

# Mother Stalk Culture Does Not Improve Plant Survival or Yield of Spring and Summer-forced Asparagus in South Carolina

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**Abstract.** Short productive lifespan is a major problem with asparagus (*Asparagus officinalis* L.), whether harvested in the spring or forced in late summer in coastal South Carolina. A modification of the Taiwanese system of mother stalk (MS) culture might enhance asparagus longevity and yield. The objective of this research was to determine if modified MS culture improved plant survival and yields in spring or summer-forced harvests compared with conventional spring clear-cut (CC) harvesting or with nonconventional summer-forced CC harvesting. 'Jersey Giant' asparagus was harvested for 3 years (1994-96) using the following harvest systems: 1) spring CC (normal emergence in February in this location); 2) spring MS followed by summer MS (mow fern down on 1 Aug. and establish new mothers); 3) spring MS only; 4) summer CC only (mow fern on 1 Aug. and harvest); and 5) summer MS only. All systems were harvested for ≈7 weeks. All MS plots produced 40 mother stalks per 12-m row length each year before harvesting began. All mother stalks were trellised and tied to prevent lodging. Three-year total yields (kg·ha<sup>-1</sup>) and stand reduction (%) for nonharvested controls, spring CC harvesting, spring MS culture, spring MS combined with summer MS, summer CC, and summer MS were: 0 and 54%, 1621 and 96%, 779 and 99%, 1949 and 86%, 4001 and 58%, 3945 and 58%, respectively. All spring harvesting systems failed because by midsummer, aged fern, harvest pressures, and, apparently, higher rates of crown respiration reduced crown carbohydrate reserves. Yearly repetition of these stresses ultimately killed the spring-harvested plants. The MS culture did not ameliorate stand loss by significantly increasing carbohydrate reserves. Yields of summer-forced asparagus were consistently acceptable because aged ferns were removed at about the time they apparently became inefficient photosynthetically. After termination of the summer harvest season and with recovery in the following spring, ample carbohydrates were produced well before summer forcing began again in August the following year. Therefore, plant longevity was better sustained by summer forcing than by traditional spring harvesting.

Asparagus is produced from January to July in the United States, but as the supply increases from winter to summer, grower prices decline. After production ceases in midsummer, fresh-market asparagus must be imported. During this time, the price rises progressively from late summer through fall and early winter until domestic production resumes again the next year. Successful forcing of asparagus in summer and fall in South Carolina could capture some of this market and provide growers with new alternatives.

Previous research in coastal South Carolina indicated that within a 5-year period after transplanting, yields of asparagus declined to unacceptable levels because of plant death.

Summer-forced asparagus yielded better and lived longer than did normal spring clear-cut (CC) plants (Dufault, 1994, 1995). Productive lifespan of spring-harvested asparagus, however, was only 2 (Dufault, 1994) to 3 years in South Carolina (Dufault, 1995). Short lifespan was caused by poor fern vigor after the harvest season, since the fern's growing season after spring harvest lasted over 7 months. Dufault (1995) suggested that the capacity for aged fern to produce carbohydrates was severely reduced and stored root carbohydrates were utilized for metabolism after midsummer. Lin

and Hung (1978) reported that asparagus fern reached greatest photosynthetic efficiency ≈3 months after emergence, but net CO<sub>2</sub> assimilation rate declined to a minimum ≈5 months after emergence. Yearly repetition of harvest pressures, plus the influence of aged fern in reducing crown carbohydrate content in late summer and fall, reduced plant vigor, stand, yield, and, ultimately, longevity (Dufault, 1994, 1995).

The advantage of summer forcing is that aged, inefficient fern is removed at the onset of photosynthetic inefficiency, enabling the asparagus to recover more successfully, elaborate more root carbohydrates, and live longer than spring-harvested asparagus (Dufault, 1995). Death after many years of summer forcing averaged ≈30% vs. ≈54% for spring-harvested asparagus (Dufault, 1994, 1995). Summer-forced asparagus exhibits a characteristic short-term single flush of spears, usually within 10 d after fern mowing. In contrast, spring production is characterized by multiple flushes of spears over a 2- to 3-month period.

Lin and Hung (1978) reported that MS culture prolonged plant lifespan and improved yield in Taiwan, where the technique originated. Mother stalk (MS) asparagus culture was developed in Taiwan and has been used commercially since 1961 to increase quality and yields in tropical/subtropical climates (Wang, 1965). The basic concept of MS culture is to allow three to five stalks per plant to develop into fern that produces photosynthate, while harvesting of adjacent spears continues. Hung (1980) reported yields of up to 8000 kg·ha<sup>-1</sup> with MS culture, but profitable production lasted only 8 years. Another desirable feature reported with MS culture is extension of the length of the harvest season. Hung stated that MS culture may be adaptable to other areas of the world with climates similar to that of Taiwan.

Coastal South Carolina experiences tropical summers and subtemperate winters and MS culture may extend the harvest season and reduce stand loss. The objective of this research was to determine if MS culture improves plant survival and yields in spring or summer compared with spring CC harvesting or with nonconventional summer-forced CC harvesting.

## Materials and Methods

On 29 Aug. 1990, 10-week-old 'Jersey Giant' asparagus seedlings were transplanted to the bottom of 10-cm-deep furrows 15 cm

Table 1. Harvesting treatments applied to 'Jersey Giant' asparagus (1994-96).

Harvesting system <sup>y</sup>	Harvest <sup>z</sup>		Time of mowing
	Spring	Summer	
Spring CC	Yes	No	January
Summer CC	No	Yes	August, January
Spring MS	Yes	No	January
Summer MS	No	Yes	August, January
Spring/summer MS	Yes	Yes	August, January
Control 1	No	No	January
Control 2	No	No	August, January

<sup>z</sup>Harvested three times weekly for ≈7 weeks, then ferns allowed to develop.

<sup>y</sup>CC = clear cut; MS = mother stalk.

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Table 2. Dates of first and last appearance of mother stalks (MS), length of time to establish 40 MS, dates of first and last harvest, length of harvest season, and marketable yield for five asparagus harvesting systems from 1994 to 1996.

Harvesting system <sup>y</sup>	1994							1995							1996							Total yield
	MS			Harvest				MS			Harvest				MS			Harvest				
	F <sup>z</sup>	L	Ln	F	L	Ln	Y <sup>x</sup>	F	L	Ln	F	L	Ln	Y	F	L	Ln	F	L	Ln	Y	
(date)	(d)	(date)	(d)	(date)	(d)		(date)	(d)	(date)	(d)	(date)	(d)		(date)	(d)	(date)	(date)	(date)	(d)			
Spring CC	---	---	---	2/28	4/27	50	538 c <sup>w</sup>	---	---	---	3/9	5/3	55	904 b	---	---	---	3/30	4/17	18	179 b	1621 c
Spring MS	2/25	4/16	40	4/7	5/30	53	1043 b	3/11	4/1	21	3/31	5/23	53	906 b	3/29	5/22	54	---	---	---	0 c	1949 c
+summer MS	8/5	8/22	17	8/25	10/15	51		8/6	10/10	---	9/28	10/20	22		---	---	---	---	---	---	---	
								(32) <sup>u</sup>														
Spring MS	2/25	3/24	27	3/24	5/17	54	101 d	3/10	3/20	10	3/20	5/12	53	678 b	4/9	5/22	44	---	---	---	0 c	779 d
															(1) <sup>u</sup>							
Summer CC	---	---	---	8/5	9/24	50	1285 a	---	---	---	8/4	9/27	54	1277 a	---	---	---	8/8	10/1	54	1439 a	4001 a
Summer MS	8/5	8/13	8	8/5	10/6	54	1034 b	8/5	8/10	5	8/10	10/4	55	1257 a	8/5	8/12	7	8/13	10/5	53	1654 a	3945 a

<sup>z</sup>F = first harvest; L = last harvest; Ln = length of time to establish 40 MS; Y = yield.

<sup>y</sup>CC = clear cut; MS = mother stalk.

<sup>x</sup>Yield and total yield in kg·ha<sup>-1</sup>.

<sup>w</sup>Mean separation within columns by LSD at P = 0.05.

<sup>v</sup>No harvest possible because of poor plant vigor or death.

<sup>u</sup>Some plots did not produce 40 mother stalks due to very poor vigor. Number in parentheses indicates the average number of mother stalks established per plot.

apart in single rows spaced 1.8 m apart from bed center (35,424 plants/ha). The soil was a Yauhannah loamy fine sand (Aquic Hapludults). Each plot consisted of a single test row bed containing 70 transplants and was bordered on each side by a guard bed of the same size and plant population. In 1991, the soil was ridged ≈20 cm above normal ground level before spear emergence and maintained at that height for 5 years. Standard commercial fertilization and cultural practices were used during the course of the experiment (Cook, 1992). Fern vigor was encouraged without harvest until Spring 1994, when the first harvests began. The harvest system treatments are outlined in Table 1. Trellises were installed in all mother stalk plots to tie and support the first 40 spears to emerge and allow fern to develop into "mother stalks."

Four replications of each harvest system were arranged in a randomized complete-block design. Stand counts were taken yearly each spring, 1 month after spear emergence, from 1990 to 1996. In Aug. 1996, plant populations were recorded to determine stand loss over the 6-year period. From 1994 to 1996, root samples from each plot were cored using a soil probe at about monthly intervals, and carbohydrate levels were determined as described by Dufault (1994). Spears were harvested by cutting them above the soil surface with a knife, and graded into either marketable or cull quality categories based on U.S. Dept. of Agriculture (USDA) standards (USDA, 1977). The diameter of each marketable spear butt was measured and graded as large (>1.3 cm), medium (0.8–1.3 cm), or small (<0.8 cm). All data were subjected to analysis of variance and means separated by least significant difference (LSD) if the F test was significant at P ≤ 0.05.

### Results and Discussion

**First harvest season—1994.** Spring harvests began 28 Feb. and continued for 50 d until 27 Apr. (Table 2); summer CC forcing began 5 Aug. and terminated 24 Sept. Traditional spring CC harvesting yielded 58% less

than did summer CC harvesting, due, in part, to the warmer temperatures in summer, which encouraged greater spear emergence during the harvest season.

Of all the harvesting systems, spring MS culture yielded the fewest spears, producing 81% less than did spring CC and 92% less than did summer CC (Table 2). Spring MS required 27 d to establish the prescribed 40 mother stalks per plot. First MS harvests began 24 Mar., almost 1 month after first spear emergence, and continued for an additional 54 d. Yields were lower in this system because of the number of spears used for mother stalks, and the apical dominance effect of the latter. Spring CC produced an average of 119 marketable spears per plot vs. 30 spears for spring MS, and total spear production was 75% less in the latter.

The total spear yield from spring MS combined with summer MS was 90% greater than for spring MS alone and 48% more than for spring CC alone (Table 2), with 30% of the total yield produced in the spring and 70% in summer. The negative effect of the combined spring/summer MS harvesting was apparent by summer because 17 d were required to establish 40 mother stalks vs. only 8 d in the summer MS system alone. The most productive harvesting system in 1994 was summer CC harvesting, which yielded from 23% to 172% more than did other systems.

Harvest season affected the quality of mar-

ketable spears (Table 3). Spring/summer MS and summer MS harvesting systems yielded the highest percentage of large spears, summer CC an intermediate percentage and spring CC and spring MS the lowest percentages. Percentage of medium-sized spears followed the same order: spring/summer MS > spring CC = summer MS > summer CC > spring MS. Relative yield by percentage of small-sized spears was spring MS > spring CC = summer CC > summer MS > spring/summer MS.

**Second harvest season—1995.** First harvests began 9 Mar. and continued for 55 d until 3 May (Table 2). Spring CC yielded 68% more in 1995 than in 1994. Summer CC forcing began 4 Aug. and terminated 27 Sept. and yielded 41% more than traditional spring CC, while yields for spring MS and spring CC did not differ significantly from one another. Summer MS yielded 46% more than did spring MS and 28% more than did spring/summer MS, and required only 5 d to establish mother stalks in summer.

Yields for spring/summer MS did not differ significantly from those for spring MS (Table 2). Harvest stress induced by combining spring and summer harvests in 1994 became apparent in 1995 as 92% of the spring/summer MS yield occurred in the spring season and only 8% in the summer. Even by 10 Oct. 1995, the spring/summer MS plants had established only 80% of the required mother stalks per plot, indicating reduced vigor, and

Table 3. Influence of five harvesting systems on asparagus spear quality from 1994 to 1996.

Harvesting system <sup>z</sup>	Spear diameter distribution (%)								
	1994			1995			1996		
	L <sup>y</sup>	M	S	L	M	S	L	M	S
Spring CC	3 c <sup>x</sup>	60 b	37 bc	0 a	53 a	47 ab	7 a	49 a	44 a
Spring/summer MS	8 a	70 a	22 d	4 a	61 a	36 c	---	---	---
Spring MS	2 c	44 d	54 a	3 a	56 a	44 bc	---	---	---
Summer CC	4 b	55 c	41 b	0 a	45 a	55 a	1 a	56 a	43 a
Summer MS	7 a	60 b	33 c	2 a	57 a	42 bc	0 a	61 a	38 a

<sup>z</sup>CC = clear cut; MS = mother stalk.

<sup>y</sup>L = large (>13 mm); M = medium (8 to 13 mm); and S = small (<8 mm).

<sup>x</sup>Mean separation within columns by LSD at P = 0.05.

<sup>w</sup>No harvestable spears.

no plants produced marketable spears. Wang (1970) also reported that harvest stresses from spring/summer CC depressed yields the following spring.

The most productive harvesting systems in 1995 were summer CC and summer MS, which were equivalent in yield (Table 2). The production of medium and large spears was unaffected by harvest system, but percentages of small spears tended to be highest in both spring CC and summer CC systems and least in spring/summer MS.

**Third harvest season—1996.** Stress induced by 1994 and 1995 harvests had become obvious by 1996. The greatest loss of stands occurred between Fall 1995 and Spring 1996, with reductions of 96%, 86%, and 99% of the original number planted in 1990 in the spring CC, spring/summer MS, and spring MS, respectively (Table 4); as a result, yields were negligible (Table 2). The loss of plants was not due totally to harvest alone, for stands declined by 55% and 52% in the two nonharvested controls, perhaps because of the very close spacing (15 cm) between plants. This close spacing was used in anticipation of stand loss, which in previous work averaged  $\approx 30\%$  after 6 years for nonharvested plants spaced 30 cm apart (Dufault, 1994, 1995). In the present study, the plant population stabilized to  $\approx 30$  cm apart after 6 years in both the controls and the summer systems, yielding  $\approx 15,675$  plants/ha. Forcing in summer, using either CC or MS harvesting, did not reduce stands relative to the controls. Both systems had similar yields, which increased 11% and 24% from 1995, respectively, indicating increased plant vigor and prolonged productivity. Cumulative yields over the three harvest years were greatest for both summer CC and summer MS harvest systems. Summer MS culture had no significant yield advantage over CC, and would require greater economic and cultural inputs, thus reducing net profitability. Summer CC forcing has better potential as a traditional production system in coastal South Carolina than does spring CC harvesting. Spear diameter distribution in 1996 was similar for spring CC, summer CC, and summer MS systems (Table 3).

Spring harvesting systems, using either CC or MS, were not viable for long-term production of 'Jersey Giant'; however, this cultivar responded exceptionally well to summer forcing. Both summer CC and summer MS harvesting systems yielded acceptably in all 3 years. Therefore, summer harvesting is a superior system of producing asparagus than the traditional spring harvesting, with summer CC preferable to summer MS because the former is less labor intensive. The superiority of summer harvesting agreed with previous work reported for 'UC 157F<sub>1</sub>' (Dufault, 1994, 1995).

Failure of spring harvesting systems appears to be caused by the poor ability of aged fern to replenish root carbohydrates required for subsequent spring harvesting. Kelly and Bai (1997) stated that in temperate regions, there may be a time in the fall when senescing fern can be removed with minimal effect on subsequent yields. This point may be reached

Table 4. Stand loss and plant populations of asparagus harvested in spring and fall using several harvest systems.

Harvesting system <sup>z</sup>	Stand loss from 1990 to 1996 (%)	No. plants/ha in Aug. 1996 <sup>y</sup>
Spring CC	96 a <sup>x</sup>	1,417 bc
Spring/summer MS	86 b	4,959 b
Spring MS	99 a	354 c
Summer CC	58 c	14,878 a
Summer MS	58 c	14,878 a
Control—no harvest or summer fern mowing	52 c	17,003 a
Control—no harvest, but fern mowed in summer <sup>w</sup>	55 c	15,941 a

<sup>z</sup>CC = clear cut; MS = mother stalk.

<sup>y</sup>Original plant population in 1990 was  $\approx 15,972$  plants/ha.

<sup>x</sup>Mean separation within columns by LSD at  $P = 0.05$ .

<sup>w</sup>All fern mowed about 1 Aug. yearly from 1994 to 1996.

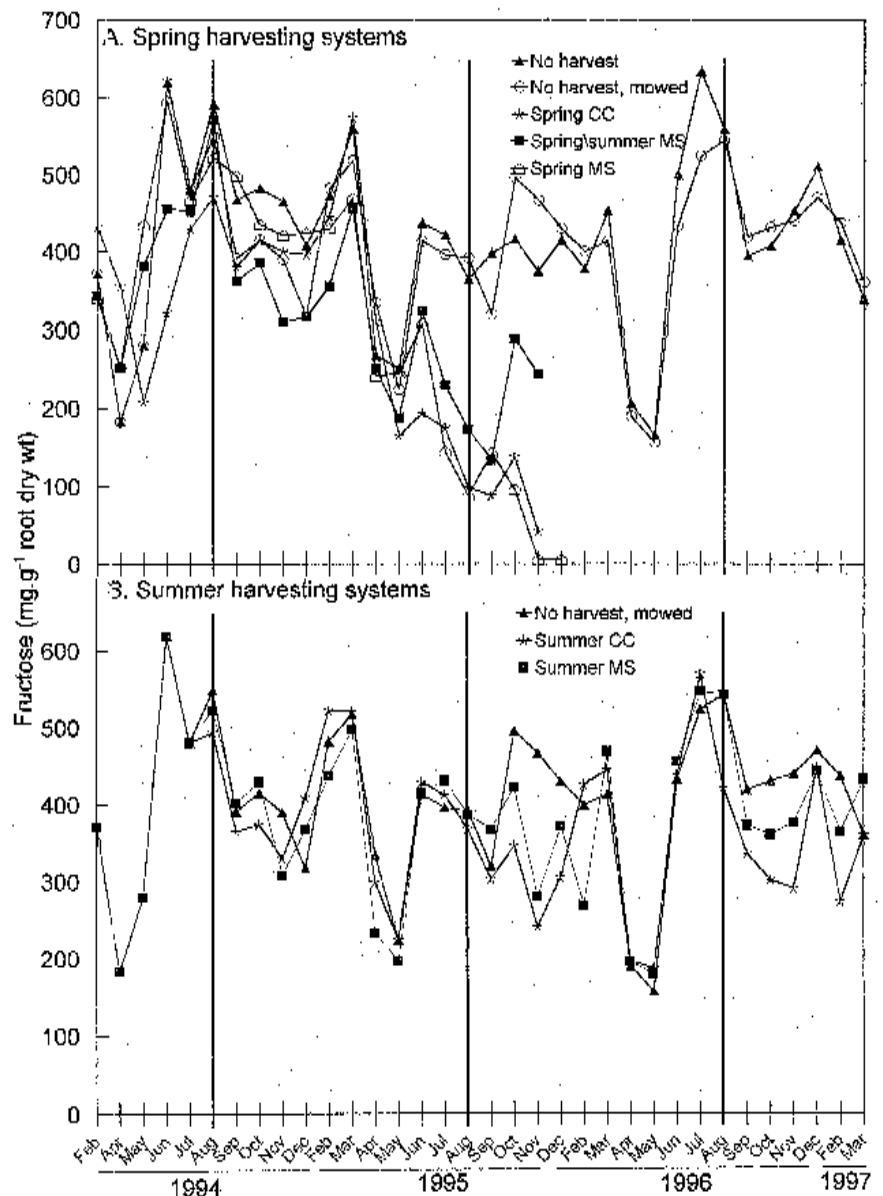


Fig. 1. Influence of (A) spring and (B) summer harvesting systems on the fructose content of 'Jersey Giant' asparagus roots from Feb. 1994 to Mar. 1997. Vertical lines indicate when the ferns were mowed.

when carbohydrate gain from photosynthesis falls below carbohydrate consumption by respiration. By midsummer, the fern in coastal South Carolina is similar in chronological age to fern in the fall in more northern zones. The failure of spring-harvested systems may be a result of high respiration of fern and root

systems by midsummer, and the net loss of carbohydrates may contribute to the plants' poor vigor and early death.

Carbohydrate levels in asparagus plants are directly related to plant vigor and hence to growth and yields (Shelton and Lacy, 1980); therefore, root carbohydrate status is a useful

indicator of harvest stress. The root carbohydrate levels in the nonmowed, nonharvested controls illustrated the natural cycling of root carbohydrates over time for 3 years without the stress imposed by harvesting (Fig. 1A). The levels were similar for nonharvested controls over the years regardless of mowings, although they usually dropped after summer mowing. This observation verifies that removal of aged summer fern is not detrimental. In late winter and early spring, the emergence, growth, and development of fern utilized carbohydrates stored the previous fall, which caused a precipitous drop in the levels in the controls, especially during April and May. Wilson et al. (1997) reported that carbohydrate content declines steadily during harvest, but especially during periods when fern are produced. Apparently, 3 months were required for carbohydrate levels to return to preemergence levels; this recovery time has been reported previously (Robb, 1984; Scott et al., 1939; Shelton and Lacy, 1980). After fern expansion and maturation, root carbohydrates increased rapidly from May to June and remained high until July before declining from July to August. The fern after July appeared aged, with the needles turning yellow and abscising, and the fern probably had a reduced photosynthetic capacity. Lin and Hung (1978) reported the highest levels of photosynthetic efficiency  $\approx$  3 months after emergence in Taiwan, but the levels declined to a minimum 5 months after emergence. From September through fern senescence in late fall, carbohydrate levels remained high until the new spring spear production began.

Spring CC and MS plants in 1994 recovered their root carbohydrate balance before the onset of the second year's harvesting in 1995, but after the harvest season, carbohydrate levels continued to decline rapidly, coinciding with plant death (Fig. 1A). Neither spring MS

nor spring/summer MS enhanced carbohydrate accumulation, since carbohydrate levels were similar to those of CC plants.

Carbohydrate levels in summer MS and CC forcing systems paralleled those in nonharvested controls (Fig. 1B). The yield superiority of the summer forcing systems was related to: 1) maximum carbohydrate production during peak photosynthetic efficiency in spring; 2) removal of aging fern by midsummer; 3) postharvest development of new, efficient fern, producing ample carbohydrates for spring spear emergence; and 4) maintenance of the best seasonal balance between accumulation and depletion of root carbohydrates. At fern mowing in August, the fern in summer CC and MS plots were  $\approx$  5 months old and carbohydrate levels had begun to decline by the July sampling. With summer forcing, this aged fern was removed and replaced with new, efficient fern. Full recovery of crown carbohydrates after summer forcing occurred from March to August the following year. A major difference between spring and summer spear production is that summer-forced spears emerged in one large flush because of high temperatures during summer, rather than over long periods under cool temperatures. To make summer harvesting commercially profitable for longer harvest periods, large plantings should be subdivided and sequentially mowed, harvested, and allowed to produce fern to synchronize multiple flushes of each subunit to produce continuous production overall.

Summer CC harvesting has potential for asparagus growers in areas with climates similar to coastal South Carolina at times when the majority of fresh product is imported and the value is very high. Summer MS culture did not yield more than did summer CC harvest; furthermore, the additional cost of labor to trellis and tie mother stalks makes the MS system more labor intensive and less profitable.

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