Long-term Effects of Rows per Bed and In-row Spacing on Yield and Spear Size of Asparagus

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Abstract. Three studies were conducted at Clinton, N.C., to investigate the relationship between number of rows per bed, in-row spacing, and spear yield of asparagus (*Asparagus officinalis* L.) over 11 to 13 years. In the first study, increasing plant densities from 21,550 to 43,100 plants/ha by doubling the number of rows/bed increased the cumulative yield from 64% to 80% for three hybrid lines ('UC 157', 'WSU 1', and 'WSU 2') but only 6% for 'Rutgers Beacon'. The effects of doubling the plant density were still apparent 13 years later. In the second study, yields of 'Princeville' ('Mary Washington' selection) crowns, grown at densities from 14,000 to 86,000 plants/ha, were also increased for 8 years by doubling rows at various in-row spacings. In a third study, in which densities ranged from 21,000 to 387,900 plants/ha, the magnitude of the response to rows/bed was dependent on in-row spacing. Efficient use of bed space and the avoidance of crowding exerted a larger influence on productivity than did average planting density. The yield response to rows/bed was greater and more persistent through the years for wider in-row spacings. Spear size was only marginally responsive to rows per bed and in-row spacing.

An asparagus crop represents a highly dynamic perennial planting because of the interaction of planting density and high individual plant growth rates in the early years of establishment. Hanna (1947) compared in-row spacings of 30, 46, 61, 76, and 92 cm, using

between-row spacing of 2.4 m. He found that during early development, yield decreased as in-row spacing increased in this range. As the crop matured (7-8 years), yields of the more widely spaced plantings approached and matched the level of the 30-cm controls. In a long-term study, Benson et al. (1978) compared yields of crown plantings spaced 30.4 cm apart with a direct-seeded planting spaced at 3.8 cm within rows and 1.8 m between rows,

an 8-fold increase in density. The number and mass of spears/ha was significantly higher in the direct-seeded planting than in the crown planting for the first 6 years of production. However, no differences in yield occurred during the remaining seven seasons of the study. The advantage gained in the early years by increasing population density diminished in later years due to competition as the individual plants became larger.

In Hanna's and Benson's studies, the planting density was altered by changing the in-row spacing, using one row per bed. The highest density treatment was 215,500 plants/ha (Benson et al., 1978). By varying rows/bed from one to three (5-cm in-row spacing), Takatori et al. (1975) evaluated densities ranging from 99,000 to 297,000 plants/ha. Yield was greater for three than for two rows per bed for the first four harvest seasons. Two rows yielded more than one row in the five harvest seasons reported, but yields in later years were not reported.

All of this work was done in the arid western United States with cut green asparagus. Our objective was to determine optimum spacing for snapped asparagus in the humid southeastern United States. Three studies were established to determine the influence of row number and/or in-row spacing on spear yield in deep sandy soils in Clinton, N.C., using several promising open-pollinated and hybrid cultivars.

Materials and Methods

First study. Seedling transplants of asparagus cultivars 'Rutgers Beacon', 'UC 157', 'WSU 1', and 'WSU 2' were planted in Aug. 1978, in single and double rows as part of a larger cultivar trial. In-row spacing was 30 cm only (Table 1).

Second study. One-year-old crowns of 'Princeville' ('Mary Washington' type) were planted in Mar. 1980. Spacing was 15, 22, 30, or 45 cm with single and double rows per bed, giving densities of 14,813 to 88,888 plants/ha (Table 2).

Third study. 'Princeville' was direct-seeded at an in-row spacing of 5 cm in 1980. At the same time, 8-week-old nursery-grown seedlings were transplanted at spacings of 15 and 30 cm within the rows. Rows per bed varied from one to three (Fig. 1), with beds 1.5 m apart on centers.

Table 1. Influence of cultivar and the number of rows/bed on yield of asparagus over 13 years at Clinton, N.C. Seedlings were transplanted at an in-row spacing of 30 cm. One row = 21,550 plants/ha; two rows = 43,100 plants/ha. (First study).

Cultivar	Rows/ bed	Harvest year				13-year accumulative
		4	7	10	13	
		(kg·ha ⁻¹)				
Rutgers Beacon	1	1173	1235	1885	1382	18,859
Rutgers Beacon	2	1173	1678	2003	1675	20,191
UC 157	1	780	1026	1681	984	16,050
UC 157	2	1554	2007	2834	1761	28,640
WSU 1	1	911	909	1532	997	14,444
WSU 1	2	1529	1611	2388	1648	23,713
WSU 2	1	901	1064	1623	1149	15,757
WSU 2	1	1586	2224	2905	1830	28,385
LSD _(0.05)		550	626	895	496	8271

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Table 2. Influence of rows/bed and in-row spacing on yield of asparagus over 11 years at Clinton, N.C. (Second study).

In-row spacing (cm)	Rows/ bed	Plants/ ha	Harvest year			11-year accumulative
			3	8	11	
			(kg·ha ⁻¹)			
15	1	44,444	2357	1659	870	18,200
	2	88,888	2855	2086	851	20,785
22	1	30,303	1940	1899	779	16,127
	2	60,605	2657	2187	920	20,775
30	1	22,222	2209	1454	810	16,791
	2	44,444	2460	1936	1083	19,822
45	1	14,813	1646	2022	840	15,934
	2	29,626	1924	2205	904	18,000
LSD _(0.05)			472	NS	NS	NS
Mean	1		2038	1754	825	16,763
Mean	2		2474	2103	936	19,846
			*	*	NS	*

NS, *Nonsignificant or significant at $P \leq 0.05$.

Fig. 1. 'Princeville' asparagus yields as affected by planting density and in-row spacing over 11 seasons of harvest. ●, one row/bed; ■, two rows/bed; ▲, three rows/bed. LSD_(0.05) = 512, 556, 372, and 4102 kg·ha⁻¹ for fourth, eighth, and 11th seasons of harvest and cumulative yield, respectively. (Third study).

For all three studies, crowns, transplants, and seeds were placed such that the top of the crown was 15 cm below the soil surface. For all double-row plantings, rows were 15 cm on either side of the center of the bed. For triple-row plantings, side rows were 15 cm on either side of the central row. The first study was planted in an Orangeburg loamy sand (Typic Paleudult-fine loamy, siliceous, thermic), while the other two studies were planted in a Wagram fine sand (Arenic Paleudult-loamy, siliceous, thermic). Both soils contained <1% organic matter. All plots were 15 m long on 1.5-m-row centers. Spears (15 to 21 cm) were snapped three times per week and sorted as marketable (>7-mm diameter) and cull. During the first 2

years spears were harvested only in March. Thereafter, spears were harvested from March through May. Fertilization was 168 kg·ha⁻¹ N as NH₄NO₃ and 186 kg·ha⁻¹ K as KCl, with half applied before and half after harvest. Herbicides used included diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] at 2.5 kg·ha⁻¹ a.i., terbacil [3-tert-butyl-5-chloro-6-methyluracil] at 0.30 kg·ha⁻¹ a.i., simazine [2-chloro-4,6-bis(ethylamino)-s-triazine] at 4 kg·ha⁻¹ a.i., glyphosate [isopropylamine salt of N-(phosphonomethyl) glycine] at 1 kg·ha⁻¹ a.i., and linuron [3(3,4-dichlorophenyl)-1-methoxypyrimidin-1-methylurea] at 2 kg·ha⁻¹ a.i. These were applied at various times during the study, with application of different materials before and after harvest.

All treatments were replicated four times in a randomized complete-block design. Analyses of variance were performed, and where F tests warranted, Duncan-Waller LSDs were calculated (SAS Institute, 1985).

Results and Discussion

First study. When planted at 30-cm in-row spacing, double rows of 'UC 157', 'WSU 1', and 'WSU 2' yielded more than single row plantings each year for 13 years (Table 1). The increase in cumulative yield was 64% for 'WSU 1', 78% for 'UC 157', and 80% for 'WSU 2' by using double rows. Double rows tended to yield more than single rows for 'Rutgers Beacon', but the difference was non-significant for any year in the 13 years of this study. Plant survival was lower with this open-pollinated line than with the other cultivars (data not shown).

Our study differs from that of Benson et al. (1978) in two ways. Yields of both crown and direct-seed populations in Benson's California study reached plateaus in their fourth season, compared with the 10th season in the present study. Our study is representative of the dynamics of asparagus crops in the southeastern United States. Also of interest is the longevity of the effects of planting density on yield. In Benson's study, the effect of high-density planting on yields disappeared after 6 years. Density effects were significant in our research for all 13 years of the study.

Second study. Yield in the third harvest season was linearly related to planting density, whether achieved by increasing in-row spacing or by doubling the rows/bed (Table 2). These results agree with those of Hanna (1947), who showed that in the early development of asparagus, yield decreased as spacing was increased above 30 cm in single rows. In the 8th or 11th years, however, yield increased with double rows for each of the in-row spacings, but was not a function of average planting density overall.

Third study. The wider the in-row spacing, the greater the effects of row number and therefore of planting density on yield (Fig. 1, top). In the fourth year, for example, yield tripled as row number increased from one to three at 30 cm (Fig. 1, top). Increasing rows from one to three at 15-cm spacing or at 5-cm spacing produced far less additional yield, even though planting density was increased far more. The highest yields in the early years were associated with the most efficient use of space within the bed, i.e., triple rows at 30 cm (Fig. 1, top). This yield was not statistically different, however, from double or triple rows at 15-cm in-row spacing. The 5-cm in-row spacing caused severe plant-to-plant competition. Yields for the single row, 5-cm treatment were little more than half of the triple-row, 15-cm treatment, a configuration of the same average density but of much greater efficiency in use of space (Fig. 1).

By the eighth harvest season, yields of all treatments had increased. Yields from the three most productive treatments (triple rows at 30 and 15 cm, and double rows at 15 cm) did not

differ significantly. By the 11th season, yield from all treatments had declined. There was no longer an effect of row number (or density) on yield except in the 30-cm in-row spacing treatment. Cumulative yield was dominated by the patterns established earlier.

Spear size, as indicated by mass per spear, was only marginally responsive to the spacing treatments. In the 4th year of harvest, no differences among treatments were statistically significant, and the average mass per spear was 10.4 g (data not shown). In the 7th year of harvest, the 5-cm treatment produced significantly smaller spears than the 30-cm treatment in two- and three-row beds, but not in one-row beds (Table 3). Average spear mass in year 7 was 9.25 g. In the 8th year, average spear mass dropped to 7.9 g, and spears from the 5-cm single row treatment weighed significantly less than those from most of the 15- and 30-cm in-row spacings (Table 3). This decrease in spear size apparently accounts for the large reduction in yield between the 5-cm, single row treatment and the 15-cm triple row treatment (Fig. 1). In the 11th year of harvest, average spear mass had dropped to 5.6 g/spear and there were no longer any meaningful differences in spear size among treatments. Although asparagus spears grown in the southeastern United States are generally smaller than those grown in California (Benson et al., 1978; Takatori et al., 1975) and Iowa (Haber, 1940), the trend observed in this study for smaller spears in very close spacings and very high plant populations is similar to trends noted in these previous studies.

Decreasing crop quality at very high plant populations has been noted previously (Willey and Heath, 1969). However, Nichols (1983) dealt with the notion of planting pattern rather than population per se with his concept of

Table 3. Influence of rows/bed and in-row spacing on size of asparagus spears over 11 years at Clinton, N.C. (Third study).

In-row spacing (cm)	Rows/ bed	Plants/ ha	Harvest year		
			7	8	11
			(g/spear)		
5	1	133,332	9.2	6.1	5.3
	2	266,664	8.1	7.7	5.1
	3	399,996	8.7	7.7	5.1
15	1	44,444	9.3	8.1	5.5
	2	88,888	9.5	8.7	5.5
	3	133,332	9.0	8.5	4.9
30	1	22,222	9.4	7.2	4.3
	2	44,444	10.1	8.6	4.7
	3	66,666	10.0	8.9	5.6
LSD _(0.05)			1.2	1.8	1.1

rectangularity, or the ratio of the between-row spacing to within-row spacing. He observed that at ratios >1, asparagus yields were lower. In our study, spacings were not uniform within the bed. But at a given population level, the average rectangularity ratios were inversely related to yield. For example, the ratio was 3.3 for the 15-cm triple row treatment vs. 30 for the 5-cm single row treatment. While this helps explain the behavior of the crop, it does not guide spacing decisions as much as accommodation to available equipment, demands of cultural practices, and other practical concerns.

Highest long-term yields were obtained by maximizing space use efficiency rather than average density in the early, most productive phase of asparagus crop growth. Optimum spacing was 30 cm in three rows per bed in beds 1.5 m apart. Although yield at this spacing did not differ from that of the 15-cm double and triple planted treatments, it was achieved at a lower overall plant population and therefore with less input.

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