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Effect of spacing and nutrient management practices on growth, yield and economics of sweet corn-chickpea under sequence cropping

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Abstract
A field experiment was conducted at Research farm of National Agricultural Research Project, Aurangabad (M.S.) during two *kharif -rabi* seasons of 2019-20 and 2020-21 to study the effect of spacing and nutrient management on sweet corn (*Zea mays* L. saccharata) - chickpea (*Cicer arietinum*) under sequence cropping. The experiment was laid out in split plot design with three replications. The factors consisted of three spacing (60 cm x 20 cm, 75 cm x 20 cm and 90 cm x 20 cm for sweet corn), three fertilizer levels (F_1-160:60:60 kg NPK ha^{-1}, F_2-180:70:70 kg NPK ha^{-1}, F_3-200:80:80 kg NPK ha^{-1}) and two biofertilizer levels (B_0 - No Bio-fertilizers and B_1– Azotobacter/ Rhizobium+ PSB + KSB (10 ml each kg $^{-1}$ seed). Fertilizers were applied to sweet corn in *kharif* season and its residual effect on succeeding chick pea in *rabi* season was studied. The results revealed that sweet corn sown at wider plant geometry of 90 cm x 20 cm (S_3) recorded higher growth and yield attributes but closer plant geometry of 60 cm x 20 cm (S_1) recorded higher cob yield, net returns and B:C ratio of sweet corn crop. Application of fertilizer level F_3-200:80:80 kg NPK ha^{-1} recorded higher growth, yield attributes, cob yield, net returns and B:C ratio of sweet corn but it was statistically on par with fertilizer level F_2-180:70:70 kg NPK ha^{-1}. Seed inoculation of biofertilizers i.e. B_1– Azotobacter (to Sweet corn) and Rhizobium (to chick pea) + PSB + KSB (10 ml each kg $^{-1}$ seed) at sowing recorded higher growth, yield attributing characters, cob yield, net returns and B:C ratio as compared over control or no biofertilizer seed treatment (B_0) during both the years.

Keywords: Nutrient, management, economics, corn-chickpea, sequence

Introduction

Maize (*Zea mays* L.) is a wonder crop emerging as the third most important cereal crop in the world next to wheat and rice with wide diversity of uses and large hidden potential for exploitation. Generally, Maize is cultivated in all the seasons successfully as it is classified as C_4 type crop due to utilizing solar radiation more efficiently as compared to other cereals. It is growing across a wide range of climatic conditions of the world due to its wider adaptability. It is popularly called queen of cereals due to high genetic yield potentials than any other cereals counterpart. Sweet corn is special type of corn used for table purpose. Among the various factors affecting the growth and yield of sweet corn, planting geometry and nutrient management plays an important role. It is an established fact that higher grain yield primarily depends on optimum plant density and adequate nutrient supply. The optimum plant spacing provides better conditions for plant growth results in timely commencement of reproductive phase and formation of sink. The establishment of an optimum plant population per unit area of land is the contributory factor, which determines growth and yield of individual plants. It is desired that the soil should have the required nutrients in desired quantities and in optimum proportion to meet the requirement of crop. Presently, greater emphasis is given to the cultivation of sweet corn due to increasing demand. There is an increasing tendency to produce sweet corn at the commercial level to augment the income of the farming community dwelling in the outskirts of big cities and metropolis. Since there is limited scope to increase the area under sweet corn cultivation because of competition from other cereals and cash crops, the only alternative is through enhancement of productivity by various management factors. Moreover, major maize area is under rainfed situations and hence adoption of suitable planting method is also of considerable importance in getting desired yield and quality. Further, inter and intra row spacing and balanced nutrition of NPK is an essential component of nutrient management and improving quality. Presently, the chemical fertilizers are considered as the major source of nutrients.

Bio-fertilizers have an advantage over chemical fertilizers, as they provide nutrients in addition to plant growth promoting substances like hormones, vitamins, amino acids etc. (Shivankar *et al.*, 2000) [24]. Liquid biofertilizer is a special formulation containing high number of desired microorganisms with high shelf life and zero contamination. They are cost effective and as a source of plant nutrients to supplement inorganic fertilizers. Besides their more important role in atmospheric nitrogen fixation, potassium mobilization and phosphorous solubilisation, these also help in stimulating the plant growth hormones providing better nutrient uptake and increased tolerance towards some environmental stress. However, no systematic research has been conducted to develop site and situation specific production technology for this crop regarding spacing and fertilizers. Hence, there is a need to establish a relationship between plant densities, nitrogen, phosphorous, potassium and biofertilizers. In view of the above present study is useful to increase the production efficiency of cropping system.

Materials and Methods

The field experiment was conducted at National Agricultural Research Project, Aurangabad research farm during two *kharif* - *rabi* seasons of 2019-20 and 2020-21. Experiment was carried out with sweet corn treatments in *kharif* season followed by chickpea treatments in *rabi* season on fixed site in split-plot design, with the main plots consisting of spacings (Sweet corn spacing: S_1- 60 cm x 20 cm; S_2: 75 cm x 20 cm; S_3: 90 cm x 20 cm and chickpea spacing: S_1 - 30 cm x 10 cm, S_2 - 45 cm x 10 cm; S_3 - 45 cm x 05 cm) and subplots consisting of three fertilizer levels (F_1-160:60:60 kg NPK ha^{-1}, F_2-180:70:70 kg NPK ha^{-1} and F_3-200:80:80 kg NPK ha^{-1}) to sweet corn and chickpea in rabi season was grown on residual nutrients after sweet corn. Two biofertilizer levels (B_0 - No Bio-fertilizers and B_1– Azotobacter to sweet corn and *Rhizobium to* chick pea + PSB + KSB (10 ml each kg^{-1} seed) were evaluated with three replications. The sweet corn and chickpea were sown by dibbling method on 7th July, 2019 and 15th November, 2019 during first year and 18th June, 2020 and 15th October, 2020 during second year, respectively. At sowing basal dose of fertilizers (one third of nitrogen, entire dose of phosphorus and potassium) in the form of Urea, Single super phosphate and Muriate of potash were applied as per the treatments. Remaining one third and one fourth of nitrogen was top dressed at 30 and 45 days after sowing (DAS), respectively. The climatic condition was favourable during 2019-20 and 2020-21 for the growth and development of sweet corn and chickpea which ultimately resulted in more accumulation of photosynthesis in both seasons. Biometric observations on growth parameters, yield attributes and yield of sweet corn and chickpea were recorded during both the years of study.

Results and Discussion

Effect of spacing on growth and yield contributing characters of sweet corn

Growth Characters

Among the different plant density, higher plant height (215.29 cm) was recorded with 60 x 20 cm^2 (S_1) spacing and it was statistically significant over 90 x 20 cm^2 (S_3) but at par with 75 x 20 cm^2 (S_3) spacing at harvest during pooled results. The increased plant height in higher plant density might be due to thick plant stand. It clearly indicates that increase in number of plants per unit area beyond optimum level certainly reduced the amount of light availability to the individual plant, especially to lower leaves due to shading. Such increase in height of the plant at higher population was reported by Ashwani *et al.* (2015) [2], Zarapkar (2006) [27] and Bhatt (2012) [4]. Wider planting geometry of 90 x 20 cm^2 (S_3) recorded significantly highest number of functional leaves plant^{-1}(14.39) of (278.25 g plant^{-1}) over 75 x 20 cm^2 (S_2) and 60 x 20 cm^2 (S_1) spacing at harvest but 90 x 20 cm^2 (S_3) was at par 75 x 20 cm^2 (S_2) regarding dry matter accumulation in pooled results. Wider plant geometry produced more number of leaves and dry matter accumulation per plant than narrow spacing, which may be due to efficient utilization of growth resources like sunlight, moisture and nutrients. These findings are substantiated by the findings of Paygonde *et al*. (2008) [19], Massey and Gaur (2006) [15] and Srikanth *et al*. (2009) [25] in maize.

Yield Attributes

Significantly higher values for the yield attributes *viz*., cob length with husk (26.64 cm), diameter of cob with husk (7.10 cm), cob weight with husk (298.58 gm), number of grains rows cob^{-1}(18.99) and number of grains cob^{-1}(507.61) were observed at wider planting geometry of 90 x 20 cm^2 (S_3) over 60 x 20 cm^2 (S_1) or lowest plant density (55,555 plants ha^{-1}) on pooled mean basis. It was at par with planting geometry of 75 x 20 cm^2 (S_2) in case of weight of cob with husk and number of grains per cob. This clearly indicates that plants at lower density have fully exploited the natural resources efficiently, besides responding to externally applied inputs. Similar results also recorded by Sahoo and Mahapatra (2004) [21] and Ashok kumar (2009) [1]. Plant geometry 60 x 20 cm^2 (S_1) produced significantly superior for green cob yield (22.41 t ha^{-1}, 23.93 t ha^{-1} and 23.17 t ha^{-1}), green fodder yield (42.04 t ha^{-1}, 45.53 t ha^{-1} and 43.79 t ha^{-1}), biological yield (64.46 t ha^{-1},69.46 t ha^{-1} and 66.96 t ha^{-1}), gross monetary returns (₹ 230613, ₹ 250239 and ₹ 240426 ha^{-1}), net monetary returns (₹ 165341, ₹ 183398 and ₹ 174370ha^{-1}) and benefit cost ratio (3.53, 3.74 and 3.64) over 75 x 20 cm^2 (S_2) and 90 x 20 cm^2 (S_3) spacing in 2019, 2020 and in pooled results, respectively. When planting density was further increased from 55,555 to 83,333 plants ha^{-1}, the increase in fresh cob yield and green fodder yield of sweet corn was mainly attributed higher plant population per unit area and more number of cobs per unit area. Higher yields under plant spacing of 60 cm x 20 cm significantly increased biological yield was mainly owing to maximum number of marketable cobs and maximum number of green fodder plant as compared with those of 75 cm x 20 cm and 90 cm x 20 cm. At higher plant density of 83,333 plants ha^{-1} more competitions for resources occurred and reduced the values of different yield attributes. These findings are substantiated by the findings of Kar *et al.* (2006), Sahoo and Mahapatra (2004) [21], Gaurkar and Bharad (1998). Sahoo and Mahapatra (2007) [22]. This higher gross returns with the closer crop geometry may be due to the increased total green cob as well as green fodder yield at closer spacing resulted from compensation of lower per plant yield with the closer spacing by increased number of plants per unit area along with the optimum and efficient utilization of the available resources. This increase in the green cob and green fodder ultimately reflected in enhanced gross and net returns. Similar result was noted by Ashwani *et al.* (2015) [2]. These results are also in accordance with the findings of Chougale (2003) [5], Sahoo and Mahapatra (2004) [21] and Paygonde *et al*. (2008) [19].

Effect of fertilizer levels on growth and yield contributing characters

Growth Characters

Sweet corn crop receiving the fertilizer level 200:80:80 kg NPK ha^{-1}(F_3) recorded significantly higher plant height (211.84 cm), number of functional leaves plant^{-1}(14.03) and dry matter accumulation (269.31 g plant^{-1}) over 160:60:60 kg NPK ha^{-1}(F_1), but it was found at par with 180:70:70 kg NPK ha^{-1} (F_2) during pooled results. Increase in the fertilizer levels increased plant height, number of functional leaves and dry matter accumulation (g plant^{-1}) that might have increased photosynthate formation and partitioning to stems that might have favourable impacts on plant height of maize. It may be due to increase in assimilation rate, cell division and metabolic activities in plant. Similar results were reported by Kaledhonkar (2003) [10], Kumar and Thakur (2004), Kunjir (2004) [12], Massey and Gaur (2006) [15] and Jat (2006) [8], Sarma *et al*. (2000) [23] and Chougale (2013) [5].

Yield Attributes

Yield attributes *viz*. cob length with husk, diameter of cob with husk, cob weight with husk, number of grains rows cob^{-1} and number of grains cob^{-1} were significantly influenced due to different fertilizer levels to sweet corn crop. The treatment with application of 200:80:80 kg NPK ha^{-1}(F_3) produced significantly maximum pooled mean cob length with husk (26.44 cm), diameter of cob with husk (6.92 cm), cob weight with husk (302.67 gm), number of of grains rows cob^{-1}(19.07), number of grains cob^{-1} (518.44) over application of 160:60:60 kg NPK ha^{-1}(F_1). The green cob yield (20.74 t ha^{-1}, 22.11 t ha^{-1} and 21.41 t ha^{-1}), green fodder yield (41.18 t ha^{-1}, 43.28 t ha^{-1} and 42.23 t ha^{-1}),biological yield (61.64 t ha^{-1}, 65.38 t ha^{-1} and 63.51 t ha^{-1}), gross monetary returns (₹ 217134, ₹ 232377 and ₹ 224756 ha^{-1}), net monetary returns (₹ 153393, ₹ 167698 and ₹ 160546 ha^{-1}) and benefit cost ratio (3.40, 3.57 and 3.49) was significantly superior over application of 160:60:60 kg NPK ha^{-1}(F_1) and was at par with application of 180:70:70 kg NPK ha^{-1} (F_2) during 2019, 2020 and in pooled mean. The application of 160:60:60 kg NPK ha^{-1}(F_1) recorded lower yield attributes, green fodder and biological yield during first and second year of investigation and in pooled results. This evidently proved that increased availability of nitrogen, phosphorous and potassium to crop at higher levels resulted in production of photosynthates and their efficient translocation for development of reproductive parts. The yield of the sweet corn crop is a function of several yield components, which are dependent on complementary interaction between vegetative and reproductive growth of the crop. Similar results were reported by Sahoo and Mahapatra (2004) [21], Kar *et al.* (2006) [9], Muniswamy *et al.* (2007) [17], Suryavanshi *et al.* (2008) [26] and Ashok kumar (2009) [1].

Effect of Biofertilizers on growth and yield contributing characters

Growth Characters

Application of *Azotobacter* + PSB + KSB (10 ml each kg^{-1} seed) treatment (B_1) recorded the significantly highest plant height (207.39 cm), number of functional leaves plant^{-1} (13.81) and dry matter accumulation (262.35g plant^{-1}) over control (B_0) at harvest during pooled results respectively.

The results of the present study are in agreement with the findings of Rathi, *et al.* (2005) and Kumar *et al.* (2006) [11]. Phosphate solubilizing microorganisms (PSMs) are ubiquitous in soils and play an important role in supplying P to plants in a more environmentally and sustainable manner (Gyaneshwar *et al.*, 2002 and Richardson, 2001) [7, 20].

Yield Attributes

The significantly higher pooled mean cob length with husk (26.04 cm), diameter of cob with husk (6.70 cm), cob weight with husk (297.30g), number of of grains rows cob^{-1} (18.67), number of grains cob^{-1} (499.37), green cob yield (20.21 t ha^{-1},21.63 t ha^{-1} and 20.92 t ha^{-1}), green fodder yield (40.03 t ha^{-1}, 42,10 t ha^{-1} and 41.07 t ha^{-1}), biological yield (60.06 t ha^{-1}, 63.73 t ha^{-1} and 61.90 t ha^{-1}), gross monetary returns (₹ 213286, ₹ 227036 and ₹ 219698 ha^{-1}), net monetary returns (₹ 149498, ₹ 161927 and ₹ 155713 ha^{-1}) and benefit cost ratio (3.37, 3.48 and 3.42) with seed treatment of bio fertilizers i.e. *Azotobacter* + PSB + KSB (B_1) over control (B_0) during 2019-20, 2020-21 and pooled results. It might be due to the fact that bio-fertilizers produce the growth promoting substance and other acids like acetic, formic, proponic, lactic, glyconic, fumaric and succinic which were positively correlated with growth, flowering and yield attributing characters like length, girth of cob, cob yield and green fodder yield. Similar result was also reported by Kumar *et al.* (2006) [11], Mahato and Neupane (2017) [13], Panchal *et al.* (2018) [18] and Biraris and Eugenia (2018) [3].

Effect of residual effect on chickpea crop

Chickpea crop sown with planting geometry 45 x 5 cm^2 (S_3) recorded higher plant height (49.52 cm), seed yield (2051 kg ha^{-1}, 2203 kg ha^{-1} and 2124 kg ha^{-1}), Stover yield (3134 kg ha^{-1}, 3354 kg ha^{-1} and 3244 kg ha^{-1}), biological yield (5180 kg ha^{-1}, 5517 kg ha^{-1} and 5368 kg ha^{-1}), gross monetary returns (₹ 89999, ₹ 105757 and ₹ 97878 ha^{-1}), net monetary returns (₹ 62315, ₹ 57834 and ₹ 69476 ha^{-1}) and benefit cost ratio (3.25, 3.63 and 3.44) during 2019-20, 2020-21 and in pooled results. It was on par with 30 x 10 cm^2 (S_1) in first, second year and pooled results. Application of 200:80:80 kg NPK ha^{-1}(F_3) to sweet corn in *kharif* exerted significant effect on increasing the growth attributes such as plant height (50.16 cm), number of pods (50.53), seed yield (2013 kg ha^{-1}, 2144 kg ha^{-1} and 2068 kg ha^{-1}), Stover yield (3079 kg ha^{-1}, 3320 kg ha^{-1} and 3222 kg ha^{-1}) biological yield (5071 kg ha^{-1}, 5464 kg ha^{-1} and 5268 kg ha^{-1}), gross monetary returns (₹ 87653, ₹ 102915 and ₹ 95284 ha^{-1}), net monetary returns (₹ 61233,₹ 75220 and ₹ 68221 ha^{-1}) and benefit cost ratio (3.31, 3.71 and 3.46) during 2019-20, 2020-21 and in pooled results but found at par with application of 180:70:70 kg NPK ha^{-1}(F_2) in chickpea crop (rabi). The seed treatment of biofertilizers i.e. B_1– *Rhizobium*+ PSB + KSB (10 ml each kg $^{-1}$seed) showed significant effect on growth and yield attributes *viz*., plant height (48.95 cm),number of pods (48.08) seed yield (1954, 2101 and 2025 kg ha^{-1}) stover yield (2946,3257and 3104 kg ha^{-1}) biological yield (4896 kg ha^{-1}, 5358 kg ha^{-1} and 5127 kg ha^{-1}), gross monetary returns (₹ 85798,₹ 100825 and ₹ 93312ha^{-1}), net monetary returns (₹ 59143, ₹ 72923 and ₹ 66033 ha^{-1}) and benefit cost ratio (3.21, 3.61 and 3.38) over control (B_0) during both the years of study. Although highest seed yield of chickpea crop obtained with residual effect of 200:80:80 kg NPK ha^{-1} but statistically higher seed yield was received by the residual effect of 180:70:70 kg NPK ha^{-1} (F_2).

This was possible due to favourable carry over residual effect of treatments in increasing the crop growth which in turn boosted the yield and yield contributing characters which enhanced the seed yield. Similar positive residual effect of organic sources of nutrient applied to previous crop in increasing the yield and yield contributing attributes of succeeding crop were reported by Meena *et al*. (2012) [16] and Mahapatra *et al*. (2018) [14].

Table 1: Effect of spacing and nutrient management practices on different growth characters of sweet corn in pooled results

Treatments	Plant Height (cm)	No. of leaves /plant	Dry matter accumulation (g plant^{-1})	Length of cob with husk (cm)	Cob diameter with husk (cm)	Cob weight with husk (gm)	Number of grain rows cob^{-1}	No. of grains cob^{-1}
Spacing								
S_1 – 60 x 20 cm^2	215.29	12.40	214.92	23.97	5.78	272.61	16.92	458.72
S_2 – 75 x 20 cm^2	204.09	13.36	244.61	25.27	6.11	284.94	17.88	482.92
S_3 – 90 x 20 cm^2	193.40	14.39	274.11	26.64	7.10	298.58	18.99	507.61
SE m (±)	2.70	0.20	9.94	0.20	0.12	3.97	0.18	9.33
CD (at 5%)	10.79	0.77	39.01	0.80	0.46	15.35	0.72	36.63
Fertilizer levels								
F_1-160:60:60 kg NPK ha^{-1}	195.25	12.34	209.72	23.70	5.51	263.03	16.41	438.59
F_2-180:70:70 kg NPK ha^{-1}	205.70	13.68	254.61	25.74	6.64	290.74	18.32	492.22
F_3-200:80:80 kg NPK ha^{-1}	211.84	14.03	269.31	26.44	6.92	302.67	19.07	518.44
SE m (±)	1.95	0.16	5.77	0.28	0.09	4.02	0.29	13.65
CD (at 5%)	6.28	0.49	17.39	0.87	0.29	12.38	0.90	42.07
Bio-fertilizers								
B_0 - No Bio-fertilizers	201.13	12.96	226.44	24.54	5.97	273.46	17.19	466.80
B_1–Azotobacter + PSB + KSB (10 ml each kg^{-1} seed)	207.39	13.81	262.65	26.04	6.70	297.30	18.67	499.37
SE m (±)	1.39	0.15	3.42	0.31	0.07	3.56	0.24	10.15
CD (at 5%)	4.03	0.42	9.87	0.90	0.17	10.27	0.70	31.01
Interactions								
S x F S.Em (±)	3.14.	0.27	10.01	0.49	0.81	6.96	0.51	23.65
CD (at 5%)	NS	NS	NS	NS	NS	NS	NS	NS
S x B and F x B S.Em (±)	2.41	0.25	5.92	0.54	0.54	6.16	0.41	17.58
CD (at 5%)	NS	NS	NS	NS	NS	NS	NS	NS
S x F x B S.Em (±)	4.18	0.42	10.25	0.93	0.94	10.37	0.72	30.45
CD (at 5%)	NS	NS	NS	NS	NS	NS	NS	NS
General Mean	204.26	13.38	244.25	25.29	6.33	285.38	17.93	483.08

Table 2: Effect of spacing and nutrient management practices on green cob, green fodder and biological yield of sweet corn in pooled results

Treatments	Green cob yield (t ha^{-1})			Green fodder yield (t ha^{-1})			Biological Yield (tha^{-1})		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Spacing									
S_1 – 60 x 20 cm^2	22.41	23.93	23.17	42.04	45.53	43.79	64.46	69.46	66.96
S_2 – 75 x 20 cm^2	18.82	19.75	19.28	38.49	40.17	39.33	57.31	59.92	58.61
S_3 – 90 x 20 cm^2	16.56	17.33	16.94	35.71	37.12	36.41	52.27	54.46	53.36
SE m (±)	0.36	0.75	0.38	0.92	1.11	0.86	1.16	1.38	1.03
CD (at 5%)	1.42	2.96	1.50	3.65	4.34	3.39	4.56	5.43	4.06
Fertilizer levels									
F_1-160:60:60 kg NPK ha^{-1}	17.33	18.03	17.68	35.48	37.95	36.71	52.81	55.98	54.39
F_2-180:70:70 kg NPK ha^{-1}	19.73	20.88	20.30	39.63	41.59	40.58	59.58	62.47	61.03
F_3-200:80:80 kg NPK ha^{-1}	20.74	22.11	21.41	41.18	43.28	42.23	61.64	65.38	63.51
SE m (±)	0.56	0.67	0.36	0.94	0.92	0.66	1.40	1.09	0.82
CD (at 5%)	1.56	2.01	1.11	2.60	2.84	2.03	3.87	3.35	2.49
Bio-fertilizers									
B_0 - No Bio-fertilizers	18.31	19.05	18.68	37.46	39.77	38.62	55.96	58.83	57.39
B_1–Azotobacter + PSB + KSB (10 ml each kg^{-1} seed)	20.21	21.63	20.92	40.03	42.10	41.07	60.06	63.73	61.90
SE m (±)	0.46	0.50	0.34	0.76	0.72	0.44	1.14	0.87	0.64
CD (at 5%)	1.27	1.39	1.02	2.12	2.08	1.27	3.16	2.53	1.84
Interactions									
S x F S.Em (±)	0.97	1.13	0.22	1.62	1.60	1.14	2.42	1.88	1.40
CD (at 5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x B and F x B S.Em (±)	0.79	0.87	0.18	1.32	1.25	0.72	1.98	1.51	1.10
CD (at 5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x F x B S.Em (±)	1.38	1.51	0.31	2.30	2.17	1.32	3.24	2.62	1.91
CD (at 5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS
General Mean	19.26	20.34	19.80	38.74	40.94	39.84	58.01	60.65	59.64

Table 3: Effect of spacing and nutrient management practices on monetary and economics of sweet corn in pooled results

Treatments	GMR (₹ ha^{-1}) (cob + fodder)			NMR (₹ ha^{-1})			B:C Ratio		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Spacing									
S_1 – 60 x 20 cm^2	230613	250239	240426	165341	183398	174370	3.53	3.74	3.64
S_2 – 75 x 20 cm^2	201596	212992	207294	138824	147972	143398	3.21	3.28	3.24
S_3 – 90 x 20 cm^2	182006	186869	184438	121734	123671	122703	2.96	3.02	2.99
SE m (±)	3907.9	4166.7	3357.1	3907.9	5173.9	3357.1	0.06	0.08	0.05
CD (at 5%)	15318.8	12839.8	13179.4	15341.8	20311.7	13179.4	0.24	0.33	0.21
Fertilizer levels									
F_1-160:60:60 kg NPK ha^{-1}	185730	196137	190934	123931	131455	127693	3.00	3.02	3.01
F_2-180:70:70 kg NPK ha^{-1}	211350	221587	216469	148575	155889	152232	3.36	3.39	3.36
F_3-200:80:80 kg NPK ha^{-1}	217134	232377	224756	153393	167698	160546	3.40	3.57	3.49
SE m (±)	3985.95	4573.9	2795.3	3121.1	4419.4	2807.9	0.07	0.07	0.04
CD (at 5%)	11596.5	13721.7	8357.14	9617.8	13250.1	8418.5	0.21	0.20	0.13
Bio-fertilizers									
B_0 - No Bio-fertilizers	196190	206364	201740	123931	131455	127693	3.14	3.17	3.15
B_1–Azotobacter + PSB + KSB (10 ml each kg $^{-1}$ seed)	213286	227036	219698	148575	155889	152232	3.37	3.48	3.42
SE m (±)	3129.09	3434.4	2451.9	153393	167698	160546	0.06	0.06	0.04
CD (at 5%)	9617.9	9917.7	7080.6	3121.1	4419.4	2807.9	0.17	0.13	0.11
Interactions									
S x F S.Em (±)	6903.5	7216.8	4585.3	6903.5	7216.8	4750.8	0.12	0.11	0.08
CD (at 5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x B and F x B S.Em (±)	5429.7	5948.6	4246.8	5405.9	5199,4	4580.9	0.09	0.08	0.07
CD (at 5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x F x B S.Em (±)	11957.6	10303.9	7355.8	11957.6	9006.8	8228.45	0.20	0.14	0.12
CD (at 5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS
General Mean	204738	216701	210719	141966	151680	146823	3.25	3.33	3.29

Table 4: Effect of spacing and residual nutrient management practices on different growth and yield contributing characters of chickpea in pooled results

	Plant Height (cm)	No. of pods at harvest	Seed yield kg ha^{-1}			Straw yield kg ha^{-1}			Biological yield kg ha^{-1}		
			2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Spacing											
S_1 – 30 x 10 cm^2	47.13	48.16	1914	2064	1989	2987	3294	3140	4901	5358	5129
S_2 – 45 x 10 cm^2	45.60	50.81	1598	1698	1648	2275	2569	2422	3873	4268	4070
S_3 – 45 x 05 cm^2	49.52	40.88	2051	2203	2124	3134	3354	3244	5180	5557	5368
SE m (±)	0.61	1.79	58.36	68.28	60.41	59.02	37.84	34.98	80.53	66.70	61.41
CD (at 5%)	2.47	7.03	229.56	268.05	237.15	231.68	148.57	137.34	316.13	261.86	241.08
Residual Fertilizer levels											
F_1-160:60:60 kg NPK ha^{-1}	44.34	42.19	1665	1801	1733	2393	2687	2540	4058	4488	4273
F_2-180:70:70 kg NPK ha^{-1}	48.75	47.14	1901	2020	1961	2924	3209	3044	4825	5230	5027
F_3-200:80:80 kg NPK ha^{-1}	50.16	50.53	2013	2144	2068	3079	3320	3222	5071	5464	5268
SE m (±)	0.49	1.13	48.30	49.64	47.58	123.19	125.21	86.19	125.91	138.84	93.99
CD (at 5%)	1.50	3.48	150.07	152.95	146.63	379.61	385.83	265.59	387.98	427.83	289.64
Bio-fertilizers											
B_0 - No Bio-fertilizers	46.15	45.15	1755	1877	1816	2651	2887	2767	4406	4764	4585
B_1–*Rhizobium* + PSB + KSB (10 ml each kg $^{-1}$ seed)	48.95	48.08	1954	2101	2025	2946	3257	3104	4896	5358	5127
SE m (±)	0.45	0.82	45.70	43.36	43.78	94.46	97.09	67.49	106.45	111.77	83.45
CD (at 5%)	1.31	2.37	131.93	125.23	126.43	272.78	280.38	194.89	307.41	322.75	240.99
Interactions											
S x F S.Em (±)	0.84	1.96	82.56	75.11	82.42	213.37	216.87	149.28	218.08	240.47	162.80
CD (at 5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x B and F x B S.Em (±)	0.75	1.42	79.89	74.24	75.83	163.61	168.17	116.89	184.38	193.58	144.58
CD (at 5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x F x B S.Em (±)	1.30	2.46	138.38	130.09	131.34	283.37	291.58	202.47	319.35	335.3	250.35
CD (at 5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
General Mean	47.55	46.62	1854	1989	1921	2799	3072	2935	4652	5061	4856

Table 5: Effect of spacing and residual nutrient management practices on monetary returns and economics of chickpea in pooled results

	GMR (₹ ha^{-1})			NMR (₹ ha^{-1})			B:C Ratio		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Spacing									
S_1 – 30 x 10 cm^2	84209	99067	91638	57834	71492	64663	3.19	3.59	3.30
S_2 – 45 x 10 cm^2	70332	81523	75927	45102	55133	50117	2.79	3.09	2.94
S_3 – 45 x 05 cm^2	89999	105757	97878	62315	76637	69476	3.25	3.63	3.44
SE m (±)	2573.3	3277.4	2789.26	2573.3	3277.4	2789.2	0.10	0.11	0.08
CD (at 5%)	10102.2	12866.3	10950.1	10102.2	12866.1	10950.1	0.37	0.44	0.30
Residual Fertilizer levels									
F_1-160:60:60 kg NPK ha^{-1}	73250	86456	79853	46820	58761	52791	2.76	3.11	2.92
F_2-180:70:70 kg NPK ha^{-1}	83637	96976	90306	57207	69281	63244	3.16	3.49	3.30
F_3-200:80:80 kg NPK ha^{-1}	87653	102915	95284	61223	75220	68221	3.31	3.71	3.46
SE m (±)	2119.3	2382.5	2190.43	2119.3	2382.5	2190.43	0.08	0.09	0.07
CD (at 5%)	6530.7	7341.8	6749.89	6530.7	7341.8	6749.89	0.25	0.26	0.22
Bio-fertilizers									
B_0 - No Bio-fertilizers	77228	90073	83651	51023	62585	56804	2.94	3.27	3.07
B_1–*Rhizobium* + PSB + KSB (10 ml each kg^{-1} seed)	85798	100825	93312	59143	72923	66033	3.21	3.61	3.38
SE m (±)	2000.8	2081.5	2011.81	2000.8	2081.5	2011.81	0.08	0.07	0.07
CD (at 5%)	5777.8	6011.0	5809.71	5777.8	6011.0	5809.71	0.22	0.22	0.20
Interactions									
S x F SEm (±)	3670.7	4126.6	3793.93	3670.7	4126.6	3793.93	0.14	0.15	0.14
CD (at 5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x B and F x B S.Em (±)	3465.4	3605.3	3484.56	3465.4	3605.3	3484.56	0.13	0.13	0.12
CD (at 5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x F x B S.Em (±)	6002.3	6244.5	6035.44	6002.3	6244.5	6035.44	0.23	0.22	0.20
CD (at 5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS
General Mean	81513	95449	88481	55083	67753	61419	3.08	3.44	3.23

Conclusion

Sweet corn sowing on 60 x 20 cm^2 in *kharif* season followed by chick pea on 30 x 10 cm^2 spacing in rabi season in sequence cropping; application of 180:70:70 kg NPK ha^{-1} to sweet corn crop only (chickpea on residual nutrients after sweet corn) and seed treatment of *Azotobacter* (to sweet corn) / *Rhizobium* (to chick pea) + PSB and KSB @ 10 ml each kg^{-1} seed to sweet corn and chickpea seed is optimum for higher seed yield, monetary returns and benefit cost ratio of sweet corn – chick pea cropping system.

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