Original Research Article

Productivity and Competitive Ability of Sweet corn (*Zea mays* L. *saccharata*) based Vegetable Legume Intercropping System during Rabi under Southern Transition Zone of Karnataka

ABSTRACT

A field experiment was conducted during *rabi* season of 2023 at Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga to evaluate the effect of different vegetable legumes as intercrops on productivity, competitive ability and profitability of sweet corn. It was laid out in randomized complete block design with ten treatments replicated thrice. The treatments consisted of sweet corn intercropping with french bean, vegetable cowpea and field bean in 2:2 and 3:2 row proportion compared with their sole cropping for their productivity and competitive ability. Sole sweet corn recorded significantly higher plant height (199.60 cm), leaf area (88.45 dm^2 $plant^{-1}$), dry matter accumulation (92.50 g $plant^{-1}$), cob yield (201 q ha^{-1}) and stover yield (287 q ha^{-1}). Among the intercropping systems, sweet corn + field bean (2:2) recorded significantly higher plant height (185.79 cm), leaf area (65.42 dm^2 $plant^{-1}$), dry matter accumulation (83.22 g $plant^{-1}$), cob yield (125 q ha^{-1}) and stover yield (179 q ha^{-1}) followed by sweet corn + vegetable cowpea (2:2). Evaluation of intercropping system was performed on the basis of several competitive indices *viz.*, sweet corn equivalent yield (SEY), land equivalent ratio (LER), area time equivalent ratio (ATER), relative crowding coefficient (RCC), system productivity index (SPI) and monetary advantage index (MAI), where significantly higher SEY (244 q ha^{-1}), LER (1.22), ATER (1.10), RCC (1.66), SPI (246) and MAI (Rs. 89,567) was obtained with sweet corn + field bean in 2:2 row proportion followed by sweet corn + vegetable cowpea in 2:2 row proportion. Therefore, sweet corn intercropped with field bean in 2:2 row proportion was found most compatible and remunerative intercropping system.

Key words: intercropping, sweet corn, field bean, vegetable cowpea, yield, competitive indices

1. INTRODUCTION

Traditional farming practices are evidenced around the world with the growing of crop mixtures which is nothing but a form of mixed cropping or intercropping (Plucknett and Smith, 1986). Early civilizations evidenced the use of intercropping that might be in a different form (Maitra *et al.*, 2021). An attractive strategy for increasing productivity of a cropping system per unit available land is to intensify land use by growing several annual crops simultaneously, known as intercropping system. The fundamental goal of intercropping is to increase total productivity per unit area and time, as well as to use land resources and farming inputs, such as labour, in a fair and rational manner and it avoids risk, as failure in one crop can be compensated from the yield of another crop. The component crops can use natural resources differently and more efficiently than if they were grown separately, which is one of the main reasons for improved yields in intercropping and helps to maintain soil fertility, reduce runoff and control weeds. Mutual competition can be greatly reduced by carefully selecting crops with different growth habits.

Spatial row arrangement in the intercropping system is one of the most important factors for better yield advantage in order to avoid limitation of reduced plant population of base crop under traditional intercropping system (Pandey *et al*., 1999). Due to 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. Sweet corn intercropping with vegetable legumes produces a successful system. Apart from the above-mentioned benefits, the ability to generate short-term money from the sale of green pods is a major factor driving the adoption of sweet corn + vegetable legume intercropping.

Specialty corns (*viz.*, sweet corn, popcorn, baby corn, and high oil corn *etc.*) assume 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 (Hugar and Salakinkop, 2022). Out of the various specialty corns, sweet corn (*Zea mays* L. *saccharata*) has big market potential. Sweet corn is an early maturing crop with 80-85 days duration and it has been bred to have higher levels of natural sugar (12%), which makes it very popular as it is rich source of Vitamin C, Vitamin A, niacin, beta-carotene, dietary fiber, antioxidant elements like calcium, potassium *etc*. The higher content of water-soluble polysaccharide in the kernel of sweet corn adds sweetness in addition to texture and quality. Hence, it is called "Sugar corn" (Venkatesh *et al*., 2003).

Therefore, it is time to switch to multiple and intensive vegetable cropping in order to increase income per unit area. Hence, the objective of the experiment is to evaluate the effect of different vegetable legumes as intercrops onproductivity and competitive ability of sweet corn.

2. MATERIALS AND METHODS

A field experiment was conducted during *rabi* season of 2023 at Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga. It lies under 13º 58'N latitude, 75º 34' E longitude with an altitude of 650 m above the mean sea level in Southern Transition Zone of Karnataka. The prevailed weather conditions during the cropping period provided favorable circumstances for the growth and yield of sweet corn and intercrops (Fig 1). The crop received rainfall of 113.2 mm during the cropping period. The mean maximum and minimum air temperature of 34.58°C and 30.81 °C was recorded. The experiment was laid out in randomized complete block design with ten treatments replicated thrice. Treatments comprised of intercropping different vegetable legumes *viz*., French bean, Vegetable cowpea and Field bean with Sweet corn at 2:2 (T_1 to T_3) and 3:2 (T_4 to T_6) row proportions and sole planting (T_7 to T_{10}) of each crops for comparative studies. The experiment was conducted in replacement series of intercropping system and their design is represented in Fig 2 and 3. The soil of the experimental site was sandy loam in texture, neutral in soil reaction (6.73) with low inorganic carbon content (4.66 g kg^{-1}) and available nitrogen (175.92 kg ha^{-1}) but medium in available phosphorus (40.83 kg ha^{-1}) and potassium (191.25 kg ha^{-1}).

The hybrid and varieties used were MITHAS 12 of sweet corn, Arka Komal of french bean, Arka Samruddhi of vegetable cowpea and Hebbal Avre-3 of field bean. The duration of the crops was 80-85 days, 70 days and 70-75 days for sweet corn, french bean and vegetable cowpea and field bean, respectively. The seed rate used was 10 kg ha^{-1} for sweet corn, 40 kg ha^{-1} for french bean, 15 kg ha^{-1} for vegetable cowpea and 37.5 kg ha^{-1} for field bean. All the intercrops were sown along with the main crop by following line sowing method. The spacing followed was 45 cm × 30 cm for sweet corn and 45 cm × 20 cm for intercrops. Plant population accommodated per hectare in 2:2 row proportions was 37,037 and 55,555 for sweet corn and intercrops, respectively whereas in 3:2 row proportions 44,444 was the population per hectare for both sweet corn and intercrops. The recommended dose of fertilizers (Sweet corn: 100:50:25; French bean: 63:100:75; Vegetable cowpea: 25:75:60; and field bean: 25:50:25; kg N, P_2O_5 and K_2O ha^{-1}) was applied in the form of urea, DAP and MOP. Fertilizer was applied based on plant population for both main as well as component crop and was placed 5 cm away from the crop row and covered with soil. For sweet corn, half of recommended nitrogen was given as basal dose and remaining nitrogen was top dressed at 30 days after sowing, while entire dose was applied at the time of sowing for all the legumes grown as intercrop.

The other management practices were done as per the recommended package of practices for both main and intercrops. Growth components of sweet corn were recorded at 20, 40, 60 DAS and at harvest. Leaf area was worked out by length x breadth method (Montgomery, 1911) which was multiplied by factor 0.74 and number of leaves per plant and expressed in dm^{2}plant^{-1}. The cob yield and stover yields were recorded as per standard procedure and harvest index was worked out by dividing economic yield of crops by biological yield of respective crops. Statistical analysis was done by using analysis of variance (ANOVA) and the standard error of means (S. Em±) and critical difference at 5% (Gomez and Gomez, 1984).

Competitive functions

The following competitive functions were calculated to evaluate competitiveness and efficiency of sweet corn – vegetable legume intercropping system as per the established procedures.

Crop equivalent yield (CEY): It is the conversion of crop yields into one form to compare the crops cultivated under intercropping system. SEY was calculated on the basis of prevailing market prices (Verma and Modgal, 1983).

Land equivalent ratio (LER): It is the ratio of land required by pure crop to produce the same yield as that of intercrop (Neamatollahi *et al*., 2013).

Area time equivalent ratio (ATER): ATER is calculated by considering the duration of crops and it permits an evaluation of crops on yield per day basis (Neamatollahi *et al*., 2013).

Monetary advantage index (MAI): The method assumes the appropriate economic assessment of intercropping in terms of increased value per unit area of land (Neamatollahi *et al.,* 2013).

Relative crowding coefficient (RCC): Relative crowding coefficient measures the dominance of one species over the other on a mixture (Hall., 1974).

System productivity index (SPI): System productivity index indicate the most productive and stable cropping pattern (Odo,1991).

3. RESULTS AND DISCUSSION:

3.1 Growth components of sweet corn

Sole sweet corn recorded significantly higher growth components *viz*., plant height, number of leaves per plant, leaf area and total dry matter accumulation (Table 1). This might be due to the absence of intercrops, which did not offer competition in terms of water, nutrients and light. Manpreet *et al.* (2016) also reported higher plant height, cobs per plant and grains per cob in sole maize compared to maize in intercropping with rajmasha. Marer (2007) also reported higher plant height, leaf area per plant, grain weight per plant and test weight in sole maize. Shridhar *et al*. (2019) also found that sole maize recorded significantly higher leaf area per plant, cob girth, grain weight per cob, kernel yield and stover yield compared to its intercropping systems. Among the different intercropping system, sweet corn + field bean (2:2) recorded higher growth components, followed by sweet corn + vegetable cowpea (2:2) (Table 1). This might be due to better spatial complementarity of the component crops that led to better utilization of growth resources and field bean did not offer competition to sweet corn at any stage of their growth and also increased nodulation which helped nitrogen fixation in soil, this gained advantage and consequently resulted in higher growth and development. It might also be due to higher photosynthetic ability, utilization pattern of photosynthate for subsequent growth and translocation and increased light transmission, which could have helped towards higher photosynthesis, dry matter accumulation and translocation to reproductive parts. These results were collaborated with the findings of Kithan and Longkumer (2017b) in maize and soybean intercropping system. Singh and Singh (1993) observed that growth and yield were generally decreased when two or more crops grown together in intercropping system compared to respective sole crops, but the combined yield was higher than either of sole crops due to higher total productivity, which indicates better compatibility between the component crops with suitable cropping geometry.

3.2 Yield

Sole sweet corn recorded significantly higher yield attributing parameters, cob yield and stover yield than it is grown in combination with vegetable legumes, *viz.*, french bean, vegetable cowpea and field bean under different row proportions (Table 2). This was due to competition free environment for growth resources *viz.*, light, soil moisture, air, nutrients and better agronomic practices which helped the crop to exhibit their full production potential. Since the experiment was conducted in replacement series the decrease in cob yield and stover yield was 37.8 and 37.6 per cent, respectively in sweet corn + field bean (2:2) compared to sole sweet corn (Fig 4). The results are similar with the findings of Kour *et al*. (2016) and Marer (2007). Among intercropping systems, sweet corn + field bean (2:2) has recorded higher yield attributing parameters, cob yield, which was on par with sweet corn + vegetable cowpea (2:2) (Table 1). The higher cob yield and stover yield is mainly due complimentary relationship between the crops and optimum spacing leading to reduced competition for the resources like light, air, moisture, and nutrients (Hugar and Salakinkop, 2022). Similar results were found with the findings of Jan *et al*. (2016) and Kithan and Longkumer (2017a). Inclusion of field bean as intercrop with sweet corn at 2:2 row proportion gave significantly higher value of sweet corn equivalent yield (SEY) than sole planting of the component crops (Table 2). The increase in SEY was 21.39 per cent with field bean as intercrop as compared to sole sweet corn. Field bean is a high yield potential crop, short duration and less competitive than other legumes so intercropping sweet corn with field bean gave higher value of SEY compared to other intercropping systems. This might be due to difference in SEY as a consequence of differences in yield of sweet corn, additional component crop yield and price of individual component crop and the results are in line with Jan *et al*. (2016).

3.3 Competitive functions

Among different competitive functions, sweet corn equivalent yield (SEY) of sweet corn +

field bean (2:2) was maximum and it was followed by sweet corn + field bean (3:2)(Table 3). Difference in SEY was a consequence of differences in yield of sweet corn, yield of component crop and price of both the crops in the system and the results are in line with Jan *et al*. (2016). SEY was significantly low in sweet corn + french bean (3:2) due to more competition for resources, less yield and low price. The land equivalent ratio of greater than one denotes the advantage of intercropping. Higher LER was recorded when sweet corn was intercropped with field bean in 2:2 row ratio and significantly lower LER was observed with sweet corn + french bean at 3:2 row proportion (Table 3) due to lower yield of both the main and the component crop. The results are in conformity with the findings of Saban *et al*. (2007), Dahmardeh *et al*. (2010) and Jan *et al*. (2016) where they also reported that higher LER of intercropping system than their sole crops. In all the inter-cropping systems, the ATER values were less than LER values (Table 3), indicating the estimation over resources utilization in the latter. Inter-cropping advantage in terms of ATER was found in sweet corn + field bean at 2:2 row proportion due to better land use efficiency and spatial and temporal complementarity under this system. ATER was lowest in sweet corn + french bean at 3:2 row proportion which indicates inefficient use of land and time. Similar results have been reported by Egbe *et al*. (2010), Jan *et al*. (2016) and Panda *et al*. (2021). The yield benefit and increased compatibility under intercropping systems are indicated by RCC value greater than one. Significantly higher RCC of sweet corn was noticed in sweet corn + field bean (2:2) and lowest RCC of sweet corn recorded with sweet corn + french bean (3:2). Similar results were revealed by Manasa *et al.* (2018) who obtained higher RCC in maize legume intercropping system.

System productivity index (SPI) indicate the most productive and stable cropping pattern (Odo,1991). Significantly higher SPI was observed in sweet corn + field bean (2:2) and lower SPI was observed with sweet corn + french bean (3:2) (Table 3). Higher SPI was in sweet corn + field bean in 2:2 row ratio was due to the dominance of sweet corn in most of the intercropping patterns. This could partially be due to the intra-specific competition between sweet corn plants where intercrops were suppressed by sweet corn, yet managed to remain the dominant species. Similar findings were obtained by Parimaladevi *et al.* (2019) under maize based intercropping in 2:2 row proportion compared to other row proportion. The ultimate interest of developed technology over existing lies in economic viability by utilizing the available resources. In intercropping system, this could be indicated in a better way by monetary advantage. All intercropping systems did not possess positive values and hence only some inter-cropping systems showed a definite yield advantage irrespective of different component crops when compared to the sole cropping of sweet corn. MAI values were high in sweet corn + field bean (2:2) intercropping system and lowest in sweet corn + french bean (3:2) (Table 3). Higher MAI might be due to higher yield levels of both the crops and higher market price of the component crop. Lower MAI might be due to lower yield of both the crops and lower market price of the component crop and the negative sign indicates loss. Similar results were reported by Manasa *et al*. (2020) in summer maize-legume intercropping system.

4. CONCLUSION

Based on the above results, it could be inferred that, intercropping of sweet corn with field bean in 2:2 row proportion proved most compatible, productive, remunerative and superior to their sole planting which recorded significantly higher sweet corn equivalent yield (SEY) and system productivity index (SPI). The competitive functions such as land equivalent ratio (LER), area time equivalent ratio (ATER), relative crowding coefficient (RCC) and monetary advantage index (MAI) calculated in the study also indicated suitability and advantages of sweet corn – vegetable legume intercropping system.

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Table 1: Effect of intercropping of vegetable legumes on plant height, number of leaves per plant, leaf area and total dry matter accumulation of sweet corn at 60 DAS

Treatment	Plant height (cm)	Number of leaves per plant	Leaf area per plant (dm^2 $plant^{-1}$)	Dry matter accumulation (g $plant^{-1}$)
T_1: Sweet corn + French bean (2:2)	158.67	12.33	53.46	79.98
T_2: Sweet corn + Vegetable cowpea (2:2)	174.90	12.67	60.23	82.16
T_3: Sweet corn + Field bean (2:2)	185.79	12.73	65.42	83.22
T_4: Sweet corn + French bean (3:2)	158.35	12.20	53.09	78.63
T_5: Sweet corn + Vegetable cowpea (3:2)	159.81	12.33	54.32	80.37
T_6: Sweet corn + Field bean (3:2)	161.27	12.60	54.60	81.38
T_7: Sole Sweet corn	199.60	13.00	88.45	92.50
S. Em. ±	9.04	0.55	3.77	2.66
C.D at 5%	27.87	NS	11.62	8.2

NS – Non significant

DAS - Days after sowing

Table 2: Effect of intercropping of vegetable legumes on yield and yield attributes of sweet corn, sweet corn equivalent yield and harvest index

Treatment	Cob length (cm)	Cob girth (cm)	Weight of cob with husk (g $plant^{-1}$)	Weight of dehusked cob (g $plant^{-1}$)	Yield (q ha^{-1})			Sweet corn equivalent yield (q ha^{-1})	Harvest index (%)
					Sweet corn	Stover	Intercrop		
T_1: Sweet corn + French	16.73	12.99	250.60	133.33	107	138	60	197	43.44

bean (2:2)									
T_2: Sweet corn + Vegetable cowpea (2:2)	17.17	13.33	312.13	195.87	114	168	82	196	40.52
T_3: Sweet corn + Field bean (2:2)	18.19	14.61	325.93	210.07	125	179	57	244	41.20
T_4: Sweet corn + French bean (3:2)	16.62	12.90	225.27	118.67	99	124	46	168	44.01
T_5: Sweet corn + Vegetable cowpea (3:2)	16.92	13.20	245.13	130.13	108	152	64	172	41.74
T_6: Sweet corn + Field bean (3:2)	17.10	13.33	255.00	138.33	110	161	46	206	40.75
T_7: Sole Sweet corn	18.55	15.60	350.53	233.87	201	287	0.00	201	41.43
T_8: Sole French bean	-	-	-	-	-	-	119	178	-
T_9: Sole Vegetable cowpea	-	-	-	-	-	-	153	153	-
T_{10}: Sole Field bean	-	-	-	-	-	-	95	199	-
S. Em. ±	0.36	0.52	14.42	10.07	7.03	9.53	3.9	10.6	1.97
C.D at 5%	1.12	1.60	44.43	31.04	21.66	29.37	11.54	31.5	NS

NS – Non Significant

Table 3: Land equivalent ratio, area time equivalent ratio, relative crowding coefficient, system productivity index and monetary advantage index as influenced by sweet corn intercropping with vegetable legumes

Treatment	Land equivalent	Area time equivalent	Relative crowding	System productivity	Monetary advantage

	ratio	ratio	coefficient	index	index (₹ ha^{-1})
T_1: Sweet corn + French bean (2:2)	1.04	0.86	1.15	209	14,451
T_2: Sweet corn + Vegetable cowpea (2:2)	1.11	1.06	1.31	223	37,884
T_3: Sweet corn + Field bean (2:2)	1.22	1.10	1.66	246	89,567
T_4: Sweet corn + French bean (3:2)	0.89	0.74	0.65	178	-44,071
T_5: Sweet corn + Vegetable cowpea (3:2)	0.96	0.93	0.78	193	-14,173
T_6: Sweet corn + Field bean (3:2)	1.04	0.93	0.81	209	14,846
T_7: Sole Sweet corn	1.00	0.00	0.00	0.00	0.00

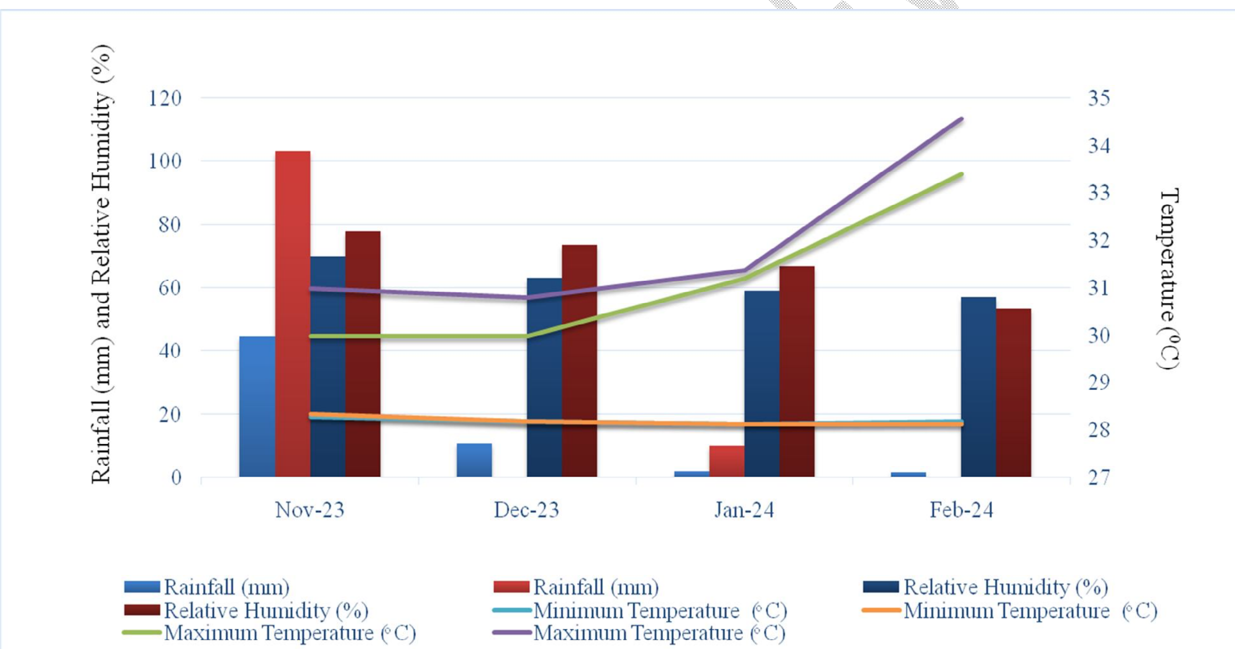

Fig 1: Meteorological data indicating monthly normal and actual rainfall, relative humidity, maximum and minimum temperature during the cropping period at ZAHRS, Shivamogga

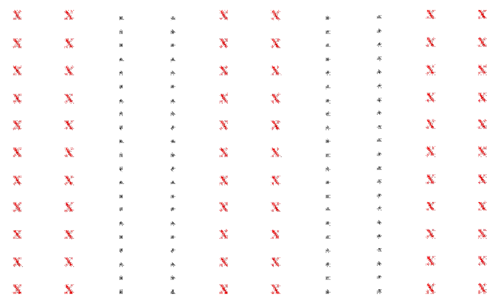

Fig 2: Sweet corn-based vegetable legume intercropping system in 2:2 row proportion

Fig 3: Sweet corn-based vegetable legume intercropping system in 3:2 row proportion

Where, X - sweet corn, * - intercrops

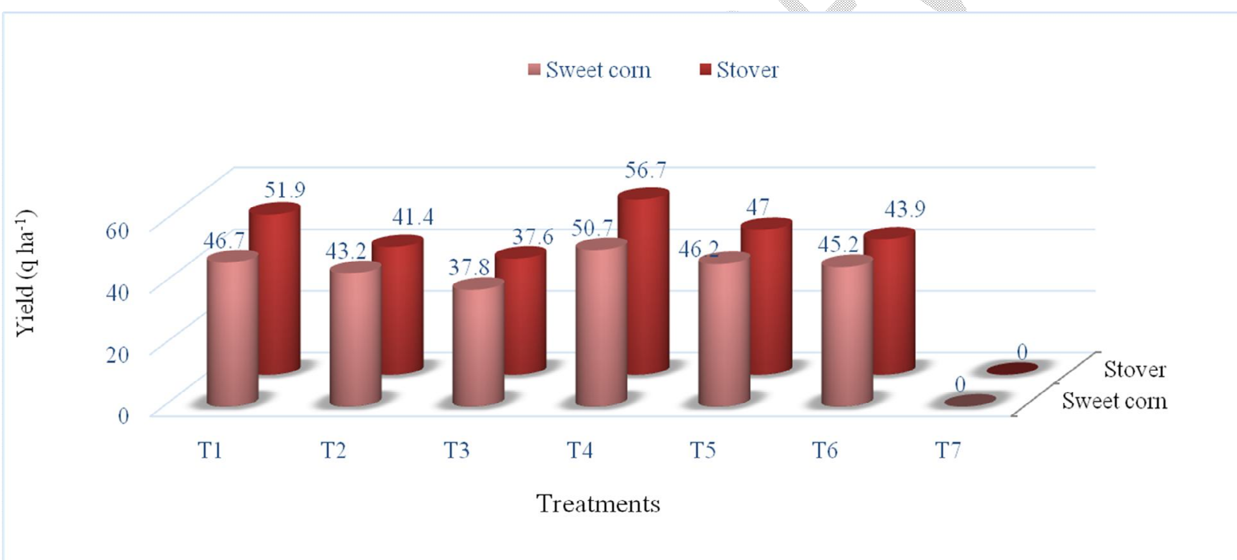

Fig 4: Per cent decrease in yield of sweet corn as influenced by intercropping different vegetable legumes

Note: Treatment details are provided in materials and methods