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Effect of plant densities on the growth, yield and quality parameters of Asparagus (*Asparagus densiflorus* 'Sprengeri' L.) under shade house conditions

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Abstract
A study was conducted on the effect of different planting densities on the growth, yield and quality parameters in asparagus (*Asparagus densiflorus* 'Sprengeri' L.) at the department of Floriculture and Landscape Architecture, Kittur Rani Channamma College of Horticulture, Arabhavi during 2022 under shade house conditions. The experiment was laid out in Factorial Randomized Block Design (FRBD) with three replications. The results revealed that planting density have significant effect at different stages of crop growth. Among the different spacing levels, 30 cm × 30 cm gives better result with respect to plant height (33.42 cm), internodal length (2.15 cm), cladophyll length (45.9 cm), leaf area (1634.95 cm^2), days to first harvest (169.75 days). While the number of cladophylls per plant (60.89), number of branches per cladophyll (31.84), cladophyll fresh weight (28.87g), vase life (9.47 days) and chlorophyll content (34.94 SPAD) was higher for 45 cm × 30 cm. Thus, the higher planting density resulted in better overall vegetative growth and enhanced yield as compared to the lower plant densities.

Keywords: *Asparagus densiflorus*, Sprengeri, planting density, cladophylls

Introduction
Asparagus is considered a highly valued florist's green and serve as an excellent filler material due to its graceful symmetry and lush green foliage. *Asparagus densiflorus* 'Sprengeri' also known as Sprenger asparagus, Basket asparagus, or Ground asparagus is a perennial monocot herb (Chase *et al*., 2009) [5]. Aerial stems are tough, green, and well-branched with spines. Leaf-like cladodes make up the leaves of the plant and emerge from the stem usually in groups of four or more. Small clusters of flowers occur in axillary racemes, which may be white or pinkish-white. It bears small round fruits called berries having a black seed of 3 mm in diameter. The root system is made up of a mat of fibrous roots with bulbous tubers. Propagation is done sexually through seeds and vegetatively by its underground creeping stems (*i.e.*, rhizomes) and also by the division of tubers.

Sprenger asparagus is a hardy plant that can thrive well in moisture-deficit soil and is considered fairly drought-tolerant. However, it can also perform very well in well-watered and organic-rich soil. It is also shade-loving and grows well under shade (Gilman, 1999) [7]. Therefore, this foliage plant can be successfully grown without the supply of large inputs. Year-round production, low investment and lesser risk make it a desirable crop for exploitation (Patil *et al.*, 2020) [13]. Sprenger asparagus is most commonly used as a filler in floral arrangements. Its fine and wispy foliage is highly preferred for creating textural contrast with flowers as well as other medium textured to coarse-textured foliage. Besides this, it is also popularly grown as potted plants for both indoor and outdoor use.

The major problem of production in asparagus is the reduction in the quality. The optimum planting density is a crucial practice for ensuring enhanced crop quality and achieving high productivity per unit area of cultivation (Khalaj and Edrisi, 2012) [9]. Proper spacing provides sufficient sunlight, conserves soil moisture, controls weeds and increases nutrients availability, resulting in enhanced quality cut foliage production (Sanjib and Talukdar, 2002) [14]. Therefore, the work was carried out with the main objective to study the effect of different plant densities on the growth, yield and quality parameters of asparagus.

Materials and Methods

The experimental study was carried out under a green shade house (50% shade level) at the Department of Floriculture and Landscape Architecture, Kittur Rani Channamma College of Horticulture, Arabhavi, University of Horticultural Sciences, Bagalkot, Karnataka.

The experiment was laid out in factorial randomized block design (FRBD) with three levels of spacing i.e. 30 cm × 30 cm (S_1), 30 cm × 45 cm (S_2) and 45 cm × 45 cm (S_3). One month old seedlings were planted during March 2022 on raised beds of 30 cm in height covered with plastic mulching sheet of 25µ. The experimental plot was divided into 45 plots each measuring 2 m × 1m with a 0.4 m spacing in between each plot. The observations were recorded at 180 days after planting.

Results and Discussion

The present investigation shows that spacing significantly affects the different growth parameters under study such as plant height, plant spread, number of cladophylls per plant, number of branches per cladophyll and internodal length throughout the crop growth stages.

The height of the plant increases with the increase in planting density. Closer spacing S_1 (30 cm × 30 cm) resulted in taller plants (33.2 cm) as compared to wider spacing. This increase in plant height attributed to closer spacing could be the resultant effect of intra-competition between the plants for light and aeration, along with moisture and nutrient sources which lead to elongation of the stem. Similar observations had been made in the previous works done on *Monstera deliciosa* by Darwesh *et al.* (2011) [5], in Boston fern by Singh and Dubey (2014) [15] and in the related crop *Asparagus cochinchinensis* (Kim *et al.*, 2010) [10].

On the other hand, a linear increase was observed in the plant spread. The minimum plant spread was obtained from closer spacing S_1 (30 cm × 30 cm) which gradually increases with the decrease in planting density with the maximum (2420.91 cm^2) in wider spacing S_3 (45 cm × 45 cm). The reason for such growth may be because, the individual plant has more space to derive sufficient light, air, soil, water and nutrition in wider spacing, enabling them to utilize more resources for better growth as compared to closer spacing. This finding was in line with the work done on chrysanthemum by Kumar *et al.* (2019) [11].

Other growth parameters like the number of cladophylls per plant (60.89) and number of branches per cladophyll (31.84) showed the best result with wider spacing S_2 (45 cm × 30 cm) as compared to closer spacing (30 cm × 30 cm). The plants in wider spacing have less competition thus the availability of resources is more which causes more lateral growth. Therefore, there is an increase in the number of cladophylls per plant as well as the number of branches. The previous research work carried out on Boston fern by Singh and Dubey (2014) [15] showed similar results. Sudhagar *et al.* (2019) [17] also reported similar results in tuberose.

However, the internodal length observed in the present investigation shows that higher planting density (30 cm x 30 cm) results in a longer internodal length (2.15 cm). This is because there is higher competition between the crop in closer spacing which results in the elongation of the stem thereby internodal length also increases (Ford, 2014) [6].

Table 1: Growth parameters of *Asparagus densiflorus* 'Sprengeri' as influenced by different levels of spacing

Spacing levels (cm)	Plant height (cm)	Plant spread (cm^2)	Number of cladophylls per plant	Number of branches per cladophyll	Internodal length (cm)
S_1: 30 × 30	33.42	1769.66	57.71	29.44	2.15
S_2: 45 × 30	31.12	2196.59	60.89	31.84	1.99
S_3: 45 × 45	28.51	2420.91	52.33	27.18	1.97
S.Em±	0.15	22.25	0.35	0.32	0.03
C.D. @ 1%	0.57	86.95	1.38	1.27	0.13

The cladophyll length of the crop was found to be the highest (45.9 cm) under higher planting density (S_1 = 30 cm × 30 cm) as compared to lower planting density (Fig. 3). This finding complies with the result of the earlier work by Singh *et al.* (2017) [16] on *Ruscus hypophyllum* who stated that high planting density has positive effects on the leaf length (cladodes in Asparagus). However, the cladophyll breadth was observed to be bigger in wider spacing S_3 (13.35 cm) this may be due to less competition which promoted lateral growth of the crop. Similar finding was reported by Darwesh *et al.* (2011) [5] in *Monstera deliciosa.*

Cladophyll fresh weight shows significant differences with respect to spacing. Maximum fresh weight (28.87 g) was observed in wider spacing S_2 (45 cm × 30 cm) as compared to closer spacing. But on increasing the spacing, the weight reduces. This may attribute to the fact that a higher number of cladophyll production per plant was obtained in S_2 and similarly decreases with a further increase in spacing. This finding is similar to the result reported in Boston fern by Singh and Dubey (2014) [15].

The leaf area is a measure of the productivity of the leaves for adequate photosynthesis to obtain a healthy and productive plant. In closer spacing S_1 (30 cm × 30 cm), the leaf area of cut cladophyll was found to be higher (1634.95 cm^2), and it gradually declines as the plant spacing increases. This may be due to the leaf (cladophyll) size being larger than that of wider spacing. A similar increase in leaf area under closer spacing was reported in heliconia by Aklade *et al.* (2016) [2] and in lilium by Amjad and Ahmad (2012) [3].

The influence of spacing on the vase life of cut cladophyll was non-significant. A similar result was reported by Marino *et al.* (2003) [12] in *Asparagus plumosus* and *Asparagus densiflorus* cv. 'Myriocladus'.

Table 2: Quality parameters of *Asparagus densiflorus* 'Sprengeri' as influenced by different levels of spacing

Spacing levels (cm)	Cladophyll length (cm)	Cladophyll breadth (cm)	Cladophyll stalk length (cm)	Cladophyll stalk girth (mm)	Cladophyll fresh weight (g)	Leaf Area (cm^2)	Vase life (Days)
S_1: 30 × 30	45.9	12.41	7.62	1.85	26.69	1634.95	9.07
S_2: 45 × 30	45.87	12.63	7.26	1.94	28.87	1632.75	9.47
S_3: 45 × 45	43.85	13.35	7.17	2.09	24.34	1380.36	8.53
S.Em±	0.23	0.13	0.08	0.03	0.38	11.16	0.35
C.D. @ 1%	0.91	0.49	0.33	0.10	1.49	43.59	NS

Cladophyll is the economic part in asparagus 'Sprengeri' that is used as cut foliage in flower arrangements bouquets, etc. In the present investigation, the cladophyll properties are observed to have a close relationship with spacing. Closer spacing S_1 was observed to take minimum days for the first harvest (169.75 days) of cut cladophylls as compared to wider spacing. This may be because the cladophylls arising from the higher planting density are longer in length and acquire the ideal length for harvest faster than lower planting density. Lesser days taken for first harvest under closer spacing were also reported by Ahmad *et al.* (2019) [1] in lilium and tuberose.

The number of cut cladophylls obtained per plant and m^2 was observed and found to vary significantly with spacing. The number of cut cladophyll per plant (9.33) was highest in S_2 (45 cm × 30 cm) while the lowest was in close spacing S_1 (30 cm × 30 cm). On the contrary, a higher number of cut cladophyll per m^2 (88.88) was observed in the closer spacing S_1 as compared to wider spacing. This can be attributed to more plant population accommodated per m^2 under the closer spacing.

The same trend as the above observation was seen regarding the weight of cut cladophyll per plant and m^2 concerning spacing treatments. The highest cladophyll weight per plant (51.82 g) was observed in S_2 (45 cm × 30 cm) whereas the maximum per m^2 cladophyll weight (514.16 g) was observed in closer spacing S_1. Similar findings for the number and weight of cut cladophyll per plant and per m^2 were reported by Marino *et al.* (2003) [12] in *Asparagus plumosus* and *Asparagus densiflorus* cv. 'Myriocladus'.

Table 3: Yield parameters of *Asparagus densiflorus* 'Sprengeri' as influenced by different levels of spacing

Spacing levels (cm)	Days to first harvest	Number of cut cladophyll		Weight of cut cladophyll (g)	
		per plant	per m^2	per plant	per m^2
S_1: 30 × 30	169.75	8.00	88.88	46.28	514.16
S_2: 45 × 30	176.17	9.33	69.12	51.82	383.99
S_3: 45 × 45	178.85	8.09	39.98	40.45	199.81
S.Em±	1.94	0.29	2.42	1.34	12.01
C.D. @ 1%	7.57	1.14	9.44	5.24	46.93

The biochemical content of the crop was affected by different spacing levels which in turn resulted in the optimum growth of the crop. The chlorophyll content in leaves determines the ability of the leaves to produce assimilates through the process of photosynthesis. The present investigation reveals that chlorophyll content in the cladophyll was significantly influenced by spacing with maximum content (34.94 SPAD reading) obtained in the spacing S_2 (45 cm × 30 cm) followed by S_1 (30 cm × 30 cm) but decreases when the spacing further increased. Higher chlorophyll content obtained in more plant density may be because of mutual shading. The results obtained are in line with the previous studies in *Asparagus plumosus* and *Asparagus densiflorus* cv. 'Myriocladus' by Marino *et al.* (2003) [12], in boston fern by Singh and Dubey (2014) [15] and in flower crops like lilium by Amjad and Ahmad (2012) [3], in carnation by Karthikeyan and Jawaharlal (2013) [8].

Table 4: Chlorophyll content (SPAD reading) and nutrient composition (%) of leaf samples of *Asparagus densiflorus* 'Sprengeri' as influenced by different levels of spacing

Spacing levels (cm)	Chlorophyll content (SPAD)	Nitrogen		Phosphorus		Potassium	
		30 DAP	180 DAP	30 DAP	180 DAP	30 DAP	180 DAP
S_1: 30 × 30	31.94	1.12	1.72	0.21	0.43	0.56	0.84
S_2: 45 × 30	34.94	1.14	2.22	0.24	0.43	0.54	0.91
S_3: 45 × 45	28.08	1.31	2.49	0.23	0.47	0.65	1.03
S.Em±	0.70	0.04	0.04	0.01	0.01	0.03	0.04
C.D. @ 1%	2.75	0.14	0.17	NS	NS	NS	NS

*NS = Non-significant

However, regarding the nutrient content in the cladophyll, spacing does not have a significant effect on the phosphorus and potassium content but the nitrogen content was higher (2.49%) in the wider spacing S_3 (45 cm × 45 cm) as compared to the closer spacing as the plant population is lower and more nutrients are available. Similar results are reported in cut foliage boston fern by Singh and Dubey (2014) [15].

Conclusion

Higher planting density (30 cm × 30 cm) resulted in better overall vegetative growth and enhanced yield as compared to the lower plant densities. The lower planting density (45 cm × 30 cm) obtained longer vase life and cut cladophyll yield per plant yet the maximum yield obtained per m^2 is under the spacing 30 cm × 30 cm. Therefore, high planting density of 30 cm × 30 cm is recommended for *Asparagus densiflorus*

'Sprengeri' for production of quality cut cladophylls with enhanced yield per unit area.

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