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Yield and Fruit Size of 'Bluecrop' and 'Blueray' Highbush B1ueberries at Three Plant Spacings

James N. Moore[1], Maurus V. Brown[2], and Bruce P. Bordelon[3]
Department of Horticulture and Forestry, University of Arkansas, Fayetteville, AR 72701

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Abstract. **The influence of in-row plant spacing on the yield and fruit size of 'Blueray' (erect growing) and 'Bluecrop' (spreading) highbush blueberry *(Vaccinium corymbosum* L.) was studied. Plants of both cultivars, spaced at 0.61 m within the row, had significantly higher yields per hectare than plants grown at wider spacings (0.92 and 1.22 m) in each of five harvest years. On a per-plant basis, however, plants spaced at 1.22 m had higher yields in the last two harvest years of the experiment than plants spaced more closely, which indicated that interplant competition reduced per-plant yields of closely spaced plants as plants grew larger. Over the 5-year harvest period, plots with 0.61-m plant spacing produced a cumulative total yield of 17.24 $t\cdot ha^{-1}$ more than plots with the conventional 1.22-m spacing. Plant spacing did not affect fruit size in this experiment.**

The influence of plant spacing on crop yields has been studied for many horticultural crops. Increasing plant density has resulted in increased yields per hectare for several fruit crops (Archbold et al., 1987; Hartman and Hill, 1983; Layne et al., 1981; Schneider et al., 1978; Testolin, 1990). For some species, such as apple *(Malus domestics* Borkh.) (Archbold et al., 1987), close spacing reduced yield per plant but increased yield per hectare due to the greater plant population.

Information on plant spacing effects on blueberry production is limited. Traditional highbush blueberry plant spacing has been 1.35 m between plants in the row and 2.70 m between rows (Eck, 1988), but the most common spacing in new plantings is 1.2 × 3.0 m (Eck et al., 1990). For rabbiteye blueberry *(V. ashei* Reade), plant spacing usually ranges from 1.5 to 2.4 m between plants in a row and from 3.7 to 4.3 m between rows (Eck et al., 1990).

Eck (1988) reported that spacing highbush blueberries within rows at 0.91 m increased production 14% over plants spaced at 1.35 m on a sandy soil in New Jersey. Austin and Mullinix (1980), working with rabbiteye blueberries, obtained yield increases of 25% and 40% from plants spaced within rows at 1.2 m when compared with 1.8 and 2.4 m, respectively, with 3.6 m between all rows. Fruit size was unaffected by spacing~.

In a study of widely spaced (50 cm) and closely spaced (25 cm) potted highbush blueberry plants, Eck and Stretch (1986) found that widely spaced plants produced more, but smaller, fruit per plant and that fruit ripened earlier than on closely spaced plants. Widely spaced plants produced more flower buds and flowers than closely spaced plants, and the authors suggested that close spacing in the field may result in restricted light penetration into the plant canopy, thus reducing flower bud development.

Our objective was to evaluate the influence of plant spacing on yield and fruit size of two highbush blueberry cultivars differing in growth habit.

The experiment was initiated in Sept. 1985 at the Main Experiment Station, Fayetteville, Ark. 'Bluecrop' and 'Blueray' highbush blueberries were planted at three in-row spacings (0.61, 0.92, and 1.22 m) with 3.05 m between rows. Cultivars were chosen on the basis of growth habit: 'Blueray' is erect, while 'Bluecrop' is more spreading.

The design was a randomized complete block with four replications. Each plot was 6.1 m long and contained either 10 (0.61 m), six (0.92 m), or five plants (1 .22 m). Yields of the 0.92-m plots were multiplied by 1.11 to equalize the amount of row length occupied (6.1/ 5.52).

Two-year-old potted plants, 45 to 60 cm high, were planted in a Captina silt loam soil with pH adjusted to 5.2 by prior application of wettable sulfur. Four liters of moist peatmoss were placed under each plant at planting, and a surface mulch of hardwood sawdust was applied 15 cm deep after planting and subsequently maintained at that depth according to Arkansas recommendations (Moore, 1976).

One month after planting, 112 kg ammonium sulfate/ha was broadcast in a 1-m band centered on the plant row. In subsequent years, the fertilization regime consisted of 330 kg 13N–13P–13K/ha at budbreak followed by two applications of 112 kg ammonium sulfate/ ha at 6-week intervals. All spacing treatments received the same fertilizer and irrigation schedules. Plants were drip-irrigated as needed and pruned annually.

Before harvest each year, the planting was enclosed in a polypropylene net to prevent bird depredation. Yields per plot were recorded, and fruit weight was calculated from the weight of 50 berries at each harvest and converted to seasonal averages. Production data were collected annually, except for 1990, when the net was destroyed in a wind storm and birds consumed a portion of the crop.

Yields for each year and total yields for the five years were analyzed, with cultivar and plant spacing as the treatment factors. The analysis of variance included the main effects of cultivar and plant spacing and the interaction of these factors. Effects of plant spacing were tested by analysis for linear and quadratic trends.

Cultivars responded similarly to the spacing treatments. There were no significant cultivar × spacing interactions in the experiment; therefore, data from the two cultivars were pooled for analysis of spacing effects. 'Blueray' outyielded 'Bluecrop' in two of the five harvest years and had a significantly higher 5-year cumulative yield (data not presented).

Yields from plots of plants at the closest spacing (0.6 1 m) were significantly higher than those from the other two spacings in each of the five harvest years (Table 1). The 0.61-m spacing yielded 86%, 90%, and 72% more than the conventional 1.22-m spacing in the first three harvest years, respectively. The percent increase from close spacing dropped to 42% and 37% in 1991 and 1992, respectively. The cumulative 5-year total yield of the 0.61-m spacing was 47% higher than the yield from the 1.22-m spacing.

Interestingly, plants spaced at 0.61 m consistently outyielded those at 0.92 m, but those at 0.92 m did not significantly outyield those at 1.22 m, although numerical yields were somewhat higher in each of the first three harvest years. As reported by Eck and Stretch (1986), the closest spacing possibly resulted in greater vegetative growth in the early years, which could then result in a greater bearing surface. However, vegetative growth was not measured in this experiment to substantiate this hypothesis.

Spacing effects on individual plant yields differed considerably from per-hectare yields. No significant differences in yields per plant due to spacing occurred during the first three harvest years (Table 1). However, in the 1991 and 1992 harvests, individual plants spaced at 1.22 m yielded significantly more than plants at closer spacings. Yield per plant did not differ between plants spaced at 0.92 and 0.61 m. Apparently, interplant competition was increased by both of the closer spacings. Increased yields per hectare, with corresponding decreased yields per plant, due to close spacing hawe been reported for apple (Archbold et al., 1987).

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[1]Distinguished Professor of Horticulture.

[2]Research Assistant.

[3]FormerResearchAssistant.Current address: Dept. of Horticulture, Purdue Univ., West Lafayette, IN 47907.

Table 1. Effect of in-row plant spacing on yield of highbush blueberry.[z]

Plant spacing (m)[x]	Year[y] 1987	1988	1989	1991	1992	Cumulative
			(t·ha^{-1})			
0.61	0.95	3.84	8.98	19.27	20.76	53.80
0.92	0.66	2.65	6.27	13.17	14.47	37.22
1.22	0.51	2.02	5.22	13.61	15.19	36.56
$LSD_{0.05}$	0.253	0.750	2.000	3.786	5.156	5.137
Trend analysis[w] Linear	**	**	**	**	*	**
			(kg/plant)			
0.61	0.18	0.71	1.67	3.58	3.86	10.00
0.92	0.18	0.74	1.75	3.67	4.04	10.38
1.22	0.19	0.75	1.94	5.06	5.65	13.59
$LSD_{0.05}$	NS	NS	NS	0.93	1.18	1.32
Trend analysis[w] Linear	NS	NS	NS	**	**	**

[z]Means of 'Blueray' and 'Bluecrop' blueberries.
[y]Planting established in 1985. Data for 1990 lost to bird damage.
[x]In-row spacing: all plots were spaced 3.05 m between rows.
[w]The quadratic trend was nonsignificant in all cases.
NS,*,**Nonsignificant or significant at $P = 0.05$ or 0.01, respectively.

There were no significant effects of plant spacing on average berry weight during the experiment. 'Blueray' produced the largest (by weight) berries, averaging 1.85 g compared to 1.55 g for 'Bluecrop', in four of the five harvest years (data not presented).

Highbush blueberry production requires high investment costs for plantation establishment and along period for maximum production. Garner and Moore (1986) calculated that annual returns do not exceed annual costs until the fifth year after planting, and cumulative net returns do not exceed cumulative costs until the tenth year after planting. This negative economic situation is due to the low yields obtained until plants have achieved their maximum size for high productivity. By increasing productivity in the early years of a blueberry plantation, the economics of growing blueberry would be enhanced greatly. In this study, we obtained a cumulative total increase in production of 17.24 t·ha^{-1} from the 0.61-m plant spacing compared with the conventional 1.22-m spacing over the 5-year harvest period. Art increase of this magnitude likely would more than offset the increase in establishment costs for the closely spaced planting, since the major additional cost for close spacing would be initial cost of plants.

The greater yields achievable from high-density plantings enhance the economics of netting for bird control in blueberries. Bird depredation is a major problem in most areas where blueberries are grown, and exclusion by nets is the only effective control measure. However, netting is expensive, and the low yields during the early years of a plantation do not justify the cost. With the higher yields of closely spaced plants, the economics of netting may be justified.

There are indications that interplant competition between closely spaced plants may have a detrimental effect on future yields in our planting. The rate of yield increase from 1991 to 1992 was less in plants from the 0.61-m spacing than in those from 1.22 m. Also, the rate of increase in per-plant yields from plants spaced at 0.61 m appeared to be leveling off. Since a highbush blueberry planting is considered to have a productive life of 30 or more years, some cultural modification may be required to maintain productivity of closely spaced plants. One available option is to remove every second plant and convert the planting to the conventional 1.22-m in-row spacing. Such a scheme has been suggested by Mitchell et al. (1983) to increase early year yields of peach *[Prunus persica* (L.) Batsch.]. This system should be well adapted for blueberries, since the shallow root system of blueberry allows successful transplanting of mature bushes. Therefore, the removed plants could be re-established in a new planting.

Higher rates of fertilization or irrigation in high-density plantings might maintain high productivity. Austin and Mullinix (1980) showed that closely spaced rabbiteye blueberry plants responded to increased fertilization rates, and Layne et al. (1981) reported greater yields from high-density peach orchards with adequate irrigation. However, the limiting factor in closely spaced blueberries may be light penetration into the plant canopy and the effect of shading on flower bud development (Eck and Stretch, 1986). New methods of blueberry pruning may be required to maintain productivity in closely spaced plantings.

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