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Research Paper

Trans-geographical introduction of cluster bean (*Cyamopsis tetragonoloba* L.) in organic regime of Sikkim Himalaya - conditions conducive for successful cultivation

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ABSTRACT

The present study was conducted to explore the possibility of cultivation of cluster bean in non-traditional areas under the organic regime of Sikkim Himalaya. The cluster bean cv. Pusa Navbahar was planted on eight different dates under four organic nutrient combinations. Results revealed that the sowing time and organic manures showed significant differences in morpho-biochemical traits of cluster bean. The crop sown during the first three dates i.e fourth week of April, the second week of May, and the fourth week of May did not germinate. The sowing on the second week of August with FYM 50% (5 t/ha) + Vermicompost 50% (2.5 t/ha) was the most appropriate combination for the better growth, yield, and biochemical traits of cluster bean in Sikkim, suggesting the possibility for expansion of cluster bean in non-traditional areas. The introduction of cluster bean in Sikkim may help in diversifying the agricultural sector and provide additional income to the farmers.

Key words: Cluster bean, FYM, Organic manure, Sowing time, Vermicompost

INTRODUCTION

Cluster bean (*Cyamopsis tetragonoloba* L.), commonly known as guar, is an important rainy season legume grown particularly in north-western India (Deka *et al.* 2015). The crop is native to India and is mostly cultivated for seeds, fodder, vegetables, and green manuring (Pathak 2015). It is an excellent source of protein, lipid, phosphorus, calcium, mineral salts, and ascorbic acid (Ntatsi *et al.* 2018). The guar gum or galactomannan, is an important polysaccharide obtained from the seeds and used in many industries, including paper, mining, petrochemicals, food processing, cosmetics, and textiles (Mishra *et al.* 2018). India is the leading producer of cluster bean in the world with 60% of global production. In India, it is grown in about 2.96 million ha area producing about 1.22 million tonnes of guar seed with an average productivity of 0.41 tonnes per hectare (Sundharaiya and Sriram 2022).

Despite of rising demand for cluster bean in various industries, the production is very scanty in the country. To date, its cultivation is mainly concentrated in the North-Western part of India, alongside some parts of Southern India. There is an urgent need to extend its area through the search for new potential growing pockets. Sikkim, being an organic state evades the use of chemical fertilizers and relies on organic manure to meet the nutritional requirements of crop plants. In an organic regime, cultivation of cluster bean may be beneficial to improve the physico-chemical properties of soil through nitrogen fixation. According to Rai and Dharmatti (2014) cluster bean, being a leguminous crop, can fix about 37–196 kg N/ha yearly. Considering these facts, it is believed that Sikkim will be a good choice for expanding its cultivation, where the farmers may fetch the extra benefit of green manure alongside green pods as vegetables.

The organic state of Sikkim encourages sustainable agricultural methods in the farming system. The introduction of cluster bean here may help in diversifying the agricultural sector and provide additional income to the farmers. The crop has an export potential, which can further help to boost the state's economy. The cultivation of cluster bean may improve soil health and reduce soil erosion. A decrease of upto 25–43% in soil C stores is observed after switching from pasture to cropping systems (Soussana *et al*. 2004). Cluster bean-based cropping systems improve the soil organic carbon, humus content, as well as N and P availability. Grain legumes may raise soil organic carbon in several ways, by providing biomass, organic C and N, and by generating hydrogen gas as a byproduct of biological nitrogen fixation, which encourages the growth of bacterial legume nodules in the rhizosphere (Garrigues *et al.* 2012).

For the introduction of any crop in new non-traditional areas, the timing of sowing will be a deciding factor as the whole plant life cycle, including seed germination, vegetative growth, reproductive growth, and crop maturity depends upon it (Luqman *et al*. 2020). Planting too early causes plants to prolong the vegetative phase (Ayaz *et al*. 2004), whereas, late-planted crops develop prematurely and are unable to complete their regular vegetative phase (Ali *et al*. 2004). Temperature plays a key role in governing the plant phenological cycle, and ultimately decides the crop yield (Lamichaney *et al*. 2021, Parihar *et al*. 2022). Other deciding factors like the annual rainfall and humidity are directly associated with the successful cultivation of cluster bean (Meena *et al*. 2014). By keeping in mind the necessity of expansion of such a valuable crop in non-traditional areas, the stated background prompted us to explore the possibility of the trans-geographical introduction of cluster bean in Sikkim Himalaya.

MATERIALS AND METHODS

A photo-insensitive variety, Pusa Navbahar was selected for the study. The seed was collected from the Department of Agriculture, Government of Rajasthan, Jaipur. Before experimentation, seeds were treated with bio-fungicide i.e., *Trichoderma viride* @ 4 g/kg seed. The experimental site was located at 7th mile, Tadong, Sikkim (27°30′36.13″N latitude and 88°58′76.24″ E longitude) during the year 2023. Before experimenting, the field was prepared and brought to fine tilth through deep ploughing twice followed by single planking. All essential bulky manures based on individual treatment combinationswere added at the time of field preparation only. All standard organic packages and practices were adopted for the successful cultivation of the crop.

The agro-climatic conditions that prevailed during the year of investigation (2023) were recorded. Physico-chemical properties of soil were tested under triplicates and data were worked out. Composite soil sample for 0-15 cm and 15-30 cm depth was collected using steel corer of 10 cm diameter and processed for estimation of physico-chemical properties. The physical properties of soil like bulk density, particle density, and porosity were measured using standard procedure through a pycnometer. A digital pH meter (Mettler Toledo, model no. FP20-Bio-Kit) was utilized to measure pH in soil: water (1:2.5) suspension (McLean 1982). Electrical conductivity was measured by using a digital conductivity meter in the sample soil: water suspension (Rhoades 1996). Soil organic carbon was calculated as per the method suggested by Nelson and Sommers (1982). Available N was estimated using the Kjeldahl method (Subbiah and Asija 1956). Available P was estimated through the method suggested by Bray (1948). Available K was estimated using a digital flame photometer (Systronics, model no. 130, Systronics, India) as per the method suggested by Stanford and English (1949).

The experiment was statistically laid out in Factorial Randomized Block Design (FRBD) design during the year 2023. Cluster bean cv. Pusa Navbahar was sown at a spacing of 25 × 45 cm between plant and row, respectively. Each treatment was laid out in the plot size of 1.35 m × 1.25 m. Nutrients were applied in organic form as per individual treatment combination as basal dose only. Sources of fertilizers used were FYM (0.5% N, 0.25% P, and 0.5% K) and Vermicompost (1% N, 0.75% P, and 0.75% K). Irrigation was applied as per the need and prevailing rain occurrence. The treatments included eight sowing times [Fourth week of April (S_1), second week of May (S_2), fourth week of May (S_3), second week of June (S_4), fourth week of June (S_5), second week of July (S_6), fourth week of July (S_7), second week of August (S_8)], and four organic manure [Control (O_1), FYM 100 % @ 10 t/ha (O_2), Vermicompost 100 % @ 5 t/ha (O_3), and FYM 50% @ 5 t/ha+ Vermicompost 50% @ 2.5 t/ha (O_4)].

The quantitative growth and yield observations like plant height [45 days after sowing (DAS) and at harvesting in cm], days taken to 1st flowering, 50% flowering and 1st picking, number of clusters/plant, number of pods/cluster, pod length (cm), pod width (mm), number of seeds/pod and pod yield/plant (g) were recorded from five randomly selected plants under each treatment. For the calculation of pod yield/plot, the mature pods from each plot were picked and weighed. Yield per hectare was expressed using the net plot yield of the harvested pods. Protein content was estimated from the pods at edible maturity using UV-vis Spectrophotometer (Shimadzu: UV-1900i) using the standard protocol (Lowry 1951). Likewise, ascorbic acid content was estimated using UV-vis Spectrophotometer (Shimadzu: UV-1900i) using the standard procedure (Kapur *et al.* 2012).

Statistical analysis

All the quantitative data were subjected to an OPSTAT online statistical package to draw critical differences and standard errors of the mean for each investigated trait (Sheoran *et al.* 1998).

RESULTS AND DISCUSSION

Agro-meteorological observation and physico-chemical properties of soil

Under agro-meteorological observation, the average maximum rainfall was received in July (565.30 mm) and the minimum was in December month (14.64 mm). However, the average maximum and minimum temperatures were noted in August (26.9 °C) and January (6.5 °C), respectively (Figure 1). The average maximum humidity was recorded in July (79.37%) and the minimum was in March (48.66%) month. Whereas, the average maximum sunshine hours was seen in August (13.57) and the minimum was in January (8.49) (Figure 1). The optimum temperature for the production of cluster bean ranged between 23.2 to 35°C (Meena *et al.* 2018). These agro-meteorological observations indicated the suitability of cluster bean in this environment (Hussain *et al.* 2022).

Under physical properties, the soil texture was clay, with a bulk density of 1.55 g/cm^3, particle density of 2.51 g/cm^3, and porosity of 38.24%. The chemical properties of the soil revealed that the soil was acidic (pH 5.60) with EC of 0.281 dS/m, organic carbon as 1.18%, available nitrogen as 242.59 kg/ha, available phosphorus as 26.37 kg/ha and potassium as 156.92 kg/ha (Table 1).

Growth and yield parameters

It was observed in our study that the seeds

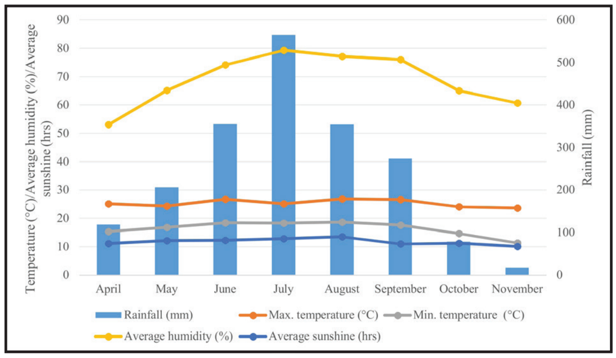


Fig. 1. Meteorological observations of experimental site

of cluster bean did not germinate in the first three sowing (S_1 = fourth week of April; S_2 = second week of May; S_3 = fourth week of May), which might be due to the unavailability of optimum temperature and other climatic factors required for seed germination. Among different treatments, plant height at 45 days after sowing and harvesting stage were found significantly superior in second week of August sowing (58.55 and 109.95 cm, respectively) and FYM 50% @ 5 t/ha+ Vermicompost 50% @ 2.5 t/ha organic manure (56.22 and 94.86 cm), while the lowest plant height at 45 days after sowing and harvesting stage were found in second week of June and control (no fertilizer) (Table 2). The interaction effect between sowing time and organic manure on plant height at 45 days after the sowing and harvesting stage was significantly superior in the second week of August + FYM 50% @ 5 t/ha+ Vermicompost 50% @ 2.5 t/ha (S_8O_4) (72.27 and 123.63 cm, respectively), while the lowest was recorded in the second week of June + control (Table 3).

The crop took comparatively fewer days to achieve 1st flowering (38.58 days), 50% flowering (43.25 days), and 1st picking (54.17 days) when sown during the fourth week of July (S_7). With regards to fertilizer application, the crop took 39.60, 44.20, and 60.67 days, respectively for flowering, 50% flowering, and 1st picking at FYM 50% @ 5 t/ha + Vermicompost 50% @ 2.5 t/ha (O_4) (Table 2). The interaction between sowing time and organic manure was statistically non-significant for days taken to 1st and 50% flowering (Table 3).

Table 1. Soil properties of experimental site

Depth (cm)	Bulk Density (g/cm^3)	Particle Density (g/cm^3)	Porosity (%)	pH	EC (dS/m)	Organic Carbon (%)	Nitrogen (kg/ha)	Phosphorus (P_2O_5) (kg/ha)	Potassium (K_2O) (kg/ha)	Soil texture
0-15	1.31	2.44	46.31	5.60	0.281	1.52	242.59	26.37	156.92	Clay
15-30	1.37	2.53	45.85	5.48	0.297	1.29	177.41	21.89	137.64	

Table 2. Effect of sowing time and organic manures on growth, yield and biochemical attributes

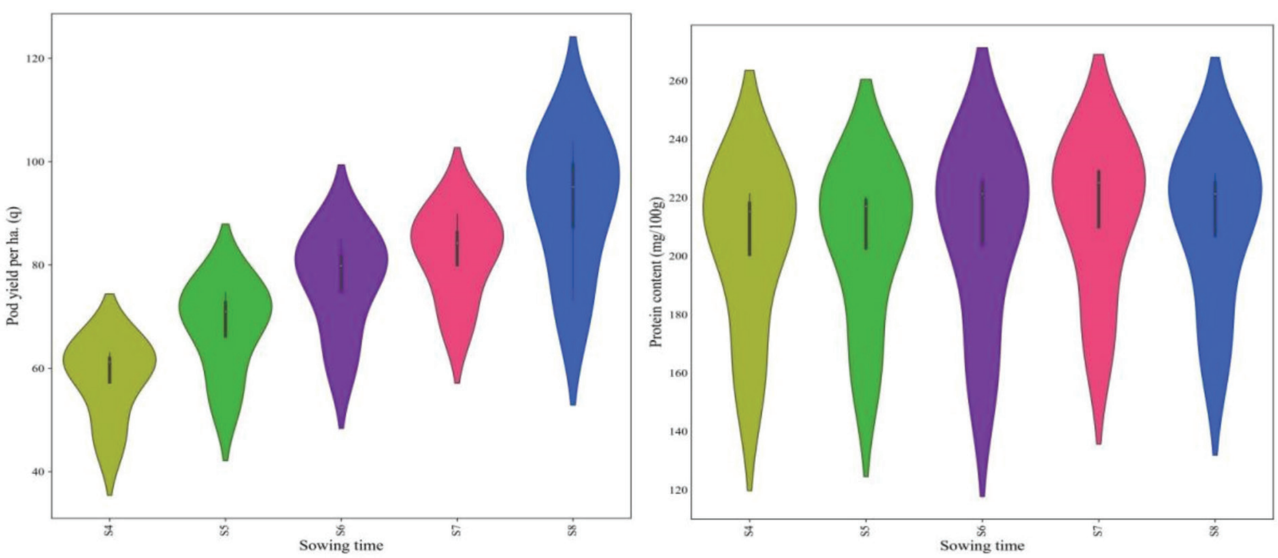
Treatment	Plant height (cm) (45 days)	Days taken to 1st flowering	Days taken to 50% flowering	Days taken to 1st picking	Number of clusters per plant	Number of pods per cluster	Pod length (cm)	Pod width (mm)	Number of seeds per pod	Pod yield per ha. (q)	Plant height (cm) at harvesting	Protein (mg/100g)	Ascorbic acid (mg/100g)
Sowing time													
S_4	23.16	54.17	58.33	83.00	4.73	3.91	6.49	8.23	7.17	58.07	51.56	203.39	52.28
S_5	33.59	45.75	50.00	71.75	5.76	4.53	7.70	8.30	7.33	68.01	66.27	204.71	53.99
S_6	51.93	39.75	43.83	63.83	6.92	5.37	8.99	8.66	7.33	76.86	87.83	207.88	55.07
S_7	55.39	38.58	43.25	54.17	9.90	6.63	12.18	8.93	7.42	82.09	100.49	213.64	55.76
S_8	58.55	40.33	44.83	56.25	11.18	6.95	12.48	8.91	7.17	91.81	109.95	210.60	56.26
SE (m)+	0.44	0.29	0.36	0.38	0.12	0.07	0.10	0.08	0.20	0.61	0.52	0.73	0.11
CD (P=0.05)	1.25	0.83	1.04	1.09	0.35	0.20	0.29	0.22	N/A	1.75	1.49	2.11	0.33
Organic manure													
O_1	29.51	48.20	52.47	71.20	5.41	4.44	8.03	7.53	6.93	61.64	68.35	167.32	49.47
O_2	41.63	44.73	49.07	67.67	7.56	5.09	8.99	8.34	7.40	77.00	80.39	217.21	55.16
O_3	50.74	42.33	46.47	63.67	8.11	5.61	9.67	9.08	7.27	79.56	89.27	224.77	56.72
O_4	56.22	39.60	44.20	60.67	9.71	6.77	11.58	9.47	7.53	83.27	94.86	222.96	57.33
SE (m)+	0.39	0.26	0.32	0.34	0.11	0.06	0.09	0.07	0.18	0.54	0.46	0.66	0.10
CD (P=0.05)	1.12	0.74	0.93	0.98	0.32	0.18	0.26	0.19	N/A	1.57	1.33	1.88	0.29

[Second week of June (S_4), fourth week of June (S_5), second week of July (S_6), fourth week of July (S_7), and second week of August (S_8)]

[Control (O_1), FYM 100 % @ 10t/ha (O_2), Vermicompost 100 % @ 5t/ha (O_3), and FYM 50% @ 5t/ha+ Vermicompost 50% @ 2.5t/ha (O_4)]

However, the fourth week of July + FYM 50% (5 t/ha)+ Vermicompost 50% (2.5 t/ha) i.e. (S_7O_4), had taken minimum days for 1st picking (51.67 days) (Table 3).

Under yield parameters, the highest number of clusters per plant and pods per cluster (11.18 and 6.95, respectively) were recorded when the crop was sown in the second week of August. Among the organic treatment, FYM 50% (5 t/ha) + Vermicompost 50% (2.5 t/ha) recorded the maximum number of clusters per plant and pods per cluster (9.71 and 6.77, respectively), while the lowest number of clusters per plant and pods per cluster was found in the second week of June and control compared to other sowing times and organic manure (Table 2). The interaction between



A B

Fig. 2. Violin plot depicting effect of sowing time on pod yield ha^{-1} (A) and protein content (B)

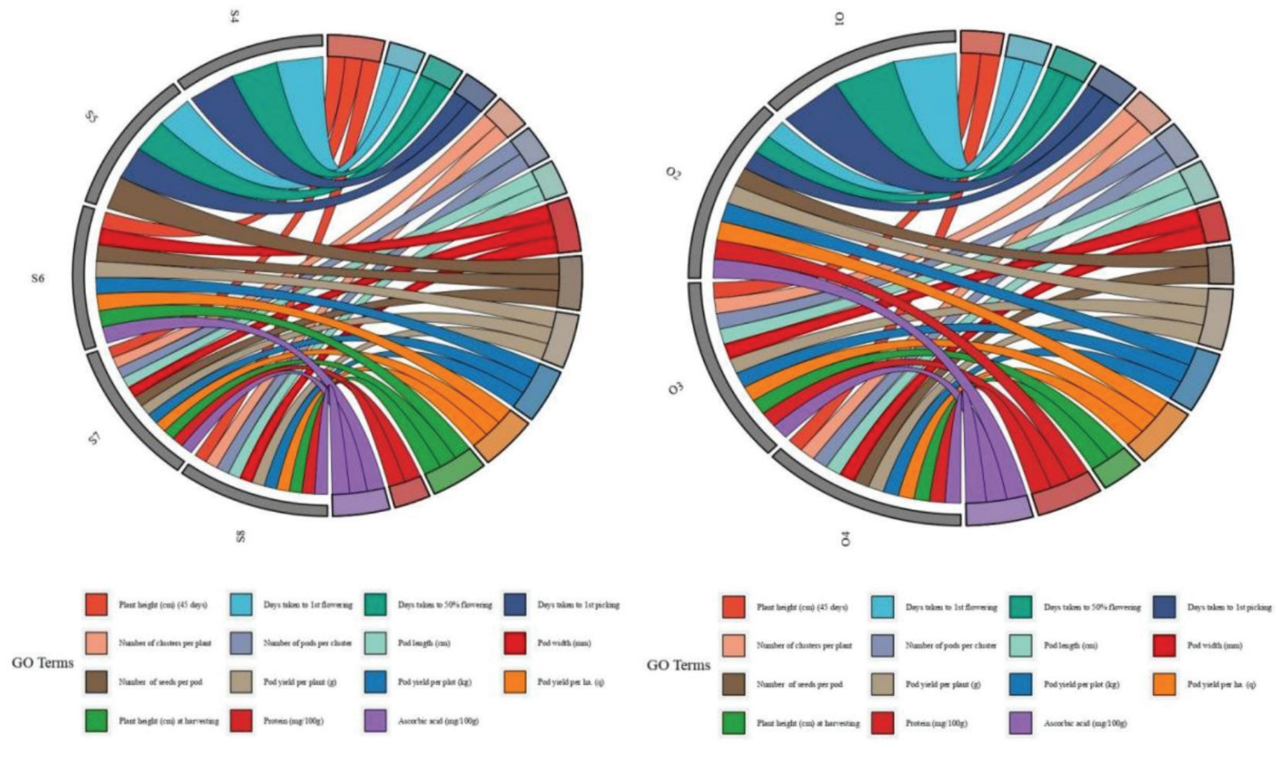
[Second week of June (S_4), fourth week of June (S_5), second week of July (S_6), fourth week of July (S_7), and second week of August (S_8)]

sowing time and organic manures on the number of clusters per plant (13.90) and number of pods per cluster (8.37) were significantly superior in S_8O_4 i.e. second week of August + FYM 50% (5 t/ha) + Vermicompost 50% (2.5t /ha), while the lowest was recorded in S_5O_1 and S_4O_1 i.e. fourth week of June + control and second week of June + control, respectively (Table 3).

The highest pod yield per hectare was recorded under sowing in the second week of August (91.81 q) and FYM 50% (5 t/ha)+ Vermicompost 50% (2.5 t/ha) organic manure (83.27 q), while the lowest pod yields were found in the second week of June and control plot (Table 2 and Figure 2A). The interaction between sowing time and organic manure in pod yield were recorded significantly higher (103.94 q) in treatment S_8O_4 i.e. (second week of August with FYM 50% (5 t/ha) + Vermicompost 50% (2.5 t/ha) (Table 3). Clusterbean is a tropical crop, and prefers a warm climate. In the present investigation, the month of August recorded the maximum sunshine hours, temperature, and adequate rainfall. This could be the reason for obtaining good plant growth and yield when sown during August. Adequate nutrients and suitable temperatures promote the germination and growth of plants (Kosa and Karaguzel 2020). Increased temperature and sunshine hours in this month might have enhanced photosynthesis, which directly affected plant growth by increasing nutrient uptake and root development (Kumar *et al*. 2023).

Biochemical parameters

The effect of sowing date and fertilizer dose has a significant effect on the protein and ascorbic acid content. Maximum protein (213.64 mg/100g) and ascorbic acid (56.26 mg/100g) were found when crop was sown during the fourth week of July and the second week of August, respectively. Likewise, maximum protein (224.77 mg/100g) was found



A B

Fig. 3. Chord diagram depicting contribution of sowing time (A) and organic manure (B) in improvement of growth, yield and biochemical attributes of cluster bean

[Second week of June (S_4), fourth week of June (S_5), second week of July (S_6), fourth week of July (S_7), and second week of August (S_8)]; [Control (O_1), FYM 100 % @ 10t/ha (O_2), Vermicompost 100 % @ 5t/ha (O_3), and FYM 50% @ 5t/ha+ Vermicompost 50% @ 2.5t/ha (O_4)]

Table 3. Effect of interaction between sowing time and organic manures on growth, yield, and biochemical attributes

	Plant height (45 days)	Days taken to 1st flowering	Days taken to 50% flowering	Days taken to 1st picking	Number of clusters per plant	Number of pods per cluster	Pod length (cm)	Pod width (mm)	Number of seeds per pod	Pod yield per ha. (q)	Plant height (cm) at harvesting	Protein (mg/100g)	Ascorbic acid (mg/100g)
S_4O_1	12.67	58.67	63.00	90.33	3.80	2.93	5.07	7.00	7.00	46.84	41.40	161.91	47.90
S_4O_2	20.17	56.00	60.33	86.00	4.13	3.63	6.07	8.06	7.33	60.79	48.00	213.27	51.94
S_4O_3	28.07	52.00	55.67	80.33	4.83	4.03	6.75	8.82	7.00	61.66	56.00	221.31	53.85
S_4O_4	31.73	50.00	54.33	75.33	6.13	5.03	8.06	9.04	7.33	62.99	60.83	217.08	55.41
S_5O_1	19.83	50.00	54.00	79.00	3.57	3.37	6.45	7.42	6.67	55.30	51.27	164.87	48.93
S_5O_2	31.53	47.00	51.33	74.33	5.47	4.27	7.11	8.18	7.67	69.86	65.90	215.18	54.77
S_5O_3	40.23	44.33	48.67	68.33	6.17	4.70	7.52	8.61	7.33	72.12	72.47	218.77	55.84
S_5O_4	42.77	41.67	46.00	65.33	7.83	5.80	9.74	8.97	7.67	74.75	75.43	220.04	56.40
S_6O_1	34.10	44.00	48.33	69.67	4.87	4.33	7.51	7.70	7.00	62.92	70.83	163.18	49.46
S_6O_2	49.83	41.00	44.33	65.67	6.83	5.07	8.23	8.27	7.33	78.91	85.07	217.50	55.87
S_6O_3	59.50	38.67	42.67	61.33	7.30	5.47	9.25	9.10	7.33	80.76	94.73	225.75	57.25
S_6O_4	64.30	35.33	40.00	58.67	8.67	6.60	10.99	9.56	7.67	84.84	100.67	225.11	57.68
S_7O_1	39.73	43.00	47.33	56.33	7.20	5.67	10.30	7.88	7.33	70.00	86.03	175.01	50.17
S_7O_2	52.53	39.00	44.00	55.67	9.97	6.03	11.69	8.58	7.67	83.33	97.80	221.52	56.76
S_7O_3	59.27	37.33	41.67	53.00	10.43	6.77	12.32	9.38	7.00	85.19	104.40	229.55	57.93
S_7O_4	70.03	35.00	40.00	51.67	12.00	8.07	14.38	9.90	7.67	89.84	113.73	228.49	58.17
S_8O_1	41.20	45.33	49.67	60.67	7.60	5.90	10.80	7.64	6.67	73.12	92.20	171.63	50.88
S_8O_2	54.10	40.67	45.33	56.67	11.40	6.47	11.86	8.62	7.00	92.10	105.20	218.56	56.43
S_8O_3	66.63	39.33	43.67	55.33	11.80	7.07	12.52	9.50	7.67	98.10	118.77	228.16	58.74
S_8O_4	72.27	36.00	40.67	52.33	13.90	8.37	14.72	9.87	7.33	103.94	123.63	224.05	58.97
SE (m)+	0.87	0.58	0.72	0.76	0.25	0.14	0.2	0.15	0.4	1.22	1.04	1.47	0.23
CD (P=0.05)	2.51	N/A	N/A	2.18	0.71	N/A	N/A	N/A	N/A	3.50	2.98	N/A	0.65

[Second week of June (S_4), fourth week of June (S_5), second week of July (S_6), fourth week of July (S_7), and second week of August (S_8)]

[Control (O_1), FYM 100 % @ 10t/ha (O_2), Vermicompost 100 % @ 5t/ha (O_3), and FYM 50% @ 5t/ha+ Vermicompost 50% @ 2.5t/ha (O_4)]

when supplemented with 100% vermicompost (5 t/ha), while maximum ascorbic acid (57.33 mg/100g) was recorded in FYM 50% (5 t/ha) + Vermicompost 50% (2.5 t/ha) (Table 2). The interaction effect between sowing time and organic manure was non-significant for protein content but it was significant for ascorbic acid (Table 3 and Figure 2B).FYM and vermicompost have a significant positive impact on ascorbic acid and protein content (Zahid *et al*. 2022). This might be attributed to the availability of necessary and beneficial nutritional elements, particularly nitrogen, through the use of FYM and vermicompost (Liu *et al*. 2016). According to (Meena *et al*. 2018), timely sowing resulted in higher yield and protein content in cluster bean, which may be attributed to enhanced microbial activity, leading to higher availability of major and micronutrients, which in turn boosts the ascorbic acid and protein content in crop plants (Dutta and Dutta 2016).

Additionally, the chord diagram also portrayed the significance of sowing time (Figure 3A) and organic manure (Figure 3B) towards improvement in growth, yield, and biochemical attributes of cluster bean. Based on average contribution, it was found that the best sowing time was in the order $S_8 > S_7 > S_6 > S_5 > S_4$ (Figure 4). Likewise, in the organic manure treatment, the order was $O_4 > O_3 > O_2 > O_1$ (Figure 5).

CONCLUSION

Based onthe above results it is conferred that the sowing of cluster bean in the second week of August in combination with the application of FYM @ 5 t/ha+ Vermicompost @ 2.5 t/ha is recommended for better growth and yield of cluster bean under climatic conditions in Sikkim's organic farming context. However, long-term research involving various ecological zones is needed to validate these findings,

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