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Strawberry Plant Spacing on Raised Beds

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Abstract

The effects of plant spacings on yield components of 'Rainier,' 'Shuksan,' 'Sumas' and 'Totem' strawberry cultivars were examined under commercial production in ribbon rows. The greatest yields of marketable fruit were obtained at the closest plant spacings. Marketable yield depended upon the numbers of crowns per plant and trusses per crown, components of yield which increased greatly from one year to the next. The increase in yield in the second year came mainly from an increase in crowns per plant. Crowns per plant were adversely effected by crowding but closer spacings still resulted in increases in marketable yield per hectare.

Introduction

In British Columbia, the ribbon row system is currently being tested to meet an increasing demand for fresh strawberries over an extended season. A single row of runner plants is spaced at 8 to 15 cm on raised beds (Scheel 1982). The beds are mulched with plastic and irrigated with a trickle system. Runners are removed to favor growth of the mother plant and its branch crowns (Hancock et al. 1982).

Plants in raised beds have a more efficient plant canopy and earlier yields (Gosselin et al. 1985). Raised beds help improve drainage and decrease soil compaction (Goulart and Funt 1985). Plastic mulch on raised beds increases fruit size and yield, enhances earliness and fruit quality (Blatt 1984), reduces fruit rot and increases fruit visibility (Scheel 1982). Berry yield increases under plastic mulch and trickle irrigation (Blatt 1984).

With increased planting density, harvest is possible in the planting year for a quicker return on investment than in the matted row system. The fruit is harvested approximately 6 to 8 weeks after planting. The harvest season is extended by sequential plantings. British Columbia has recorded yields of 8.4 tonnes per hectare in 'Rainier,' 4.3 tonnes per hectare for 'Sumas,' 3.2 tonnes per hectare of 'Shuksan' and 2.9 tonnes per hectare with 'Totem' in the planting year (Baumann and Daubeny 1987).

Cultivars selected on the basis of performance in matted rows (Hancock et al. 1984a) differ in their suitability for ribbon rows (Goulart and Funt 1986). Specific cultivars should be selected for their yield and growth habit (Goulart and Funt 1985).

Many components contribute to yield. Strawberry yield is correlated with crown productivity which in turn is associated with the number of trusses per crown (Swartz et al. 1982). The relative importance of individual yield components varies within and among cultivars (Hancock et al. 1983) and according to growing technique. Yield components that differ among planting systems are crowns per plant and yield per crown while trusses per crown, number of flowers and yield per truss were not effected (Popenoe and Swartz 1985).

Strawberry yield increased at closer plant spacings (Durner and Poling 1986, Goulart and Funt 1986, Poling and Durner 1986). However, the number of crowns per plant and yield per crown may decrease under greater planting densities (Durner and Poling 1986). Increasing densities may have negative effects on yield components

but these may not completely compensate for a stronger effect of planting density on yield per plot (Hancock et al. 1984b).

It is possible to study how treatments influence yield through the contributions of its components (Eaton et al. 1986). In the present study, two-dimensional partitioning of yield variation (Eaton et al. 1986, Eaton 1987) was used to evaluate yield and its components in response to different plant spacings in ribbon row trials of four strawberry cultivars commonly grown in the Pacific Northwest.

Materials and Methods

The experiment was factorial, using four cultivars and four spacings in each of five randomized complete blocks. The two years were analyzed as a sub-plot effect in a split-plot design. In July 1987 cold-stored runner plants of 'Rainier,' 'Shuksan,' 'Sumas' and 'Totem' were planted as ribbon rows at Driediger Bros. Farms Ltd. in Langley, British Columbia. The spacings within the row were 7, 12, 19, and 32 cm. The distance between the rows was 107 cm (42 inches) on centers. The corresponding plant densities were thus 133,912, 78,155, 49,336, and 29,293 plants per ha respectively. There were twelve plants per plot including two guard plants. Data were collected during the planting year and again in 1988.

Data collected on a per plot basis included crowns, trusses, flowers, marketable fruit, culled fruit and fruit size index. The number of crowns and trusses included the sum for ten plants in each plot. Flower numbers were represented by two randomly choosen plants per plot. The marketable fruit, culled fruit and fruit size index (average weight of 25 marketable berries) were weighed during several harvests approximately a week apart.

The variables computed on a per hectare basis were crown, truss and flower numbers, yield of marketable fruit, culled fruit and total fruit mass. The number of marketable berries per hectare was calculated by dividing yield of marketable fruit by the fruit size index. Ratios of variates were computed, forming a mltiplicative model of yield. The yield component equation which expressed marketable yield per hectare was the product of plants per ha X crowns per plant X trusses per crown X flowers per truss X yield per flower X marketable yield per yield X berries per marketable yield X marketable yield per berry. The final variate made no contribution to yield and is omitted from our tables.

Analysis of variance (ANOVA) was used to detect treatment effects on these ratios (Table 1). Next the natural logarithms of the ratios were calcu-

Table 1. Abbreviations for cultivars, variates measured on a per hectare basis and sources for ANOVA.

Cultivars

R = 'Rainier'
Sh = 'Shuksan'
Su = 'Sumas'
T = 'Totem'

Variates measured on a per hectare basis

P = plants
C = crowns
T = trusses
F = flowers
Y = yield
M = Marketable yield
B = berries
XX = correction factor or sums of products among components

ANOVA sources

Lin = linear
Quad = quadratic
Cub = cubic
Dev = deviation, lack of fit
Y = year
S = spacing
C = cultivar

lated, which provided a linear and additive model. The adjusted variates were analyzed by two-dimensional partitioning (Eaton et al. 1986, Eaton 1987). The trial was terminated at the end of 1988 because it was included in a large commercial enterprise scheduled for replanting in 1989. Commercial plantings in British Columbia are normally kept for three or four years.

Results and Discussion

Most (68%) of the marketable yield variation was accounted for by differences between years (Table 2). Much of this variation in yield was accounted for in turn by variation in crowns per plant (35%) and to a much lesser degree by trusses per crown (2%). Yield per flower and berries per marketable yield were also significant but made very small contributions.

Table 2. Two-dimensional partitioning of the effects of plant spacings upon the sum of squares for marketable yield of four strawberry cultivars.

Source	df	P	C/P	T/C	F/T	Y/F	M/Y	B/M	XX	M[z]
Total	159	10	65	14	2	7	3	0	0	100
Block	4		0	1*	0	0*	0*	0	-1	1**
Cultivar	(3)		9**	2**	0**	0*	0*	0	-4	7**
R+Sh/Su+T	1		3**	0	0	0	0*	0	1	4**
R/Sh	1		4**	0	0**	0	0	0	-1	3**
Su/T	1		2**	2**	0	0*	0	0	-4	0*
Spacing	(3)	10	0	0	0	0*	0	0	0	10**
Lin (Log)	1		0	0	0	0	0	0	10	10**
Quad (Log)	1		0	0	0	0**	0	0	0	0**
Cubic (Log)	1		0	0	0	0	0	0	0	0
C X S	(9)		1	0	0	1**	0	0	-2	1
R+Sh/Su+T X L	1		1**	0	0	0	0	0*	-1	0
R+Sh X Lin	1		0	0	0*	0**	0	0	0	0*
Su+T X Lin	1		0	0	0	0**	0*	0	0	0*
R+Sh/Su+T X Quad	1		0	0	0	0	0	0	0	0
R/Sh X Quad	1		0	0	0	0	0	0	0	0
Su+T X Quad	1		0	0	0	0	0	0	0	0
R+Sh/Su+T X Dev	1		0	0	0	0	0	0	0	0
R/Sh X Dev	1		0	0	0	0	0	0	0	0
Su/T X Dev	1		0	0	0	0	0	0	0	0
Error (A)	60		5	3	1	1	1	0	-9	2
Year	1		35**	2**	0	0**	0	0*	31	68**
Y X C	(3)		8**	1**	0	1**	0*	0**	-1	8**
Y X R+Sh/Su+T	1		4**	0	0	0	0	0	1	5**
Y X R/Sh	1		0	1**	0*	0*	0	0**	1	2**
Y X Su/T	1		3**	0	0	1**	0*	0**	-4	1**
Y X S	(3)		1*	0	0	0*	0	0	-1	1**
Y X Lin (Log)	1		1**	0*	0	0*	0	0	-1	0**
Y X Quad (Log)	1		0	0	0	0	0	0	0	0
Y X Cubic (Log)	1		0	0	0	0*	0	0	0	0*
Y X C X S	9		1	1	0	0	0	0	-2	0
Error	64		5	4	1	2	1	0	-10	2

[z]The total sum of squares for marketable yield in kilograms per hectare was 15,391.
*, **—significant at P = 0.05 and 0.01 respectively.
NOTE: A value of zero results from rounding 0.01 to 0.49 downward to zero. Notation as in Table 1.

Variation in marketable yield was also accounted for by spacing (10%) (Table 2). This variation was due to small contributions by yield per flower. Variation in marketable yield was also due to differences among cultivars (7%) which in turn arose from variation in crowns per plant and to a lesser extent trusses per crown, flowers per truss, yield per flower and marketable yield per yield.

The years by cultivar interaction contributed to variation in marketable yield (8%) which was largely due to crowns per plant and to a lesser amount to trusses per crown and yield per flower. The components of the year by spacing interaction made a small contribution to marketable yield variation totaling 1%.

Crowns per plant contributed 65% of the total sum of squares in marketable yield (Table 2). Crowns per plant differed between the fresh cultivars 'Rainier' and 'Shuksan' and the processed cultivars 'Sumas' and 'Totem' and between cultivars within each group (Table 3). 'Rainier' had the most crowns per plant in 1987 followed by 'Shuksan,' 'Sumas' and 'Totem.' In 1988, 'Sumas' had the most crowns followed by 'Shuksan,' 'Totem' and 'Rainier' (Table 6).

'Sumas' had more crowns per plant than 'Totem' for each of the four

Table 3. Geometric means for calculated ratios of yield components and marketable yield (tonnes/ha) for cultivars.

Cultivar	C/P	T/C	F/T	Y/F	M/Y	M
Rainier	3.0	1.2	6.8	11.5	0.9	13.3
Shuksan	2.2	0.9	10.0	8.2	1.0	10.5
Sumas	2.8	0.9	7.4	9.5	1.1	12.9
Totem	1.9	1.1	7.0	7.8	1.1	9.6
Contrasts						
R+Sh/Su+T	°°	--	°	--	°	--
R/Sh	°°	°°	°°	°°	--	°°
Su/T	°°	°°	--	--	--	°°

°, °°—significant at P = 0.05 and 0.01 respectively. Notation as in Table 1.

Table 4. Geometric means for calculated ratios of yield components and marketable yield (tonnes/ha) for spacing.

Spacing (cm)	C/P	T/C	F/T	Y/F	M/Y	M
7	2.1	1.0	7.6	7.5	1.1	15.5
12	2.3	1.0	7.4	10.1	1.0	13.7
19	2.6	1.1	7.6	9.7	1.0	10.2
32	2.9	1.1	8.6	9.7	1.1	6.8
Contrasts						
Linear (Log)	°°	°	--	--	--	°°
Quad (Log)	--	--	--	--	--	--
Cubic (Log)	--	--	--	--	--	--

°, °°—significant at P = 0.05 and 0.01 respectively. Notation as in Table 1.

Table 5. Geometric means for calculated ratios of yield components for cultivar and spacing.

Cultivar	Spacing (cm)	C/P	T/C	F/T	Y/F	M/Y
Rainier	7	2.9	1.0	7.7	6.5	0.9
Rainier	12	2.9	1.1	7.0	11.2	0.9
Rainier	19	2.9	1.3	6.1	13.1	0.9
Rainier	32	3.4	1.3	6.5	15.3	0.9
Shuksan	7	2.1	0.9	9.1	7.1	1.0
Shuksan	12	2.0	0.9	7.9	10.6	1.0
Shuksan	19	2.3	1.0	9.4	8.7	1.0
Shuksan	32	2.4	1.0	13.7	6.4	1.0
Sumas	7	2.0	0.8	7.1	9.2	1.0
Sumas	12	2.5	0.7	7.9	11.4	1.0
Sumas	19	3.0	0.9	7.2	9.2	1.1
Sumas	32	3.6	1.0	7.2	8.2	1.4
Totem	7	1.5	1.2	6.6	7.3	1.5
Totem	12	1.9	1.1	7.0	7.1	1.1
Totem	19	2.2	1.0	7.5	7.9	1.0
Totem	32	2.2	1.1	6.8	8.8	1.0
Contrasts						
R+Sh/Su+T X Linear	°°	--	--	--	--	
R/Sh X Linear	--	--	°°	°°	--	
Su/T X Linear	°°	°	--	--	°°	
R+Sh/Su+T X Quad	--	--	°	--	--	
R+Sh X Quad	--	--	--	--	--	
Su+T X Quad	--	--	--	--	--	
R+Sh/Su+T X Dev	--	--	--	--	--	
R/Sh X Dev	--	--	--	--	--	
Su/T X Dev	--	--	--	--	--	

°, °°—significant at P = 0.05 and 0.01 respectively. Notation as in Table 1.

spacing treatments and these differences were largest at the widest spacing of 32 cm (Table 5). In each cultivar the most crowns per plant were found at the widest spacing of 32 cm and decreased linearly with closer spacings (Table 4). In 1987, the most crowns per plant were obtained at 32 and 19 cm spacings and decreased slightly as the spacing decreased. In 1988, the most crowns per plant were obtained at the widest spacing (32 cm) and decreased more rapidly than in 1987 as the spacings decreased (Table 7). The different pattern of crown density for 1987 and 1988 suggests crowding effects upon crown number.

Trusses per crown contributed 14% of the variation in marketable yield (Table 2). Trusses per crown differed between cultivars within each group. 'Rainier' had more trusses per crown than 'Shuksan' and 'Totem' had more trusses per crown than 'Sumas' (Table 3). 'Rainier' had more trusses per crown in 1987 than 'Shuksan,' but in 1988 there was little difference (Table 6).

Higher planting densities decreased the number of trusses per crown (Table 4) and cultivars differed in their response (Table 5). 'Totem' had more trusses per crown than 'Sumas' at each spacing treatment but the differences were greater at closer spacings. In respect of truss production, 'Totem' was more tolerant of crowding than 'Sumas.' Truss number was apparently not related to density in 1987 but trusses were slightly depressed by crowding in 1988 (Table 7).

Yield per flower contributed 7% of the variation in marketable yield (Table 2). 'Rainier' had greater yield per flower (Table 3) and was more sensitive to crowding (Table 5) than 'Shuksan.'

Marketable yield per yield contributed 3% of the variation in marketable yield (Table 2) and processing cultivars had greater values than did fresh fruit cultivars (Table 3). In respect of this yield component, 'Totem' was more tolerant of crowding than was 'Shuksan' (Table 5).

Flowers per truss contributed 2% of the variation in marketable yield (Table 2). The fresh fruit cultivars 'Rainier' and 'Shuksan' had more

Table 6. Geometric means for calculated ratios of yield components and marketable yield (tonnes/ha) for year and cultivar.

Year	Cultivar	C/P	T/C	F/T	Y/F	M/Y	M
1987	Rainier	2.4	1.1	7.6	8.9	1.0	8.3
1987	Shuksan	1.8	0.6	10.4	4.8	1.0	3.3
1987	Sumas	1.3	0.5	7.9	6.4	1.0	1.6
1987	Totem	1.3	0.8	7.1	4.4	1.0	1.9
1988	Rainier	3.6	1.3	6.0	14.2	0.9	18.3
1988	Shuksan	2.6	1.3	9.7	11.6	0.9	18.0
1988	Sumas	4.2	1.2	6.8	12.6	1.2	24.1
1988	Totem	2.5	1.5	6.9	11.2	1.3	17.3
Contrasts							
Y X R+Sh/Su+T		°°	°°	--	--	--	°°
Y X R/Sh		--	°°	--	--	--	°°
Y X Su/T		°°	--	--	--	--	°°

°, °°—significant at P = 0.05 and 0.01 respectively. Notation as in Table 1.

Table 7. Geometric means for calculated ratios of yield components and marketable yield (tonnes/ha) for year and spacing.

Year	Spacing (cm)	C/P	T/C	F/T	Y/F	M/Y	M
1987	7	1.6	0.8	7.4	5.2	1.0	5.9
1987	12	1.7	0.7	7.3	6.3	1.0	3.9
1987	19	1.8	0.8	7.9	7.1	1.0	3.2
1987	32	1.8	0.7	10.4	5.9	1.0	1.7
1988	7	2.7	1.2	7.8	9.9	1.2	25.0
1988	12	2.9	1.2	7.6	13.9	1.0	23.5
1988	19	3.4	1.4	7.2	12.4	1.0	17.2
1988	32	4.0	1.5	6.7	13.4	1.1	11.9
Contrasts							
Y X Linear (Log)		°°	°°	°°	--	--	°°
Y X Quad (Log)		--	--	--	--	--	--
Y X Cubic (Log)		--	--	--	--	--	--

°, °°—significant at P = 0.05 and 0.01 respectively. Notation as in Table 1.

flowers per truss than did the processing cultivars and 'Shuksan' had more flowers per truss than 'Rainier' (Table 3). Flowers per truss also reflected the cultivar by linear spacing interaction; while 'Shuksan' had more flowers per truss at every spacing than did 'Rainier,' the maximum flower number in 'Shuksan' was at the widest spacing and in 'Rainier' the maximum was at the closest spacing (Table 5).

The greatest marketable yields were obtained at the closest spacings (7 cm) and the lowest at the widest spacings (32 cm) (Table 4), especially in 1988 (Table 7). Cultivars within each of the cultivar groups differed in their marketable yields although the group means were not significantly different. 'Rainier' had greater total marketable yield over the two years than 'Shuksan' and 'Sumas' had more than 'Totem' (Table 3). This was not true in each year, however, for in 1987 'Rainier' had more marketable yield than 'Shuksan' but the marketable yields were similar in 1988 (Table 6). The main features of the year by cultivar interaction contrasts apparently arose from the relatively high yield of 'Rainier' in 1987 and of 'Sumas' in 1988.

Closer plant spacings increased marketable yield per hectare even though certain components of yield were adversely effected by crowding. Apparently inter-plant competition was not sufficient to compensate for the extra yield arising from closer spacings. The increase in yield in the second year came mainly from an increase in crowns per plant. Crowns per plant were adversely effected by crowding but closer spacings still resulted in increases in the number of crowns per hectare. At spacings of 7, 12, 19 and 32 cm the crowns per square meter were 28.1, 18.0, 12.8 and 8.5 respectively.

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