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Effect of spacing and thinning on growth and flowering of *Alstroemeria hybrida* L.

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Abstract
Flower production of *Alstroemeria hybrida* (L.) cvs. Pluto and Alladin were evaluated to determine response to the different planting density and by thinning of vegetative shoots by pulling. The experiment comprised of two spacing (30 × 45 cm and 60 × 45 cm), three levels of thinning (0%, 25% and 50%) and two cvs. Pluto and Alladin constituting 12 treatment combinations replicated thrice in Split Plot Design under protected conditions. Wider spacing significantly improved vegetative and flowering characteristics. Cultivar Pluto and Alladin show significant difference in all the flowering parameters. Pluto was found to be better with days to flower bud formation (164.51), number of florets (2.88), duration of flowering flush (67.99 days), total number of flowering shoots (39.55), percent class-I flowering stems (87.49) and length of cymes of class-I flowering stems (19.90cm) while Alladin was ahead in number of cymes/inflorescence (4.41), diameter of primary floret (5.60cm), diameter of flowering shoot (9.33mm) and number of nodes on generative shoots (26.01). Interactive effect of spacing, variety and thinning indicates that with spacing of 60 × 45 cm and 25% thinning in cv. Pluto resulted in minimum days to flower bud formation (161.11), maximum number of florets/cyme (3.77), duration of flowering flush (71.40 days), number of flowering shoots (47.33) and percent class-I flowering stems (92.66) whereas maximum number of cymes/inflorescence (5.33), diameter of primary floret (5.83mm), diameter of flowering shoot (9.51mm) and number of nodes on generative shoots (28.77) was observed with spacing of 60 × 45 cm and 25% thinning in cv. Alladin.

Keywords: Spacing, thinning, growth, vegetative, *Alstroemeria hybrida* L.

Introduction
Alstroemeria hybrid L. (Huxley *et al*. 1992) [1] commonly known as the Peruvian Lily or the Lily of the Incas is a native of South America. The genus is a rhizomatous monocot and belongs to family Alstroemeriaceae (Baily, 1976) [2]. Previously, Alstroemeria was assigned to family Amaryllidaceae and Liliaceae (Stinson, 1942; Vonk Noordegraaf, 1981) [3, 4]. Alstroemeria plants are widely cultivated in many countries especially in Western Europe and North America and popularity has increased recently due to its long-vase life, large variety of colours and low energy requirement during cultivation (Sung-Soo *et al*. 2012) [5]. In Kenya in terms of popularity and foreign exchange Alstroemeria stands third after roses and statice (www.kenyarep-jp.com) [6]. The popularity of this flower is still growing and has attained the status of one of the ten most important cut flowers in the world.

In India, Alstroemeria was introduced in 2001 by Ministry of Agriculture, GOI, under Food and Agriculture Organization programme at three Model Floriculture Centres at Ooty (Tamil Nadu), Chial (Himachal Pradesh) and Srinagar (Jammu and Kashmir). The Crop was introduced in SKUAST-K, Shalimar in 2005-06 under ICAR sponsored Horticulture Mini Mission-I.

Alstroemeria is a perennial crop and plantings if properly managed can last and retain commercial viability for 4-6 years. In order to maximize crop life, management in terms of spacing and thinning during peak periods of crop growth is very important. Under Kashmir conditions work on nutritional management under poly house conditions has been done (Samoon, 2012) [7]. However, behaviour of the crop under varied canopy configurations in terms of spacing and thinning is yet to be evaluated under Kashmir conditions. There are conflicting reports regarding the efficacy of shoot thinning methods (Pull v/s cut) (Healy and Wilkins 1991; Bakken 2000) [8, 9]. The present investigation is proposed to be under taken with the objectives to enhance the flowering of Alstroemeria by optimizing planting density and thinning.

Materials and Methods

The present investigation entitled "Effect of spacing and thinning on growth and flowering of *Alstroemeria hybrida* L." was carried out during year 2016 and 2017-18 at the Experimental Field of the Division of Floriculture and Landscape Architecture, Sher-e-Kashmir University of Agriculture Sciences and Technology of Kashmir (SKUAST-K), Shalimar Campus, Srinagar. The crop was sown once in the month of April 2017 and remained under observation for 16 months. The treatment combinations were randomly assigned to plots. To avoid bias three plants assigned to each treatment combination were selected and tagged for recording observations. Rhizomes of Alstroemeria were divided, and uniform and healthy propagules were selected. Single rhizomes were planted under two spacing's of 30 × 45 cm and 60 × 45 cm as per the technical programme. Planting was done in April 2017. Immediately after planting watering was done and thereafter once or twice a week depending on moisture content in the soil. Shading was provided using 50% shade nets during the period of high light intensity and temperature (May-July) to prevent plants from getting damaged due to scorching heat. As per the technical programme 25% and 50% vegetative shoots were removed by the method of hand pulling twice each month up to the initiation of generative shoots. The observations were recorded on number of vegetative shoots removed/plant, fresh weight of shoots removed/plant, dry weight of shoots removed/plant, days to flower bud formation, diameter of primary floret, diameter of flowering shoots, duration of flowering flush, total number of flowering shoots/plant, percent class-I flowering stems, percent class-II flowering stems and length of cymes of class-I flowering stems. The statistical analysis was done at 5% level of significance.

Results and Discussion

The data Pertaining to vegetative parameters (Table 1) clearly indicated that the plants showed differential response towards changes in spacing and thinning of vegetative shoots. During statistical analysis of data pertaining to vegetative parameters the data of T_0 (No thinning) was not taken into consideration as all the values for T_0 were recorded zero as no shoots were removed from these plants. Perusal of data reveals higher number of shoots removed/plant (9.00) at 60 × 45 cm spacing as against an average of 5.66 shoots/plant removed from plants spaced at 30 × 45 cm. While number of shoots removed from cultivar Pluto (8.16/plant) was more than those removed from cultivars Alladin (6.50). However, the difference was statistically not significant. Significant differences in number of vegetative shoots removed per plant were observed under 50% (9.66) and 25% (5.00) thinning practice. The data reveals that fresh weight of shoots removed/plant was significantly higher (101.62 g) under wider spacing of 60 × 45 cm in comparison to 61.64 g removed per plant under 30 × 45 cm spacing. 50% thinning significantly improved fresh weight of vegetative shoots removed/plant (107.38g) as against 55.88g removed under 25% thinning. Differences in fresh weight of vegetative shoots removed/plant in variety Pluto 89.87 g and Alladin 73.39 g were not significant. Dry weight of shoots/plant removed under 60 × 45 cm spacing was 25.60 g in comparison to 15.53 g recorded under 30 × 45 cm spacing. Dry weight of shoots removed per plant increased significantly from 14.05 g under 25% thinning to 27.08 g under 50% thinning. Differences in total dry weight of shoots removed in two cultivars were not significant.

Alstroemeria is a geophyte with underground sympodial rhizome that grows at an angle to the ground surface. Usually commercial Alstroemeria plantings are retained for 4-6 years and hence provision for ample space for the growing rhizome has to be integrated into cultural practices in view of the long in situ duration of the crop. Being sympodial Alstroemeria rhizome tip ends either in a vegetative or generative above ground shoot and encourages lateral buds to develop into rhizomes underground. The underground rhizomes continue to develop/increase in length and branching if soil temperature remains below 15^0C. However, under Kashmir conditions soil temperature rises in summer thus slowing the branching and growth of rhizome. Thinning practices recommended in several studies by Mourne and Stomme (1980) [10], Aker and Healy (1990) [11] and Bakken (2000) [9] are thought to increase branching of underground rhizomes and number of generative shoots. In the current study also rhizomes planted at 60 × 45 cm sent out higher number of vegetative shoots which is also reflected in higher mean of thinned out fresh weight and subsequent dry weight of vegetative shoots. These results are in conformity with findings of Cireasa (1984) [12] in Alstroemeria and Jhon and Paul (1995) [13] in Chrysanthemum. Wider spacing encourages more branching of rhizomes, the latter being further enhanced with thinning. More underground branching is translated into more number of vegetative shoots aboveground and hence higher removal of biomass in terms of fresh and dry weight. Wilkins and Heins (1976) [14] was the earliest researcher to suggest benefits of thinning in Alstoemeria. He contended that majority of shoots emerging from rhizome are vegetative and hence should be removed.

The perusal of data presented in Table 2 indicated significant influence of spacing on days to flower bud formation. Plants spaced at 30 × 45 cm reached flower bud formation in 170.98 days in comparison to 169.57 days recorded in those spaced at 60 × 45 cm. Variety Pluto exhibited precocity of more than 12 days in flower bud development taking 164.51 days in comparison to 176.03 days in Alladin. Thinning significantly reduced the number of days to flowering with least of (167.88 days) recorded under 25% thinning regime followed by 169.99 and 172.94 days under 50% and no thinning regime respectively. Increment recorded in number of cymes/inflorescence under 60 × 45 cm spacing (4.31cymes/inflorescence) in comparison to 4.11 cymes under 30 × 45 cm spacing was statistically not significant. Cultivar Alladin recorded significantly higher average of cymes/inflorescence (4.41) as against 4.01 recorded in cv. Pluto. 25% thinning (5.09) significantly improved number of cymes/inflorescence in comparison to control (3.30) and 50% thinning (4.24). Significant differences in number of florets/cyme were recorded in two varieties. Cultivar Pluto on an average bore 2.88 florets/cyme in comparison to 2.46 recorded in cv. Alladin. Thinning significantly improved number of florets/cyme in comparison to control. Highest mean number of florets/cyme (3.27) was recorded under 25% thinning in comparison to 2.72 and 2.03 florets/cyme recorded under 50% and no thinning regimes respectively. Plants spaced at 60 × 45 cm bore flowers with a mean diameter of 4.98 cm in comparison to 4.91 cm in plants spaced at 30 × 45 cm. Cultivar Alladin bore flowers with a mean diameter of 5.60 cm which was significantly superior to variety Pluto where a mean floret diameter of 4.29 cm was recorded. Thinning significantly improved floret size. A mean floret size of 5.11 cm under 25% thinning was statistically at par

with 5.01 cm recorded under 50% thinning regime but both were significantly superior to a 4.71 cm diameter recorded under control. There was a significant impact of increased spacing on diameter of flowering shoots with maximum (8.98 mm) recorded in 60 × 45 cm spaced plants in comparison to 8.89 mm recorded in 30 × 45 cm spaced plants. Significant differences in mean diameter of flowering shoots were recorded among two varieties. Maximum diameter of flowering shoots (9.33 mm) was observed in variety Alladin in comparison to 8.53 mm recorded in variety Pluto. 25% thinning significantly improved shoot diameter in comparison to control (8.81mm). However, shoot diameter of 9.05 and 8.93mm under 25% and 50% thinning respectively were statistically at par. Maximum duration of flowering flush (64.38 days) recorded under 60 × 45 cm spacing was significantly superior to 62.50 days for 30 × 45 cm spacing. Duration of flowering flush (67.99 days) recorded in cv. Pluto was significantly longer in comparison to 58.89 days recorded in cv. Alladin. Thinning significantly influenced the duration of flowering flush with longer duration of 66.46 days recorded under 25% thinning followed by 63.16 and 60.69 days under 50% and no thinning regimes respectively. Generative shoots of cv. Alladin had a mean number of 26.01 nodes in comparison to 21.18 recorded in cv. Pluto. Number of nodes on generative shoots (25.88) was significantly higher in 25% thinning comparison to 23.85 and 21.05. nodes recorded under 50% and no thinning regimes respectively.

Perusal of data shows significant improvement in number of flowering shoots/plant under wider spacing. Significantly more number of flowering shoots/plant (39.74) was recorded in 60 × 45 cm spaced plants in comparison to 35.74 recorded in 30 × 45 cm spaced plants. Cultivar Pluto on an average produced 39.55 flowering shoots/plant in comparison to 35.92 recorded in cv. Alladin. Thinning significantly improved number of flowering shoots/plant. 25% thinning regime recorded 42.71 flowering shoots which was significantly superior to 37.91 and 32.57 recorded under 50% and no thinning regimes respectively. Highest 86.73 percent class-I flowering stems were recorded under spacing of 60 × 45 cm in comparison to 84.16 under 30 × 45 cm spaced plants. Cultivar Pluto produced 87.49 percent class-I flowering stems in comparison to 83.40 % recorded in cultivar Alladin. Thinning significantly improved percentage of class-I flowering stems. Highest (89.49) percent class-I flowering stems was recorded under 25% thinning in comparison to 85.10 and 81.74 under 50% and no thinning regimes respectively. higher length of cymes of class-I flowering stems (16.07 cm) was recorded under 60 × 45 cm spacing in comparison to 15.04 cm recorded under 30 × 45 cm spacing. Maximum length of cymes of class-I flowering stems (19.90 cm) was recorded in cv. Pluto in comparison to 11.20 cm recorded in Alladin. Thinning significantly increased the length of cymes of class-I flowering stems with maximum (17.46 cm) recorded under 25% thinning followed by 15.77 and 13.42cm under 50% and no thinning regimes respectively.

Alstroemeria is a perennial geophyte that flowers seasonally in its native habitat. However, modern cultivars have been bred to flower continuously if the plantation is managed well and media temperature is below 13^0C. Under Kashmir conditions rhizomes pass through requisite media temperature conditions in autumn and early winter and subsequently through early spring. During this period rhizome branches thus priming the plants to produce number of flowering stems in the April – May flush.

In the current experiment variable spacing and thinning was aimed to arrive at an optimum cultural practice regime for maximizing flower yield and quality. Thinning out of weak vegetative shoots for maximizing flower yield and quality in Alstroemeria has been reported by several researchers Heins and Wilkins, 1976, Molnar, 1975 and Vonk Noordegraaf, 1975 [15, 16, 17] who observed shoot thinning of 'Regina' and 'Orchid' cultivars increased flower production. In the foregoing study plants spaced at 60 × 45 cm reached bud appearance stage significantly earlier and the resultant flowering spikes had significantly superior floral attributes recorded in terms of number of cymes/inflorescence, number of florets/cyme, diameter of primary floret and diameter of flowering shoots. Also duration of flowering flush exhibited significant increase in comparison to closer spacing. In terms of quality, proportion of Class I spikes harvested under wider spacing was significantly higher. Wider spacing allows free unrestricted branching of rhizomes that send out larger numbers of above ground shoots thus increasing photosynthetic area. Larger area of green top in return supports higher growth of underground storage organs thus enabling the plants to produce desirable quality of flowers. Moreover, plants spaced at wider distance have to compete less for nutrients and light which might have translated into improved flower quality parameters. Optimizing spacing for improved quality has been studied in several related geophytic crops like Mane et al. (2000) [18] in tuberose and Rajib *et al*. (2014) [19] in gladiolus.

The current experiment was aimed at optimum level of photosynthetic area by regulating number of above ground green shoots through the practice of thinning. The aim is to retain optimum number of vegetative shoots so as to encourage quality generative shoot production without sacrificing the growth and branching of underground rhizomes and storage roots. The results indicate 25% thinning was superior to 50% thinning and control in improving various floral quality parameters. Apparently removal of 25% vegetative shoots encouraged branching of rhizomes and also improved spike quality parameters like number of cymes/inflorescence, number of florets/cyme, diameter of primary floret , diameter of flowering shoots and percentage of class I flowering stems without drastically reducing the plants ability to photosynthesize. Decline in flower quality parameters under 50% thinning might be attributed to reduced photosynthetic surface area of individual plants. The results confirm to the study of Heins and Wilkins, 1976 [15], Mourne and Stromme (1980) [10], Aker and Healy (1990) [11] and Singh *et al.* (2006) [20] in Alstroemeria.

Table 1: Effect of spacing and thinning on growth of *Alstroemeria hybrid*a (L.)

Treatments		No. of vegetative shoots removed	Fresh weight (gm) of vegetative shoots removed	Dry weight (gm) of vegetative shoots removed
$S_1V_1T_1$		4.66	49.41	12.28
$S_1V_1T_2$		8.00	85.36	21.66
$S_1V_2T_1$		3.33	38.35	9.77
$S_1V_2T_2$		6.66	73.44	18.40
$S_2V_1T_1$		6.66	74.99	18.78
$S_2V_1T_2$		13.33	149.73	38.07
$S_2V_2T_1$		5.33	60.76	15.36
$S_2V_2T_2$		10.66	120.99	30.18
C.D ($p<0.05$)	Spacing	1.818	21.828	6.275
	Variety	NS	NS	NS
	Thinning	0.692	7.495	2.109

Table 2: Effect of spacing and thinning on flowering of *Alstroemeria hybrida* (L.)

Treatments		Days to flower bud formation	No. of cymes / inflorescence	No. of florets / cyme	Diameter of primary floret (cm)	Diameter of flowering shoots (mm)	Duration of flowering flush (days)	No. of nodes on generative shoots	No. of flowering shoots / plant	Percent class-I flowering stems	Percent class-II flowering stems	Length of cymes of class-I flowering stems (cm)
$S_1V_1T_0$		166.99	3.00	2.00	4.11	8.36	64.84	17.99	33.33	82.99	17.00	16.79
$S_1V_1T_1$		163.44	4.88	3.44	4.40	8.59	69.43	23.10	42.44	99.06	9.33	21.11
$S_1V_1T_2$		165.33	3.77	2.88	4.30	8.51	66.92	20.99	37.33	86.33	13.67	19.43
$S_1V_2T_0$		179.33	3.66	2.00	5.25	9.17	54.13	23.33	28.99	77.99	18.67	9.35
$S_1V_2T_1$		174.55	5.03	2.88	5.76	9.44	61.78	27.33	37.77	85.66	14.33	12.44
$S_1V_2T_2$		176.22	4.33	2.33	5.66	9.25	57.92	25.55	34.55	81.33	18.67	11.10
$S_2V_1T_0$		166.55	3.11	2.11	4.13	8.45	66.93	18.33	35.55	84.21	15.78	17.95
$S_2V_1T_1$		161.11	5.11	3.77	4.47	8.67	71.40	24.33	47.33	92.66	7.33	23.43
$S_2V_1T_2$		163.66	4.22	3.11	4.37	8.61	68.43	22.33	41.33	88.10	11.89	20.70
$S_2V_2T_0$		178.88	3.44	2.00	5.35	9.26	56.88	24.55	32.44	81.77	18.22	9.61
$S_2V_2T_1$		172.44	5.33	3.00	5.85	9.51	63.23	28.77	43.33	88.99	11.00	12.87
$S_2V_2T_2$		174.77	4.66	2.55	5.73	9.35	59.40	26.55	38.44	84.66	15.33	11.84
C.D ($p<0.05$)	Spacing	0.651	NS	NS	0.052	0.083	1.048	NS	0.505	1.071	1.575	0.761
	Variety	0.671	0.227	0.245	0.160	0.083	0.987	1.637	1.259	1.229	2.587	0.498
	Thinning	1.053	0.288	0.207	0.164	0.151	1.076	0.823	0.701	0.780	1.285	0.424

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