed that among the intercropping system, maize + rajmash in 1:1 row ratio produced maximum net return (₹ 52,190 ha^{-1}) and B:C ratio (1.9) as compared to maize + rajmash in 2:1 row proportion.

Conclusion

Based on above results, it could be inferred that, intercropping of sweet corn with green pea at 1:1 ratio proved most compatible, productive, remunerative and superior to their sole planting which recorded significantly higher sweet corn equivalent yield, gross returns, net returns and B:C ratio.

Table 4. Light transmission ratio (LTR) and Light interception ratio (LIR) of sweet corn at different growth stages as influenced by intercropping system

Tr. No.	Treatment details	Light transmission (%)		Light interception (%)	
		30 DAS	60 DAS	30 DAS	60 DAS
T_1	Sole sweet corn	55.79	39.50	44.21	60.50
T_2	Sole green pea	36.16	17.61	63.84	82.39
T_3	Sole field bean	39.42	19.68	60.58	80.32
T_4	Sole french bean	33.65	16.92	66.35	83.08
T_5	Sweet corn + field bean (1:1)	47.05	23.23	52.95	76.77
T_6	Sweet corn + green pea (1:1)	46.66	22.50	53.34	77.50
T_7	Sweet corn + french bean (1:1)	46.19	22.31	53.81	77.69
T_8	Sweet corn + field bean (2:2)	42.20	19.91	57.80	80.09
T_9	Sweet corn + green pea (2:2)	41.42	19.50	58.58	80.50
T_{10}	Sweet corn + french bean (2:2)	41.06	18.19	58.94	81.81
	S.Em. ±	2.10	1.24	2.10	1.24
	C.D. at 5 %	6.26	3.68	6.26	3.68

DAS: Days after Sowing

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