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EFFECT OF PLANTING DISTANCE ON GROWTH AND FROND PRODUCTION IN BOSTON FERN [*Nephrolepis exaltata* (L.) Schott]

Parminder Singh and R.K. Dubey

Department of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana 141 004, Punjab.
**E-mail:parminder.flori@pau.edu*

ABSTRACT : Studies were conducted to optimize planting distance for frond production in Boston fern [*Nephrolepis exaltata* (L.) *Schott*]. The suckers were planted at a spacing of 30 x 30 cm, 30 x 45 cm, 45 x 45 cm, 45 x 60 cm and 60 x 60 cm, in the month of March, 2012 under net house conditions which provided 50 per cent shading. Planting density had significant effect on plant spread, frond length, mean lamina length and leaf area. Increase in planting density (30 x 30 cm) led to increase in frond production per unit area but with regard to the production per plant, it was at par in all the spacings where row to row distance was 45 cm i.e. 45 x 30 cm, 45 x 45 cm and 45 x 60 cm. Number of fronds per plant increased as the plants were widely spaced, highest being recorded at 60 x 60 cm. The fronds produced from wider spaced plants were of superior quality in terms of length and strength of the stem. Quality parameters, *viz.* length of longest frond as well as fresh and dry weights of fronds was observed to be higher with closer spacing. Frond production per plot and yield per hectare exhibited significant increase with decreasing plant spacing. Planting density did not affect longevity of the fronds. Considering the yield of fronds per hectare, cost of production and net return, 30 x 45 cm spacing is recommended for the cultivation of Boston fern.

Keywords : *Nephrolepis exaltata, planting distance, frond production.*

Cut greens are an important component of floricultural industry, largely used as fillers in bouquet making and in flower arrangements. Cut foliage is either used alone in large quantities as a source of decoration or in association with flowers and other accessories for value addition. In general, the foliage that is deep green with long lasting evergreen properties is commonly used by the floral industry as accents in floral arrangements (Schlosser and Blatner, 21). There has been a tremendous increase in the volume and usage of cut foliage in the ornamental industry. The trade of foliage indicates that India has emerged as the top most supplier among the developing countries and has been successful in developing a sustainable market in the EU (Ladha and Gunjal, 13).

Leaves of several ferns are used as cut foliage. Commercially important species are *Rumohra adiantiformis* (leather leaf fern), giant holly fern (*Polystichum munitum*) and *Nephrolepis exaltata* L. Schott (flat fern) commonly called as Boston fern (Carow, 5). Besides, ferns are an attractive addition to the landscape of any home, office or garden because of their graceful foliage, growth habit and ability to grow in low light (Pacifici *et al.,* 18). The foliage of fern is highly valued in the international florist greenery market because of its long post harvest life, low cost, year-round availability and versatile design qualities in form, texture and color (D'Souza *et al.,* 7; Muthukumar and Prabha, 17).

Amongst various ferns used by the florists, cut foliage of *Nephrolepis species* remains in great use for the floral decorations that are characterized by their attractive form, colour, freshness and long shelf life in flower arrangements. Different varieties of this species can be grown in Punjab but due to fluctuating environment, plant growth and production of cut foliage has been observed to be erratic. Proper planting distance is an important practice for providing good open position for sunlight, availability of moisture and nutrients vital for successful crop production and quality (Khajal and Edrisi, 11). Planting density plays an important role in achieving high productivity per unit area. Total and early marketable yield increased linearly as plant density increased (Khajal *et al.,* 12). Since there is hardly any data available in India regarding the production technology of ferns and their vase life, studies were planned to work out an optimum planting distance for the production of quality fronds in Boston fern (*Nephrolepis exaltata*) under 50% shade and its effect on the post harvest performance of the fronds under sub-tropical climatic conditions of Punjab.

MATERIALS AND METHODS

.The experiment was conducted at the research farm of the Department of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana,

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India during the two successive years of 2012-13 and 2013-14. Chemical and physical characteristic of the soil at the experimental site showed that the farm soil was loamy sand in texture with pH of 8.30. The available organic carbon, phosphorus and potassium was 0.69kg/ha, 18.4 kg/ha and 237 kg/ha, respectively. The experiment was laid out in a Randomized Complete Block Design with five replications and five planting densities i.e. 30 x 30 cm, 30 x 45 cm, 45 x 45 cm, 45 x 60 cm and 60 x 60 cm. The nutrient content of farmyard manure used in the experiment in the 2012-13 experiment was 0.43% N, 0.18% P_2O_5 and 0.42% K_2O, whereas in the 2013-14 was 0.48% N, 0.21% P_2O_5 and 0.40% K_2O, respectively. The plants of Boston fern (*Nephrolepis exaltata* L. Schott) were planted in the plots measuring 3.60 x 1.80 m in the first fortnight of March under 50% shade. The basal dose of farmyard manure at 25 tones per ha per treatment was added and well mixed in the soil a week prior to the planting. The beds were watered and left for one week before the planting to enable carbon dioxide to escape to prevent burning and scorching of the tender plants. Nitrogen at 250 Kg per ha was applied in four equal split doses, i.e., one-fourth at the time of planting and remaining at quarterly intervals *i.e.* in March, June, September and December. The crop was irrigated depending on the moisture status of the soil and requirement of plants. Fronds were cut 1 cm above the ground level. Growth and yield parameters (plant height, spread, average length of fronds, length of longest frond, mean lamina length, leaf area index, number of fronds per plant and chlorophyll content) were recorded in the months of March, June, September and December. A set of 10 fronds per treatment was used to record fresh and dry weight of fronds. The leaves from each treatment were dried at 60°C to constant weight, ground, powdered and analyzed for nitrogen, phosphorous and potassium contents. Nitrogen was analyzed by Kjeldahl's method using semi auto analyzer nitrogen estimation system (M/S Pelican Equipment, Chennai). For estimating P and K, 0.50 g of samples was wet digested using concentrated nitric acid and perchloric acid (4:1 v/v). Phosphorous content of samples was determined by vanadate-molybdate colorimetric method (Analyst 200, Perkin Elmer, Shelton, CT, USA). Leaf potash was determined by the Flame Photometer method (AOAC, 1). All the nutrient contents were expressed on dry matter basis. The total leaf area of the fronds was recorded using CI- 203 portable leaf area meter. The chlorophyll content of the leaf was determined in form of SPAD values with a portable chlorophyll meter (supplied by M/S Minolta SPAD 502 type) from the basal three leaves. Postharvest studies were carried out on cut fronds harvested during the months of March, June, September and December. Foliage were harvested at the commercial stage. Immediately after harvest, cut foliage was transferred to the postharvest evaluation laboratory with a temperature of 20±2°C, 60±5% RH and 12 h light of 10 µmol m^{-2} s^{-1} PAR. Observations were recorded for vase life (till the fronds began to show the first sign of yellowing) and water uptake in ml at the end of vase life. Three randomly selected plants were used in each replication and treatment for observations. The results presented a mean of four quarters (March, June, September and December) for both the years (2012-13 and 2013-14). The data were statistically analyzed with the procedure described by Cheema and Singh (6) in statistical package CPCS-1 for significant differences between treatments.

RESULTS AND DISCUSSION

Effect of spacing on growth parameters

The results presented in Table 1 show that the mean plant height increased with increase in planting density and maximum plant height was attained at 30 x 30 cm during the two years. The variations in plant height were statistically non-significant. The height was the minimum at wider spacing of 60 x 60 cm during both the two years, respectively. The increased plant height under maximum planting density could be ascribed to intra plant competition for light, moisture, space, nutrients and aeration. Similar observation had also been reported in gaillardia (Hugar, 8), chrysanthemum (Karavadia and Dhaduk, 9) and tuberose (Mane *et al.,* 14). Modawei (16) also reported that increasing of plant spacing decreased plant height of different flowering annuals. Closer spacing enhanced the plant height significantly whereas wider spacing increased the other growth parameters including chlorophyll content in leaves (Ahirwar *et al.,*2).

Plant spread differed significantly under different spacing levels (Table 1). It increased with increase in planting distance and maximum plant spread was recorded in plants of the widest spacing (60x60 cm) during both the years, respectively and was significantly at par with 45 x 45 cm and 45 x 60 cm spacing. The lowest plant spread was recorded from the closest spacing of 30 x 30 cm during both the years, respectively. The beneficial effect of wider spacing on plant spread, leaf length and number of leaves has also been reported by Karavadia and Dhaduk (9) in

Table 1 : Effect of planting distance on growth parameters under 50% shade level in Boston fern {*Nephrolepis exaltata* (L.) Schott}.

Planting distance	Plant height (cm)		Plant spread (cm)		Growth index		Average frond length (cm)	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
30 x 30	36.40	40.13	29.33	30.27	32.86	35.22	35.80	38.87
30 x 45	35.70	39.87	30.91	32.23	33.31	36.05	36.79	39.07
45 x 45	35.63	39.33	31.65	35.33	33.64	37.33	35.11	39.47
45 x 60	34.22	38.71	32.18	36.97	33.19	38.22	29.72	40.00
60 x 60	34.00	36.40	32.92	37.07	33.46	36.73	32.55	36.40
Mean	35.11	38.69	31.40	34.17	32.89	36.33	33.99	38.76
CD(P=0.05)	NS	2.60	NS	3.75	NS	2.30	4.86	NS

Table 2: Effect of planting distance on growth and yield parameters under 50% shade level in Boston fern {*Nephrolepis exaltata* (L.) Schott}.

Planting distance	Length of longest frond (cm)		Mean lamina length (cm)		Leaf area (cm^2)		Number of fronds	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
30 x 30	39.40	40.73	32.27	34.31	203.39	199.67	58.00	54.20
30 x 45	38.18	40.20	33.64	34.80	295.66	258.05	68.27	60.47
45 x 45	36.58	43.40	32.32	35.30	270.03	246.77	70.47	61.67
45 x 60	33.40	42.73	27.40	35.33	199.67	207.89	69.53	63.87
60 x 60	35.70	36.53	28.76	30.70	217.85	202.04	73.27	68.33
Mean	36.65	40.72	30.88	34.09	237.32	222.88	67.91	61.71
CD(P=0.05)	4.01	4.62	4.26	NS	54.81	21.62	NS	NS

chrysanthemum, Khalaj *et al* (12) in tuberose and Ram *et al.* (19) in gladiolus.

Similar trend was observed with regard to the growth index. The growth index continues to increase with increasing planting distance. The maximum growth index was observed at 45 x 45 cm spacing in both the years, respectively. The average frond length also differed significantly with the planting distance and was the maximum at the spacing of 30 x 45 cm in 2012-13 and at 45 x 60 cm in 2013-14 (Table 1). The plant spacing was found to significantly influence length of the longest fronds. Length of the longest fronds was the maximum at 30 x 30 cm in 2012-13, whereas in 2013-14 the maximum length was observed at 45 x 45 cm (Table 2). Similar trends were observed for mean lamina length.

Leaf area also differed significantly at different spacing levels (Table 2). The maximum leaf area was observed at a spacing of 30 x 45 cm during both the years. Leaf area was the minimum in closer planting of 30 x 30 cm during both the years, respectively and could be ascribed to lesser penetration of light and increased competition among the plants for nutrients and water. Similar results were obtained by Akparobi (3) in *Amaranthus cruentus.*

Planting distance had no significant effect on the number of leaves produced (Table 2). However, the average number of leaves produced per plant increased with increasing planting distance. The wider spacing produced more leaves per plant relative to plants of the closer spacing throughout the study period. The frond production per plant was the maximum at 60 x 60 cm during both the years but was statistically at par under all the other planting densities. The minimum number of leaves per plant was recorded from 30 x 30 cm plant spacing. Considering the planting density per unit area, it was observed that closer plantation of 30 x 30 cm exhibited the maximum frond production per unit area and was hence, inversely related to the plant spacing. The higher yield of fronds in closer spacing was mainly contributed by

Table 3 : Effect of planting distance on fresh/dry weight, chlorophyll content and vase life of fronds under 50% shade level in Boston fern {*Nephrolepis exaltata* (L.) Schott}.

Planting distance	Fresh weight of fronds (g)		Dry weight of fronds (g)		Chlorophyll content		Vase life (days)	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
30 x 30	13.90	16.52	4.14	5.44	28.76	40.22	15.92	18.08
30 x 45	15.06	17.00	4.73	5.57	29.18	41.38	16.73	19.12
45 x 45	13.94	16.16	4.13	5.67	29.04	43.07	14.65	20.16
45 x 60	13.23	14.38	4.04	5.48	28.91	39.21	13.96	18.80
60 x 60	11.38	13.00	3.18	3.71	27.39	28.21	13.83	15.43
Mean	13.50	15.41	4.04	5.17	28.66	38.42	15.02	18.32
CD (P=0.05)	NS	NS	NS	NS	NS	7.65	NS	NS

Table 4 : Effect of planting distance on total N, P and K uptake of fronds under 50% shade level in Boston fern {*Nephrolepis exaltata* (L.) Schott}.

Planting distance	Water absorbed (ml)		Available N (%)		Available P (%)		Available K (%)	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
30 x 30	12.28	8.80	1.47	1.61	0.14	0.13	1.23	1.48
30 x 45	13.20	11.53	1.50	1.63	0.14	0.13	1.19	1.53
45 x 45	13.20	11.2	1.56	1.68	0.16	0.15	1.11	1.39
45 x 60	12.20	9.20	1.66	1.74	0.13	0.14	1.50	1.35
60 x 60	11.00	8.13	1.53	1.73	0.13	0.16	1.12	1.47
Mean	12.38	9.77	1.54	1.68	0.14	0.14	1.23	1.44
CD (P=0.05)	NS	NS	0.11	NS	NS	NS	NS	NS

the higher plant population per unit area. However, decrease in inter or intra plant competition under wider spacing resulted in an increased number of fronds per plant. Marino *et al.* (15) also observed that the higher planting density in *Asparagus plumosus* and *Asparagus densiflorus* increased the number of stems.

Similarly Al-Kiyyam *et al.* (4) reported that the higher plant densities resulted in significant increase in fresh weight of branches, number of leaves and fresh weight of leaves produced per unit area in marjoram, a perennial herb.

The fresh weight of the fronds did not vary significantly in different planting densities and ranged from 11.00 to 15.06 g in 2012-13 and 13.00 to 17.00 g in 2013-14 (Table 3). The maximum fresh weight of fronds was recorded in the closer spacing of 30 x 45 cm during both the years. Marino *et al.* (15) observed that the higher planting density in *Asparagus plumosus* and *Asparagus densiflorus* increased total fresh weight in both the species. Similar trend was observed for dry weight of the fronds.

There was no significant effect of plant distance on chlorophyll content of leaves in 2012-13, whereas, the content was significantly higher at closer planting of Boston fern during 2013-14 (Table 3). The SPAD value indicating chlorophyll content was observed to be maximum at a spacing of 30 x 45 cm in 2012-13 and at 45 x 45 cm in 2013-14. The higher chlorophyll content found in the fronds of *Asparagus* planted at closer planting was suggested to be due to mutual shading (Marino, *et al.,* 15). Higher chlorophyll content in carnation planted at closer spacing (Karthikeyan and Jawahar, 10) also supports to the present findings. The effect of shading on chlorophyll content is, however, reported to vary in different species as observed in several woody cut foliage crops (Stamps, 22).

Vase life

Cut fronds did not show significant differences in vase life with respect to the planting distance. Longevity of the fronds ranged from 13.83 days to 16.73 days in 2012-13 and 15.43 days to 20.16 days in 2013-14 (Table 3). Marino *et al.* (15) observed that cut

Asparagus foliage did not show any significant differences in vase life regardless of planting density. However, closer planting density has been reported to decrease vase life of different flowering annuals (Ahirwar *et al.*, 2; Modawei, 16). In contrast, vase life of tuberose (Mane *et al.,* 14) and gladiolus (Sanjib *et al.,* 20) is reported to increase with an increase of plant spacing.

Planting distance did not significantly affect water absorption by the fronds (Table 4). Similar observations were recorded by Marino *et al.* (16), who reported that water uptake did not differ between cut foliage of *Asparagus* harvested from the two planting densities.

Available NPK

Planting distance had no significant effect on the available of P and K (Table 4). However, the availability of N was higher at wider spacing.

CONCLUSION

The studies revealed that in *Nephrolepis exaltata* L. Schott frond production per plant was higher at wider planting but total production per unit area was maximum with close planting. Higher chlorophyll content was found in the fronds at close planting. Vase life of the fronds of *N. exaltata* ranged between 13 and 20 days. Therefore, from the above results, 30 x 45 cm spacing was found to be the best for quality production of Boston fern under the sub-tropical conditions of Punjab.

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