Establishment and Yield of Asparagus as Influenced by Planting and Irrigation Method

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Abstract. New Jersey 'Syn 4' asparagus (*Asparagus officinalis*, L.) was grown on a sandy loam soil to compare plant survival and yield of asparagus grown from crowns and transplants under four irrigation treatments: sprinkler (SPR), surface trickle (ST), subsurface trickle (SST), and no irrigation (NI). While plant survival of crowns was not appreciably influenced by any irrigation treatment, survival of transplants was significantly increased by SST. Total and marketable yields from crowns and transplants were similar in the first harvest season (year 3). However, in years 4 and 5, the yield of crowns was higher than that of transplants. Subsurface trickle increased yield from transplants in years 4 and 5 and increased yield from crowns in year 5. All irrigation methods significantly increased both spear production (spear/ha) and average spear weight. Subsurface trickle irrigation resulted in the largest increase over NI in total yield and spear production.

The yield of many hybrid asparagus cultivars is higher than that of older, open-pollinated cultivars (Benson and Takatori, 1980; Damicone and Manning, 1987; Mapplebeck and Tiessen, 1983; Price, et al., 1986). Although transplanting crowns is the primary method of establishing commercial asparagus plantings (Kirpes et al., 1985; Mapplebeck and Tiessen, 1983), the limited seed supply and grower interest in rapid establishment of these new cultivars has resulted in increased interest in using asparagus transplants. Use of greenhouse-grown transplants reduced risk of infection by fusarium wilt and crown rot (*F. oxysporum* and *F. moniliforme*), increased mechanization of planting, reduced planting time and labor, and more efficiently used expensive hybrid seed (Ombrello and Garrison, 1978; Fisher, 1982; Sanders, 1985).

Wilcox-Lee (1987) concluded that maximum growth occurs in young asparagus plants when soil water potential is close to field capacity, indicating that newly established plantings should benefit from irrigation to minimize moisture stress. Advantages of trickle irrigation over sprinkler irrigation are improved growth and early yield of perennial crops (Elfving, 1979), improved water efficiency over sprinklers (Elfving, 1982; Sammis, 1980), and maintenance of a fairly constant soil water content in the root zone (Bucks, et al., 1982). Furthermore, subsurface trickle irrigation requires less yearly labor than surface trickle, has a

longer life expectancy, increases water-use efficiency, and reduces soil compaction (Chase, 1985; Phene et al., 1987; Sammis, 1980). Yield enhancement has been reported for several row crops with subsurface trickle irrigation (Mitchell and Sparks, 1982; Phene et al., 1987).

A complete stand of vigorous plants is needed for long-term profitable production of asparagus (Mapplebeck and Tiessen, 1983). Ombrello and Garrison (1978) reported that, with sprinkler irrigation, plant survival was greater for transplants (98% to 100%) than for direct seeding (23%). The differences in plant establishment and yield of crowns and transplants have not been well-documented, particularly when supplemental irrigation is limited. Also, several researchers have reported positive correlations between vegetative growth measurements and yield, but plant population was not included in these models (Dufault and Greig, 1983; Ellison and Scheer, 1959; Moon, 1976). Our study evaluated the influence of irrigation and planting method (crowns or transplants) on plant establishment and subsequent yield and quality. The relationship between vegetative growth measurements, plant population, and yield was also evaluated.

Materials and Methods

One-year-old crowns and 9-week-old transplants of New Jersey 'Syn-4' asparagus were planted in Apr. 1984 (year 1) on a Bojac sandy loam (coarse-loamy, mixed thermic Typic Hapludult). Each plot consisted of two rows, 7.5 m in length and 1.5 m apart, with 0.3 m between plants within the row. Irrigation treatments included surface trickle (ST), subsurface trickle (SST), sprinkler (SPR), and a nonirrigated control (NI). A single trickle tube (0.30 mm) with 0.2-m emitter intervals was installed in each record row of the trickle treatments. Subsurface trickle lines were installed in the planting furrow at a depth of 0.3 m, and the furrow filled to 0.25 m before planting of crowns and transplants. The furrows were filled gradually during the first

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growing season. Hence, the tops of the established crowns were ≈ 0.21 m below the soil surface.

To avoid overlap of irrigation treatments, a common border row separated adjacent plots. Tensiometers were placed between plants in the second and third replicate of each irrigation/planting method combination, resulting in a total of 16 tensiometers. Irrigation was started on 7 May 1984, 7 May 1985, 20 May 1986, and 6 June 1987, respectively. Irrigation ceased on 30 Sept. of each year. Sprinkler irrigation was applied by micro-sprinklers on 0.6-m risers, wetting most of the fern in the record rows with minimum drift to adjacent border rows. Irrigation was applied to all replications of each treatment when soil moisture tension as measured by tensiometers within that treatment at the 0.3-m depth reached 20 kPa (Pogue and Dooley, 1985). Irrigation was applied until tensiometers registered 0 kPa. After the first year, irrigation was needed on an average of every 5 to 7 days. Recommended cultural practices were followed regarding fertilizer and herbicide applications with insecticides applied as needed. During the first growing season, monthly average temperatures were within 1°C of the 30-year monthly average temperatures for Painter, Va. (NOAA, 1984). However, precipitation was below the 30-year average for June through October (-30 , -3 , -91 , -34 , and -54 mm, respectively) (NOAA, 1984).

Growth measurements were taken on 11 Nov. 1984, 9 Oct. 1985, 24 Nov. 1986, and 7 Oct. 1987. Plant population was recorded for each plot. Height of the tallest fern, diameter of the largest stem, and total number of stems per plant were recorded for 10 consecutive plants.

No spears were harvested during the first two growing seasons. Plots were harvested by cutting spears at the soil surface for 2 weeks in 1986 (year 3), 4 weeks in 1987 (year 4), and 7 weeks in 1988 (year 5). All harvested spears were trimmed to 0.23 m. Marketable yield consisted of straight, unblemished spears >6 mm in diameter.

A split-plot design with plant type as the main effect was used with data analyzed by SAS General Linear Model Procedure (SAS, 1985). Single-degree-of-freedom contrasts were used to measure irrigation treatment effects and the associated interactions. A very low plant population (12%) was recorded for one replicate of transplant ST, apparently caused by a localized variation in soil type. Since this was identified as an outlier using the method of Snedecor and Cochran (1967), observations from this plot were subsequently omitted and Type III sum of squares was used in the analyses of variance.

Results and Discussion

Plant population of asparagus from crowns after four growing seasons averaged 94% (92.5% to 95.6%) of the original population, regardless of irrigation treatment (Table 1, Fig. 1). However, establishment of transplants was significantly improved with subsurface irrigation. After the fourth growing season, 83% of the original transplant population remained with SST compared with 55%, 56%, and 40% with NI, ST, and SPR, respectively. Plant population of transplants was significantly lower with SPR than with either ST, SST, or NI. Ferns of transplants under SPR during the first season were more likely to bend and become encased in the soil than those in other irrigation treatments. Ombrello and Garrison (1978) noted similar problems with direct-seeded seedlings.

More frequent irrigation during the first growing season may have improved plant survival of transplants. Because of the small, shallow root system of transplants early in year 1, the

Table 1. Analysis of variance for effects of plant type and irrigation method on plant population and total yield of asparagus.

Source of variation	Plant survival				Total yield		
	Year				Year		
	1	2	3	4	3	4	5
Main Effect							
Plant type ^z	**	**	**	**	**	**	**
Contrasts ^y							
O vs. irrigation	NS	NS	NS	NS	*	**	**
ST + SST vs. SPR	**	**	**	**	NS	**	**
ST vs. SST	*	**	**	NS	NS	**	**
Plant $\times$ O vs. Irrigation	NS	NS	NS	NS	NS	NS	NS
Plant $\times$ ST + SST vs. SP	**	**	**	**	NS	**	NS
Plant $\times$ ST vs. SST	*	**	**	*	NS	*	*

^zPlant type—crowns or transplants.

^yO = no irrigation, SPR = sprinkler, ST = surface trickle, SST = subsurface trickle.

NS,*,**Nonsignificant or significant at $P = 0.05$ or 0.01 , respectively.

soil tension measurements of the tensiometers in the row between plants may not have been an adequate measure of soil tension within the root zone. Stem diameter and plant height of crowns were significantly larger for crowns than transplants for the first three growing seasons, but not by year 4 (Table 2). In year 2, more shoots per plant were recorded for transplants than crowns, but the stems were thinner. Number of shoots per plant in years 3 and 4, and diameter in year 4, were similar for crowns and transplants.

Vegetative growth was enhanced by irrigation, regardless of irrigation method. Irrigation increased stem diameter of both crowns and transplants in years 1 and 2, number of shoots per plant in all 4 years, and plant height in years 1, 2, and 4. Vigorous fern development has been associated with improved root weight (Benson and Takatori, 1980; Dufault and Greig, 1983; Liptay, 1984) and improved yield during the first harvest season (Liptay, 1984).

Since the trends for total and marketable yield were quite similar, only total yield is presented in Fig. 2. Total yield in year 3 (first year of harvest) was significantly influenced by plant type and additional irrigation, but the yield in all treatments was low. Cool weather during the short (2-week) harvest season (Mapplebeck and Tiessen, 1983) may have had a greater influence on spear growth than irrigation treatment from the previous year.

Yield was significantly affected by plant type, irrigation, and method of irrigation in years 4 and 5, (Table 1, Fig. 2). The total yield ($t\text{-ha}^{-1}$) of each crown treatment exceeded that of transplant treatments, except SST in year 5. By year 5, the yield of transplants with SST exceeded that of crowns with NI or SPR. Benson et al. (1978) reported delayed harvest with crown-established plantings and suggested high-density, direct-seeded plantings for some areas of California production. In our study, planting crowns resulted in greater plant survival and higher yields than transplants, except transplants with SST, during the early years of production.

Total spear production was greater for crowns than transplants, but there was no influence on average spear weight after year (Table 3). However, both the average spear weight and number of spears per hectare were enhanced by supplemental irrigation. The improved yield noted with SST is primarily a result of increased spear production (159% of NI), since SST

Fig. 1. Percent survival of asparagus transplants and crowns with no irrigation (NI) surface trickle (ST), subsurface trickle (SST), or sprinkler (SPR). Standard error of the mean was 6.2, 6.1, 6.2, and 6.1 for 1984 through 1987, respectively. ■, Year 1; ▨, year 2; ▩, year 3; ▪, year 4.

Table 2. Stem diameter, number of shoots per plant, and plant height of asparagus from crowns and transplants as influenced by method of irrigation.

Treatment	Stem diam (mm) ^z				Plant ht (cm) ^y				No. shoots per plant			
	Year				Year				Year			
	1	2	3	4	1	2	3	4	1	2	3	4
Plant type												
Crowns	5.1	11.3	14.7	17.4	79.8	164	197	228	4.8	12.2	13.8	13.2
Transplants	3.0	8.5	12.2	17.0	54.2	138	177	218	4.1	14.3	12.4	14.2
Significance	**	**	**	NS	**	**	**	NS	**	*	NS	NS
Irrigation ^x												
NI	3.6	8.8	13.1	16.7	58.1	116	184	198	3.8	7.7	9.9	7.3
ST	3.9	10.1	13.0	16.9	66.6	162	187	223	3.9	15.2	13.3	14.7
SST	4.4	10.8	14.0	17.6	73.4	170	194	231	5.3	16.3	14.8	14.9
SPR	4.5	10.1	14.0	17.7	71.6	158	184	239	4.6	13.9	14.8	17.9
Contrasts												
NI vs. Irrigation	*	**	NS	NS	**	**	NS	**	*	**	**	**
ST + SST vs. SPR	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	*
ST vs. SST	*	NS	NS	NS	**	*	NS	**	NS	NS	NS	*
Plant type × vs. Irrigation ^w	NS	NS	NS	NS	NS	NS	**	**	*	NS	NS	NS

^zDiameter of the largest stem averaged over 10 adjacent plants.

^yHeight of tallest fern, average of 10 adjacent plants.

^xNI = no irrigation, SPR = sprinkler, ST = surface trickle, SST = subsurface trickle.

^wOther interactions: plant type × ST + SST vs. SPR and plant type × ST vs. SST not significant.

NS,*,**Nonsignificant or significant at $P = 0.05$ or 0.01 , respectively.

did not increase average spear weight over other irrigation methods. Improved yield of transplants with SST can be attributed to both increased plant population (Fig. 1) and an increased number of spears per plant (data not shown).

Multiple coefficient correlation using plant population, fern height, stem diameter, and total number of stems per plant indicates a stronger relationship between yield and plant population than any of the vegetative growth measurements. (Table 4). The stalk index (number of shoots × stem diameter) of Ellison and Scheer (1959) did not improve this relationship (data not shown). This result agrees with previous observations that adequate plant establishment is essential for high yields and

long-term profitability of asparagus (Benson et al., 1978; Maplebeck and Tiessen, 1983).

The use of asparagus transplants has been advocated to avoid the cost and increased time needed to produce crowns, although transplants require more intense management of irrigation and weed control (Benson et al., 1978; Ombrello and Garrison, 1978; Sanders, 1985). While the yields reported for transplants in year 5 (except that of transplants with SST) of this study were equivalent to average commercial yields reported by Lorenz and Maynard (1988), yield was substantially improved with crowns and/or subsurface trickle irrigation.

In this study we found that improved plant survival and in-

Fig. 2. Total yield ($\text{t}\cdot\text{ha}^{-1}$) of transplants and crowns in years 3 (first harvest season), 4, and 5 as influenced by planting method and irrigation method. Standard error of the mean was 0.02, 0.19, and 0.48 for 1986 through 1988, respectively. ■, NI; ▨, ST; ▩, SST; ▤, SPR.

Table 3. Average spear weight and spear number as influenced by plant type and irrigation method.

Treatment	Average spear wt (g/spear)			Spear number (1000/ha)		
	Year			Year		
	3	4	5	3	4	5
Plant type						
Crowns	17.7	22.3	23.9	24.1	159	317
Transplants	12.2	22.4	25.0	18.5	79	186
Significance	**	NS	NS	**	**	**
Irrigation						
NI	17.5	19.9	22.8	18.1	106	207
ST	13.5	23.4	25.2	19.4	126	237
SST	13.9	22.1	24.6	22.8	150	330
SPR	15.1	24.0	25.2	25.0	100	231
Contrasts ^z						
NI vs. Irrigation	**	**	**	**	*	**
ST + SST vs. SPR	NS	NS	NS	NS	**	**
ST vs. SST	NS	NS	NS	NS	**	**
Plant × NI vs. Irrigation ^y	NS	NS	*	NS	NS	NS
Plant × ST vs. SST	NS	NS	NS	NS	NS	*

^zNI = no irrigation, SPR = sprinkler, ST = surface trickle, SST = subsurface trickle.

^yInteraction Plant × ST + SST vs. SPR nonsignificant.

NS,*,**Nonsignificant or significant at $P = 0.05$ or 0.01 , respectively.

Table 4. Multiple correlation coefficients using growth variables to estimate yield.

Model	Variables (partial R^2)	1986	1987	1988
Total yield	Model (R^2)	0.24*	0.98**	0.81*
	Plant population	0.24**	0.84**	0.66**
	Stem diameter	---	0.07**	0.12**
	Number of shoots	---	0.03**	0.03**

*Variable not in the model of the year indicated.

*,**Significant at $P = 0.05$ or 0.01 , respectively.

creased yield during the early harvest seasons can be obtained with crowns rather than transplants, when adequate supplemental irrigation is not available. However, Sterrett et al. (1978) reported lower cost of establishment for transplants with SST

than for crowns without irrigation, provided the facilities for trickle irrigation (water source, pump, etc.) are available. When SST is feasible, the slightly higher yield from crowns may be offset by the expediency (time, cost of plants, and labor) of planting transplants. Since asparagus is a perennial crop that requires a long-term investment, improved plant survival of crowns or transplants with SST, and improved yield with trickle irrigation, would benefit growers by increased economic return during the early harvest seasons.

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