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CR Chatarkar
M.Sc. Scholar, Department of Vegetable Science, College of Horticulture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri, Maharashtra, 415 712, India

YR Parulekar
Vegetable Specialist, Vegetable Improvement Scheme, Central Experiment Station, Wakawali, Ratnagiri, Maharashtra, India

Pradnya S Gudadhe
Assistant Horticulturist, AICRP on Tuber Crops, Central Experiment Station, Wakawali, Ratnagiri, Maharashtra, India

SB Thorat
Assistant Professor, Department of Plantation, Spices, Medicinal and Aromatic crops, Collage of Horticulture, Dapoli, Maharashtra, India

More VG
Deputy Director of Research, Dr Balasaheb Swant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

Pooja A Dabholkar
Ph. D. (Hort.), Department of Vegetable Science, College of Horticulture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri, Maharashtra, 415 712, India

Corresponding Author:
CR Chatarkar
M.Sc. Scholar, Department of Vegetable Science, College of Horticulture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri, Maharashtra, 415 712, India

Response of spacing and nitrogen levels on growth and yield of cluster bean (*Cyamopsis tetragonoloba* L.)

CR Chatarkar[1], YR Parulekar[2], Pradnya S Gudadhe[3], SB Thorat[4], More VG[5], Pooja A Dabholkar[6]

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Abstract
The present investigation entitled "Response of spacing and nitrogen levels on growth and yield of cluster bean (*Cyamopsis tetragonoloba* L.)" was carried out during the *rabi-summer* season of 2025–2026 at the Department of Vegetable Science to study the response of different spacing and nitrogen levels on growth and yield of cluster bean. The experiment was laid out in Strip Plot Design with nine treatment combinations replicated forth. During investigation, three levels of spacing viz. S_1: (50 × 15 cm), S_2: (50 × 30 cm) and S_3: (50 × 45 cm) and three nitrogen levels viz. N_1: (60:60:60 kg NPK ha^{-1} + 10 t FYM ha^{-1}), N_2: (75:60:60 kg NPK ha^{-1} + 10 t FYM ha^{-1}) and N_3: (90:60:60 kg NPK ha^{-1} + 10 t FYM ha^{-1}) were evaluated. In growth parameters, highest plant height at 120 DAS (150.56 cm) was recorded in S_1N_2 and S_1N_3, maximum number of primary branches (5.42) was recorded in S_3N_2. In case of yield and yield attributing characters, highest number of pods per plant (161.70) and maximum pod yield per plant (169.60 g) was recorded in S_2N_3, while highest pod length (6.93 cm) was recorded in S_1N_3. Maximum green pod weight (1.07 g) was recorded in S_1N_2. Highest pod yield per plot (10.16 kg) and pod yield per hectare (22.58 t ha^{-1}) were recorded in S_1N_3. Considering the comparative performance and ranking of different spacing and nitrogen levels in terms of growth, yield and yield attributing characters, it was observed that S_1N_3 (50 × 15 cm spacing with 90:60:60 kg NPK ha^{-1} + 10 t FYM ha^{-1}) performed better for overall productivity and recorded the highest pod yield of 22.58 t ha^{-1}.

Keywords: Cluster Bean, Spacing, Nitrogen Levels, Growth and Yield

Introduction

The vegetable sector in India has witnessed remarkable growth and has become one of the major contributors to the horticulture industry. According to the National Horticulture Board (NHB, 2024) [1], vegetables occupy the largest share among horticultural crops in terms of production. During 2023–24, India recorded vegetable production of approximately 205.8 million tonnes from an area of about 11.17 million hectares, highlighting the significant contribution of vegetables to Indian agriculture and food supply (NHB, 2024) [1]. In this context, evaluating the response of cluster bean to different spacing and nitrogen levels is important for developing suitable recommendations for improving growth and yield under specific agro-climatic conditions (Priyadarshini *et al*., 2017) [2]. Among vegetable crops, cluster bean (*Cyamopsis tetragonoloba* L.), commonly known as guar, is an important leguminous vegetable crop belonging to the family Fabaceae. The tender green pods of cluster bean are consumed as a vegetable due to their nutritional value, while its seeds are commercially valuable as a source of guar gum used in food processing, pharmaceutical, textile and industrial applications (Kumar *et al*., 2022) [3]. The crop possesses excellent adaptability to drought and moisture stress conditions and can be successfully cultivated under arid and semi-arid environments. Being a leguminous crop, cluster bean has the ability to fix atmospheric nitrogen through symbiotic association with *Rhizobium*, which helps in improving soil fertility and maintaining sustainability of cropping systems (Rathore *et al*., 2018). However, proper crop management practices such as optimum plant spacing and balanced nitrogen nutrition are essential for improving plant growth, yield attributes and productivity of cluster bean (Priyadarshini *et al*., 2017) [2]. Growth and yield performance of cluster bean is greatly influenced by crop geometry and nutrient availability, particularly plant spacing and nitrogen management. Plant spacing plays an important role in determining plant population density, availability of sunlight, air circulation, nutrient utilization and competition among plants. Among nutrients nitrogen is one of the most important nutrients required for plant growth and development as it plays a major role in chlorophyll formation, protein synthesis, enzyme activity and vegetative growth. Although cluster bean is a leguminous crop capable of fixing atmospheric nitrogen through symbiotic association with *Rhizobium*, the fixed nitrogen alone may not be sufficient to meet the crop requirement during active growth and pod formation stages. Optimum spacing and nitrogen application are expected to improve plant vigour, branching, and yield attributes, whereas im

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proper levels may reduce productivity. The interaction between spacing and nitrogen levels may significantly influence the overall performance of cluster bean under local agro-climatic conditions. Increase in application of nitrogenous fertilizers and planting at close spacing may result vigorous growth and more plant population producing higher yield from a unit area. Therefore, comparative evaluation of different spacing and nitrogen levels may help to identify the most suitable combination for obtaining higher yield and better economic returns for vegetable growers.

Cluster bean (*Cyamopsis tetragonoloba* L.) is a multipurpose leguminous vegetable crop having importance as a vegetable, fodder and industrial crop due to its nutritional value and guar gum content. Although, the crop is traditionally cultivated in arid and semi-arid regions of India, its cultivation has potential to expand in non-traditional areas such as the Konkan region of Maharashtra due to increasing demand for fresh vegetables and industrial uses of guar gum. The Konkan region possesses diverse agro-climatic conditions, and studies have indicated the suitability of cluster bean cultivation under the agro-climatic conditions of Konkan, including evaluation of varieties for growth, yield and quality performance. The lateritic soils of Konkan are generally acidic and may have limitations regarding nutrient availability, especially nitrogen, which makes nutrient management an important factor for successful crop production. Similarly, close spacing may cause excess vegetative growth in humid climatic conditions which may increase incidence of pest and diseases. Therefore, the study on response of spacing and nitrogen levels in cluster bean has considerable scope for identifying suitable plant population and nitrogen requirement for improving growth, yield attributes and green pod production under Konkan conditions.

Material and methods

The field experiment was conducted at the Department of Vegetable Science, College of Horticulture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (Maharashtra) during the *rabi* season, 2025-26. The selection of the site was done on the basis of suitability of land for the cultivation of cluster bean. Dapoli represents a tropical climate having average humidity 78% and warm climate throughout the year, with equable temperature. Dapoli Dist. Ratnagiri is situated on the West coast of Maharashtra.

Experimental details

1	**Crop**	**Cluster Bean (*Cyamopsis tetragonoloba* L.)**
2	Season	*Rabi* – summer season 2025-26.
3	Total no. of Treatment Combinations	9
4	Design	Strip plot design
5	replications	4

Treatment details

Factor 'A'	**Factor 'B'**
Spacing	**Nitrogen Level**
S_1 - 50 × 15 cm	N_1 -10 t FYM + 60:60:60 kg NPK/ha
S_2 - 50 × 30 cm	
S_3- 50 × 45 cm	N_2 -10 t FYM + 75:60:60 kg NPK/ha
	N_3 -10 t FYM + 90:60:60 kg NPK/ha

Results and discussion

Growth parameters

Effect of spacing (S)

The different spacings had significant effect on plant height (cm) and number of primary branches as shown in Table 1 (a) and (b). At 30 DAS, the highest plant height was recorded in S_1 (28.68 cm), whereas the lowest was observed in S_2 (25.01 cm) with a mean of 26.24 cm. At 60 DAS, the highest plant height was recorded in S_1 (51.38 cm), while the lowest was in S_2 (50.08 cm), with a mean of 50.62 cm. At 90 DAS, S_1 recorded the highest plant height (118.21 cm), whereas S_2 recorded the lowest (109.99 cm), with a mean of 113.65 cm. At 120 DAS, the highest plant height was recorded in S_1 (148.80 cm) and the lowest in S_2 (142.30 cm), with a mean of 144.74 cm. The superior performance under closer spacing may be attributed to increased plant population which provided limited space for each plant and greater competition for sunlight, which stimulated vertical stem elongation and internodal growth, resulting it to higher plant height at all the stages, similarly the height was also observed increasing with advancement in the stage of the plant. The present results are consistent with the findings of Priyadarshini *et al.* (2017) [2], Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5], Kumar *et al.* (2022) [3] and Singh *et al. (2014)* [6], who observed that spacing influenced plant height in cluster bean and other leguminous vegetable crops.

The number of primary branches was significantly influenced by spacing. Wider spacing S_3 (50 × 45 cm) recorded the highest mean number of primary branches at 30 DAS (2.48), which was at par with S_2 (1.51), and at 60 DAS (3.18), which was at par with S_2 (2.20). At 90 DAS, S_3 recorded the highest value (3.53), which was significantly superior to S_2 (2.42), while at 120 DAS S_3 recorded the highest value (4.76), which was at par with S_2 (3.55). The lowest values were recorded under S_1. The cluster bean is a crop having erect growth habit and with low branching habit, hence the significant differences among the various spacings investigated during present study. The numerically higher number of branches in wider spacing may reduce to availability of spacing which ultimately increased the availability of better air circulation and penetration of sunlight into the growing plants. The observed response is in accordance with reports by Priyadarshini *et al.* (2017) [2], Patel *et al.* (2016), Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5], Kumar *et al.* (2022) [3] and Singh *et al. (2014)* [6], who observed that spacing influenced number of primary branches in cluster bean and other leguminous vegetable crops.

Effect of nitrogen (N)

The growth observations varied significantly among different nitrogen levels. N_3 (90:60:60 kg NPK ha^{-1} + 10 t FYM ha^{-1}) recorded the highest mean plant height at 30 DAS (26.96 cm), which was significantly superior to N_1 (25.89 cm), and at 60 DAS (50.86 cm), which was significantly superior to N_2 (50.59 cm). At 90 DAS, N_3 recorded 114.88 cm, significantly superior to N_2 (113.44 cm). At 120 DAS, N_2 and N_3 recorded the same highest value of 146.87 cm. The response to nitrogen may be explained by its role in chlorophyll formation, protein synthesis, enzyme activity and cell division, thereby supporting photosynthetic activity and crop growth. These findings are in agreement with the reports of Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5] and Singh *et al. (2014)* [6], who reported that nitrogen nutrition influencing plant height in cluster bean.

N_3 recorded the highest mean number of primary branches at 30 DAS (1.98), which was at par with N_2 (1.61), and at 90 DAS (3.05), which was at par with N_2 (2.49); at 120 DAS, N_2 and N_3 recorded the same highest value of 3.98 branches. It is well known for that nitrogen plays vital role in accelerating the vegetative growth. But in present investigation no significant effect of nitrogen was observed in increasing number of leaves. These findings are in agreement with the reports of Patel *et al.* (2016), Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5] and Singh *et al. (2014)* [6], who reported that nitrogen nutrition influenced number of primary branches in cluster bean.

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Effect of interaction

The interaction between spacing and nitrogen significantly influenced the major growth parameters. In case of plant height, the highest values at 30, 60 and 90 DAS were recorded under S_1N_3 (30.81, 51.56 and 118.65 cm), while at 120 DAS the highest value was recorded under S_1N_2 (150.56 cm). The significant difference due to interaction of spacing and nitrogen may be attributed to the combined influence of crop geometry and nitrogen availability on vegetative growth, photosynthesis and assimilate production. Closer spacing increases competition for light, which promotes more upright growth. On the other hand, higher nitrogen availability supports vegetative development. Therefore, the interaction between closer spacing and higher nitrogen supply can contribute to greater plant height. Similar response to spacing and nitrogen nutrition, which provide a basis for the observed treatment combination effects, have been reported by Patel *et al.* (2016), Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5] and Singh *et al. (2014)* [6].

For number of primary branches, S_3N_3 recorded the highest value at 30 DAS (3.21), whereas at 60 DAS S_3N_2 recorded the highest value (3.92), at 90 DAS S_3N_3 recorded the highest value (4.58), and at 120 DAS S_3N_2 recorded the highest value (5.42). The significant variation in the interaction and spacing availability may be attributed to the availability of more growing space and more nitrogen availability induce lateral shoot initiation and more canopy spread. Similar responses to spacing and nitrogen nutrition, which provide a basis for the observed treatment combination effects, have been reported by Patel *et al.* (2016), Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5] and Singh *et al. (2014)* [6].

Yield parameters

Effect of spacing (S)

The different spacings had significant effect on number of pickings, pod yield per plant and pod yield per ha. as shown in Table 2 (a), (b) and (c). At number of pickings, spacing exerted a significant effect on number of pickings. S_2 (50 × 30 cm) recorded the highest mean number of pickings (9.56 days), which was at par with S_1 (50 × 15 cm) (9.35 days), whereas the lowest number of pickings (9.13 days) was recorded in S_3 (50 × 45 cm). The better performance related to number of pickings in S_2 (50 × 30 cm) can be attributed to production of more number of pods in S_2 (50 × 30 cm) which might have provided optimum space for growth of the plane as well as sufficient availability of sunlight resulting into better photosynthesis and accumulation of carbohydrates required for continuous harvesting of pods. These results corroborate the observations of Priyadarshini *et al.* (2017) [2], Singh *et al.* (2018), Patel *et al.* (2016), Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5], Kumar *et al.* (2022) [3] and Singh *et al. (2014)* [6], who observed that spacing influenced number of pickings in cluster bean and other leguminous vegetable crops.

The effect of spacing on pod yield per plant to spacing was significant. S_2 (50 × 30 cm) recorded the highest mean pod yield per plant (163.20 g), which was at par with S_1 (50 × 15 cm) (158.70 g), whereas the lowest pod yield per plant (148.78 g) was recorded in S_3 (50 × 45 cm). The spacing in S_2 might have provided optimum space and light for potential growth of the plant resulting into production of higher yield per plant. Optimum light penetration also might have produced more photosynthesis as compare to other spacings. The present results are consistent with the findings of Priyadarshini *et al.* (2017) [2], Singh *et al.* (2018), Patel *et al.* (2016), Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5], Kumar *et al.* (2022) [3] and Singh *et al. (2014)* [6], who observed that spacing influenced pod yield per plant in cluster bean and other leguminous vegetable crops.

In case of pod yield per hectare, pod yield per hectare showed a significant response to the different spacing treatments. S_1 (50 × 15 cm) recorded the highest mean pod yield per hectare (21.16 t ha^{-1}), which was significantly superior than S_2 (50 × 30 cm) (10.88 t ha^{-1}) where the lowest pod yield per hectare (6.61 t ha^{-1}) was recorded in S_3 (50 × 45 cm). The response to spacing may be attributed to the balance between plant population and the availability of light, moisture and nutrients, which influenced flowering, pod setting and pod development. Similarly, in S_1 the plant population is high as compared to the other spacing treatments which have contributed in recording higher yield per hectare. These results corroborate the observations of Priyadarshini *et al.* (2017) [2], Singh *et al.* (2018), Patel *et al.* (2016), Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5], Kumar *et al.* (2022) [3] and Singh *et al. (2014)* [6], who observed that spacing influenced pod yield per hectare in cluster bean and other leguminous vegetable crops.

Effect of nitrogen (N)

A significant influence of nitrogen levels on number of pickings was evident at number of pickings. N_3 (90:60:60 kg NPK ha^{-1} + 10 t FYM ha^{-1}) recorded the highest mean value for number of pickings (9.57 days), which was at par with N_2 (75:60:60 kg NPK ha^{-1} + 10 t FYM ha^{-1}) (9.54 days), whereas the lowest mean value mean value for number of pickings (8.93 days) was recorded under N_1 (60:60:60 kg NPK ha^{-1} + 10 t FYM ha^{-1}) It is evident that higher nitrogen supply ensured continuous supply of N to the plant throughout investigating and nitrogen has important role in chlorophyll formation, protein synthesis, enzymatic processes and cell division, which enhanced photosynthetic activity and overall crop growth. These findings are in agreement with the reports of Patel *et al.* (2016), Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5] and Singh *et al. (2014)* [6], who reported that nitrogen nutrition influenced number of pickings in cluster bean.

The nitrogen application significantly influenced the pod yield per plant. N_3 (90:60:60 kg NPK ha^{-1} + 10 t FYM ha^{-1}) recorded the highest mean value for pod yield per plant (164.95 g), which was at par with N_2 (75:60:60 kg NPK ha^{-1} + 10 t FYM ha^{-1}) (157.19 g), whereas the lowest mean value for pod yield per plant (148.53 g) was recorded under N_1 (60:60:60 kg NPK ha^{-1} + 10 t FYM ha^{-1}). It is evident that nitrogen has important role in chlorophyll formation, protein synthesis, enzyme activity and cell division, thereby supporting photosynthetic activity and crop growth. The more availability of nitrogen in higher doses provided continuous supply throughout life cycle resulting in more yield. These findings are in agreement with the reports of Patel *et al.* (2016), Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5] and Singh *et al. (2014)* [6], who reported that nitrogen nutrition influenced pod yield per plant in cluster bean.

A significant influence of nitrogen levels on pod yield per hectare was evident at pod yield per hectare. N_3 (90:60:60 kg NPK ha^{-1} + 10 t FYM ha^{-1}) recorded the highest mean value for pod yield per hectare (13.61 t ha^{-1}), which was at par with N_2 (75:60:60 kg NPK ha^{-1} + 10 t FYM ha^{-1}) (12.93 t ha^{-1}), whereas the lowest mean value pod yield per hectare (12.12 t ha^{-1}) was recorded under N_1 (60:60:60 kg NPK ha^{-1} + 10 t FYM ha^{-1}). The nitrogen plays important role in chlorophyll formation, protein synthesis, enzyme activity and cell division, which enhanced photosynthetic activity and overall crop growth. In N_3 the higher quantity of nitrogen was applied which was available to the plant throughout growth periods. These findings are in agreement with the reports of Patel *et al.* (2016), Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5] and Singh *et al. (2014)* [6], who reported that nitrogen nutrition influenced pod yield per hectare in cluster bean.

Effect of interaction

The interaction effect of spacing and nitrogen on number of pickings was significant. The highest value mean value for number of pickings (9.69 days) was recorded in S_1N_3, which was at par with S_2N_2 (9.64), S_2N_1 (9.58), S_2N_3 (9.58), S_2N_3 (9.45) and S_3N_2 (9.39) whereas the lowest mean value for number of pickings (8.42 days) was recorded in S_3N_1. The significant interaction effect may be attributed to the combined influence of crop geometry and nitrogen availability in optimum quantity throughout the growth period which positively impacted on vegetative growth, photosynthesis and assimilate production. As the effect of spacing and nitrogen was significant their interaction effect was also found significant with respect to number of

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pods per plant. Similar responses to spacing and nitrogen nutrition, which provide a basis for the observed treatment combination effects, have been reported by Patel *et al.* (2016), Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5] and Singh *et al. (2014)* [6].

The interaction effect of spacing and nitrogen on pod yield per plant was significant. The highest value for pod yield per plant (169.60 g) was recorded in S_2N_3, which was at par with S_1N_3(169.39 g) whereas the lowest for pod yield per plant (141.82 g) was recorded in S_3N_1. The superior interaction treatment provided a favorable balance between plant population and nutrient availability, thereby improving vegetative growth, flowering, pod setting and pod development. Similarly, as the spacing and nitrogen effects on yield per plant were superior in S_2 and N_3 recorded highest yield in present investigation. These findings are in agreement with the reports of Patel *et al.* (2016), Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5] and Singh *et al. (2014)* [6], who reported that nitrogen nutrition influenced pod yield per plant in cluster bean.

The combined effect of spacing and nitrogen on pod yield per hectare was significant at pod yield per hectare. The highest value pod yield per hectare (22.58 t ha^{-1}) was recorded in S_1N_3, whereas the lowest pod yield per hectare (6.30 t ha^{-1}) was recorded in S_3N_1. The superior interaction treatment provided a favorable balance between plant population and nutrient availability, thereby improving vegetative growth, flowering, pod setting and pod development. The higher plant population and more availability of nitrogen had significantly contributed in recording higher yield per hectare. Similar findings are in agreement with the reports of Patel *et al.* (2016), Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5] and Singh *et al. (2014)* [6], who reported that nitrogen nutrition influenced pod yield per ha. in cluster bean.

Qualitative character effect of spacing (S)

Effect of spacing (S)

The different spacings had significant effect on pod length (cm) and pod weight (g) as shown in Table 3 (a) and (b). The effect of spacing on pod length was significant. S_1 (50 × 15 cm) recorded the highest mean pod length (6.74 cm), which was significantly superior than S_2 (50 × 30 cm) (6.39 cm), whereas the lowest pod length (6.29 cm) was recorded in S_3 (50 × 45 cm). The variation in pod length in S_1 can be attributed to availability of favorable microclimate due to closer spacing which in turn is the effect of proper vegetative growth. Similar, findings were also reported by Priyadarshini *et al.* (2017) [2], Singh *et al.* (2018), Patel *et al.* (2016), Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5], Kumar *et al.* (2022) [3] and Singh *et al. (2014)* [6], who observed that spacing influenced pod length in cluster bean and other leguminous vegetable crops.

In case of green pod weight, the effect of spacing was significant. S_1 (50 × 15 cm) recorded the highest mean green pod weight (1.07 g), which was significantly superior than S_2 (50 × 30 cm) (1.01 g), whereas the lowest green pod weight (0.98 g) was recorded in S_3 (50 × 45 cm). Appropriate vegetative growth due to favorable microclimate might be responsible for higher pod weight in S_1. The variation may be attributed to differences in canopy development, assimilate partitioning and nutrient availability during pod development. These results corroborate the observations of Priyadarshini *et al.* (2017) [2], Singh *et al.* (2018), Patel *et al.* (2016), Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5], Kumar *et al.* (2022) [3] and Singh *et al. (2014)* [6], who also observed that spacing influenced green pod weight in cluster bean and other leguminous vegetable crops.

Effect of nitrogen levels (N)

The response of pod length to nitrogen nutrition was significant at pod length. N_3 (90:60:60 kg NPK ha^{-1} + 10 t FYM ha^{-1}) recorded the highest mean value for pod length (6.62 cm), which was significantly superior than N_2 (75:60:60 kg NPK ha^{-1} + 10 t FYM ha^{-1}) (6.44 cm), whereas the lowest mean value for pod length (6.36 cm) was recorded under N_1 (60:60:60 kg NPK ha^{-1} + 10 t FYM ha^{-1}). The variation in pod length in N_3 can be attributed to availability of favorable microclimate due to higher dose of nitrogen which in turn is the effect of proper vegetative growth. These findings are in agreement with the reports of Patel *et al.* (2016), Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5] and Singh *et al. (2014)* [6], who reported that nitrogen nutrition influenced pod length in cluster bean.

The various nitrogen doses significantly influenced the green pod weight. N_3 (90:60:60 kg NPK ha^{-1} + 10 t FYM ha^{-1}) recorded the highest mean value for green pod weight (1.05 g), which was at par with N_2 (75:60:60 kg NPK ha^{-1} + 10 t FYM ha^{-1}) (1.02 g), whereas the lowest mean value for green pod weight (0.99 g) was recorded under N_1 (60:60:60 kg NPK ha^{-1} + 10 t FYM ha^{-1}) Variation under the nitrogen treatments can be associated with the contribution of nitrogen to chlorophyll synthesis, protein formation, enzymatic processes and cell division. These findings are in agreement with the reports of Patel *et al.* (2016), Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5] and Singh *et al. (2014)* [6], who reported that nitrogen nutrition influenced green pod weight in cluster bean.

Interaction effect (S × N)

The pod length response to the spacing and nitrogen combination was significant at pod length. The highest value for pod length (6.93 cm) was recorded in S_1N_3, whereas the lowest for pod length (6.21 cm) was recorded in S_3N_2. The observed interaction may reflect the combined influence of crop geometry and nitrogen availability on vegetative growth, photosynthesis and assimilate production. These findings are in agreement with the reports of Patel *et al.* (2016), Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5] and Singh *et al. (2014)* [6].

At green pod weight, the interaction between spacing and nitrogen was significant for green pod weight. The highest value for green pod weight (1.07 g) was recorded in S_1N_2 and S_1N_3 which was at par with S_1N_1 (1.05 g) and S_2N_3 (1.05 g) whereas the lowest for green pod weight (0.94 g) was recorded in S_3N_1. As the S_1 spacing and higher nitrogen supply might have been the higher green pod weight. The interaction response may be attributed to the combined influence of crop geometry and nitrogen availability on vegetative growth, photosynthesis and assimilate production. Similar responses to spacing and nitrogen nutrition, which provide a basis for the observed treatment combination effects, have been reported by Patel *et al.* (2016), Rathore *et al.* (2007) [4], Vasava *et al.* (2020) [5] and Singh *et al.* (2014) [6].

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Table 1. (a): **Response of spacing and nitrogen levels on plant height of cluster bean**

Plant height (cm)																
Treatment	**30 DAS**				**60 DAS**				**90 DAS**				**120 DAS**			
	Nitrogen Level (N)				**Nitrogen Level (N)**				**Nitrogen Level (N)**				**Nitrogen Level (N)**			
Spacing (*S*)	**N_1**	**N_2**	**N_3**	**Mean**	**N_1**	**N_2**	**N_3**	**Mean**	**N_1**	**N_2**	**N_3**	**Mean**	**N_1**	**N_2**	**N_3**	**Mean**
S_1	27.63	27.61	30.81	28.68	51.24	51.33	51.56	51.38	118.06	117.93	118.65	118.21	147.45	150.56	150.56	148.80
S_2	25.00	25.02	25.00	25.01	49.92	50.02	50.31	50.08	109.08	109.78	111.12	109.99	140.82	143.87	143.87	142.30
S_3	25.05	24.97	25.06	25.02	50.10	50.41	50.71	50.41	110.78	112.61	114.89	112.76	140.36	146.19	146.19	143.13
Mean	25.89	25.87	26.96	26.24	50.42	50.59	50.86	50.62	112.64	113.44	114.88	113.65	142.88	146.87	146.87	144.74
	Result	S.Em(±)	C.D at 5%		Result	S.Em(±)	C.D at 5%		Result	S.Em (±)	C.D at 5%		Result	S.E(±)	**C.D at 5%**	
S	SIG	0.61	2.12		SIG	0.19	0.67		SIG	1.21	4.18		SIG	1.02	3.53	
N	SIG	0.18	0.62		SIG	0.06	0.22		SIG	0.33	1.14		SIG	0.58	2.01	
S × N	SIG	0.53	1.63		SIG	0.04	0.12		SIG	0.44	1.37		SIG	0.40	1.24	

Table 1. (b): **Response of spacing and nitrogen levels on number of primary branches in cluster bean.**

Number of primary branches																
Treatment	**30 DAS**				**60 DAS**				**90 DAS**				**120 DAS**			
	Nitrogen Level (N)				**Nitrogen Level (N)**				**Nitrogen Level (N)**				**Nitrogen Level (N)**			
Spacing (*S*)	**N_1**	**N_2**	**N_3**	**Mean**	**N_1**	**N_2**	**N_3**	**Mean**	**N_1**	**N_2**	**N_3**	**Mean**	**N_1**	**N_2**	**N_3**	**Mean**
S_1	0.26	0.41	0.81	0.49	0.62	1.37	0.98	0.98	1.00	1.31	1.79	1.37	1.31	2.51	2.51	1.91
S_2	0.81	1.81	1.91	1.51	1.47	2.67	2.20	2.20	1.69	2.79	2.79	2.42	2.61	4.03	4.03	3.55
S_3	1.61	2.61	3.21	2.48	2.37	3.92	3.18	3.18	2.63	3.37	4.58	3.53	4.06	5.42	5.42	4.76
Mean	0.89	1.61	1.98	1.49	1.48	2.23	2.65	2.12	1.77	2.49	3.05	2.44	2.66	3.98	3.98	3.40
	Result	S.Em(±)	C.D at 5%		Result	S.Em(±)	C.D at 5%		Result	S.Em (±)	C.D at 5%		Result	S.E(±)	C.D at 5%	
S	SIG	0.29	0.99		SIG	0.32	1.10		SIG	0.31	1.08		SIG	0.41	1.43	
N	SIG	0.16	0.55		SIG	0.17	0.59		SIG	0.19	0.64		SIG	0.20	0.68	
S × N	SIG	0.15	0.48		SIG	0.19	0.36		SIG	0.19	0.59		SIG	0.11	0.35	

Table 2. (a): **Response of spacing and nitrogen levels on number of pickings in cluster bean.**

Treatments	**Number of pickings**			
	Nitrogen Level (N)			
Spacing (*S*)	N_1	N_2	N_3	Mean
S_1	8.79	9.58	9.69	9.35
S_2	9.58	9.64	9.45	9.56
S_3	8.42	9.39	9.58	9.13
Mean	8.93	9.54	9.57	9.35
	Result	S.E(±)	C.D at 5%	
S	SIG	0.06	0.21	
N	SIG	0.10	0.36	
S × N	SIG	0.18	0.54	

(continued on next page)

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Table 2. (b): **Response of spacing and nitrogen levels on pod yield per plant in cluster bean.**

Treatments	Pod yield plant^{-1} (gm)			
	Nitrogen Level (N)			
Spacing (*S*)	N_1	N_2	N_3	Mean
S_1	146.90	159.81	169.39	158.70
S_2	156.87	163.12	169.60	163.20
S_3	141.82	148.65	155.86	148.78
Mean	148.53	157.19	164.95	156.89
	Result	S.E(±)	C.D at 5%	
S	SIG	2.13	7.37	
N	SIG	2.37	8.20	
S × N	SIG	1.36	4.19	

Table 2. (c): **Response of spacing and nitrogen levels on pod yield per ha. in cluster bean.**

Treatments	Pod yield ha^{-1} (t)			
	Nitrogen Level (N)			
Spacing (*S*)	N_1	N_2	N_3	Mean
S_1	19.59	21.31	22.58	21.16
S_2	10.46	10.87	11.31	10.88
S_3	6.30	6.61	6.93	6.61
Mean	12.12	12.93	13.61	12.88
	Result	S.E(±)	C.D at 5%	
S	SIG	2.16	7.47	
N	SIG	0.22	0.75	
S × N	SIG	0.33	1.02	

Table 3. (a): **Response of spacing and nitrogen levels on length of pod in cluster bean.**

Treatments	Length of pod (cm)			
	Nitrogen Level (N)			
Spacing (*S*)	N_1	N_2	N_3	Mean
S_1	6.52	6.76	6.93	6.74
S_2	6.30	6.35	6.53	6.39
S_3	6.27	6.21	6.40	6.29
Mean	6.36	6.44	6.62	6.47
	Result	S.E(±)	C.D at 5%	
S	SIG	0.07	0.23	
N	SIG	0.04	0.13	
S × N	SIG	0.04	0.13	

Table 3. (b): **Response of spacing and nitrogen levels on weight of green pod in cluster bean.**

Treatments	Pod weight (g)			
	Nitrogen Level (N)			
Spacing (*S*)	N_1	N_2	N_3	Mean
S_1	1.05	1.07	1.07	1.07
S_2	0.98	1.01	1.05	1.01
S_3	0.94	0.98	1.02	0.98
Mean	0.99	1.02	1.05	1.02
	Result	S.E(±)	C.D at 5%	
S	SIG	0.01	0.04	
N	SIG	0.01	0.03	
S × N	SIG	0.01	0.02	

Conclusion

The present investigation it was evident that, among the different spacing treatments evaluated, the interaction between spacing and nitrogen levels exhibited that the response of the crop significantly varied with the combination of plant geometry i.e. spacing and nitrogen

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supply. The treatment S_2N_3 recorded the highest pod yield per plant (169.60 g), whereas S_1N_3 recorded the highest pod yield per hectare (22.58 t ha^{-1}). The treatment combination S_1N_3 (50 × 15 cm spacing + 10 t FYM ha^{-1} + 90:60:60 kg NPK ha^{-1}) also recorded the highest B:C ratio (2.90). Then it can be concluded that for higher yield and more economic benefit the cluster bean should be planted at spacing of 50 × 15 cm and fertilizer dose of 10 t + 90:60:60 kg NPK ha^{-1} be applied during *rabi-summer* season under the agro-climatic conditions of the Konkan region.

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