Response of Spring and Summer-harvested Asparagus to Harvest Pressures

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Abstract. The objective of this study was to determine the effect of cutting pressures on fern and crown growth of spring- and summer-harvested asparagus (*Asparagus officinalis*). Two-year-old 'UC 157 F₁' asparagus seedlings, grown outdoors in 57-liter pots, were harvested for the first time in spring (Mar. 1988) or summer (July 1988) at cutting pressures of three, six, nine, or 12 spears/plant. Fern was mowed to encourage spear emergence in summer. Cutting pressures had no effect on spear diameter in either season. Summer harvesting required 52% less time to complete than spring harvesting. Fern of spring-harvested plants lived 63 days longer than fern emerging after summer harvests; cutting pressure had no effect on fern lifespan. By Nov. 1988, crown quality and growth, harvest times, and storage root carbohydrates were similar among all cutting pressures; however, carbohydrate content was higher in summer-harvested than spring-harvested crowns. Crowns were cold-stored during Winter 1988 and planted in the field in Spring 1989. Plants harvested in Summer 1988 produced 21% more fern in Summer 1989 than those harvested in Spring 1988. Fern production in 1989 was similar for all cutting pressures.

Domestic production of asparagus in North America is scarce from July to December when the price of imported fresh-market asparagus increases. To enter into this market, the practice of forcing asparagus in summer and fall has been attempted in Mississippi (Farish, 1937), the Sandhill region of South Carolina (Scott et al., 1939), Delaware (Brasher, 1956), Canada (Jasmin and Laliberte, 1962), and Mexico (Campbell Inst. Agr. Res., 1970). Generally, summer forcing has some potential in areas with long growing seasons, but no practicality in areas with short growing seasons. Quality of summer-forced asparagus in these studies was

generally inferior to the traditional spring product. Small spear size is related to low carbohydrate levels in storage root systems (Scott et al., 1939). Reducing the growing period of the fern after the harvest season restricts the supply of storage carbohydrates and may reduce the yield the following year (Haber, 1940; Lewis, 1934).

Cutting pressure severity or harvest pressure is a critical production factor in asparagus production. Various studies have evaluated the effect of harvest pressure severity on asparagus yields (Benson and Motes, 1982; Lewis, 1934; Lloyd and McCollum, 1938; Scott et al., 1939; Shelton and Lacy, 1980; Takatori et al., 1970; Williams and Garthwaite, 1973). Generally, excessive harvest pressure reduces plant vigor and recovery, causing yield the following season to be significantly reduced.

In major production regions in the United States, asparagus harvests last 8 to 14 weeks during the spring. After the harvest season,

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Table 1. Effect of cutting pressure and harvest season on production characteristics of spring- and summer-harvested 2-year-old asparagus plants in the first year of harvest and fern production the following growing season.

Harvest season	No. spears harvested/plant ^z				Significance	Mean
	3	6	9	12		
<i>Harvest season duration (days)</i>						
Spring	10 a	23 a	30 a	58 a	L**	30 a
Summer	3 b	6 b	13 b	15 b	L*	9 b
Mean	7	15	22	37	L**	
<i>Days from first to last emergence after end of harvest season</i>						
Spring	203 a	196 a	188 a	149 a	L*	183 a
Summer	91 b	91 b	79 b	87 b	NS	87 b
Mean	147	144	134	118	L*	
<i>Number of live ferns at end of experiment</i>						
Spring	9	9	12 a	7 a	Q*	9
Summer	7	8	7 b	10 b	Q*	8
Mean	8	9	10	9	Q*	
<i>Total spears (%) emerged after end of harvest season to survive until experiment's end</i>						
Spring	23 a	28 a	28 a	25 a	NS	26 a
Summer	34 b	43 b	52 b	57 b	L*	47 b
Mean	29	36	40	41	L*	
<i>Fern weight (g)/plant at experiment's end</i>						
Spring	2000	2080	2050	1830	Q*	1990
Summer	1930	2030	1980	2140	NS	2020
	1970	2060	2010	1980	NS	

^aSeparation of means within variables and columns by F test; $P = 0.05$.

*,**,NS Linear (L) or quadratic (Q) effects significant at $P = 0.05$ or 0.01 or not significant, respectively.

the plants accumulate storage root carbohydrates and may be dormant 20 to 25 weeks in the winter. Asparagus harvested twice annually in spring and summer in the Bajío area of Mexico produced significantly higher cumulative yields than sole spring harvests (Campbell Inst. Agr. Res., 1970). In this area of Mexico, the plants remained dormant for ≈ 15 weeks. In the coastal area of South Carolina, the normal dormant period for asparagus is similar to that reported in Mexico.

Since harvest pressure severity may be critical in forcing asparagus, the interaction between the two needs evaluation. The objectives of this study were to test the effect of cutting pressure severity and spring and summer harvesting on 1) fern longevity, 2) fern and crown growth at the end of the first season after harvesting, and 3) recovery from harvest pressures in the following year.

Ten-week-old 'UC 157 F₁' asparagus seedlings were transplanted 5 Aug. 1986 into 19-liter black plastic pots, filled with Terra-lite Redi-Earth medium (W.R. Grace, Cambridge, Mass.) and placed in a greenhouse until Spring 1987. Each pot was fertilized with 19 g Osmocote (14N-6P-12K). On 23 Apr. 1987, the plants were transplanted into 57-liter black plastic pots filled with Terra-lite medium. The pots were moved outdoors parallel to the east side of a greenhouse, but were not shaded by it. The plants were drip-irrigated daily with tap water. Each pot was fertilized with 56 g Osmocote (14N-6P-12K) on 23 Apr., 20 July, and 21 Sept. 1987. The fern was contained within tomato cages to prevent lodging. On 20 Nov. 1987, the pots were moved into an unheated greenhouse (10 + 5C) and were not watered further to encourage fern desiccation and induce dormancy for winter storage.

The pots were moved outside 24 Feb. 1988, and treatments were assigned in a random-

ized complete block design. Cutting pressure treatments included harvesting three, six, nine, and 12 spears/plant. These cutting pressures were imposed in spring (March) and in summer (July). Fern was permitted to grow after the indicated number of spears had been cut. Spear emergence and hence spring harvest treatments began as soon as the pots were moved outside in February. To encourage spear emergence in summer, the fern was cut back to the media surface on 1 July. Cutting pressure and harvest timing treatments were factorially combined to produce eight treatments. Each treatment was replicated 12 times with one plant per replication. To prevent confounding of treatment effect with sex, six males and six females were assigned to each treatment across all replications.

Each pot was drip-irrigated daily with tap water. Osmocote (14N-6P-12K) at 56 g/pot was applied 24 Feb. 1988. Fern was contained within tomato cages. On 4 May 1988, Osmocote (17N-3P-11K) at 75 g/pot was applied to each pot, as well as a 2-liter drench of the following: calcium nitrate (2.6 g/liter), 20N-9P-17K (135 ppm), and 313 mg-liter⁻¹ of Soluble Trace Element Mixture (W.R. Grace). On 24 May 1988, 46 g dolomitic lime and 20 g calcium nitrate were added to each pot.

Spear diameter at the butt end of all harvested spears was measured. Each spear emerging after completion of harvest was tagged with a plastic tape and Julian date recorded. Fern was considered "dead" if it could be removed from the plant with light manual pulling. The following data were determined from these measurements: number of spears to emerge after harvest season ended, days from first spear to last emergence after the harvest season ended, length of the harvest season, number of "live" spears at experiment's end, lifespan of fern emerging after

harvest, and percentage of total number of spears emerging after harvest season to survive until experiment's end on 9 Nov. 1988.

On 9 Nov. 1988, all ferns were removed from all pots and were counted and weighed. Crowns were removed from the pots, washed and allowed to air dry in a greenhouse for 2 days before being weighed. The number of storage roots was counted. A subjective rating of crown growth was taken for the following: number of bud clusters, number of buds within clusters, general bud size, percentage of rhizome considered spent or dead, degree of crown segmentation, root vigor and quality, and overall crown quality. Randomly selected root tissue was collected from each crown for carbohydrate analysis. Root tissue was dried for 24 h at 32C and then for 48 h at 75C. The dried samples were ground with a Tekmar A-10 analytical mill (Tekmar, Cincinnati). Fructose content (Shelton and Lacy, 1980) was determined using the anthrone method (Morris, 1948). The crowns were stored at 4C until spring planting.

The crowns were field-planted on 2 Feb. 1989 at the Clemson Coastal Research and Education Center, Charleston, S.C. The soil was a Yauhanna loamy fine sand, an Aquic Hapudults. Preplant fertilizer of 32N-15P-29K at 324 kg-ha⁻¹ was banded in the bottom of the furrows. Crowns were covered with soil and beds prepared. Final crown depth was ≈ 20 cm. The rows were on 1.8-m centers. Crowns were spaced 0.9 m apart within rows. 4-Amino-6-(1,1-dimethylethyl)-3-[methylthio-1,2,4-triazin-5(4H)-one] (metribuzin) at 2.2 kg a.i./ha was applied as a pre-emergence spray after planting. The cumulative numbers of live stems were counted on 3 May, 7 July, and 9 Sept. 1989.

The diameter of harvested spears did not differ among those plants harvested at different cutting pressures in spring or summer (data not shown). These results are similar to those of Williams and Garthwaite (1973), who reported that the number of spears considered of best quality were similar between plots harvested for long vs. shorter time periods.

The duration of the summer harvest season (pooled over all cutting pressures) was 70% shorter than the spring harvest (Table 1). In both seasons, as cutting pressures increased, there was a linear increase in duration of the harvest season. Differences in the rate of spear emergence between spring and summer harvests can be attributed to higher ambient temperatures during summer.

The longer the harvest season, the less time available for production of fern and storage root carbohydrates after harvest terminates. Plants must have enough time to recover from harvest to accumulate carbohydrates in the crowns for use the following harvest year (Shelton and Lacy, 1980). To accomplish this, spear count and diameter must be enhanced because they highly correlate with yields (Ellison and Scheer, 1959). Cutting pressure treatments affected the number of days counted from first to last spear emergence after the end of the spring harvest season for fern growth and development;

however, this factor was not significant for summer harvests (Table 1). As cutting pressure increased in spring, time for spear emergence decreased linearly. There were ≈ 96 more days available after the end of the spring harvests (pooled over all cutting pressures) for fern regrowth and development and carbohydrate production than after summer harvests. In spite of the decrease in harvest season length with cutting pressures, there was no significant difference in the number of spears to emerge after either the spring or summer harvest seasons at any cutting pressure. Summer-harvested plants (pooled over all cutting pressures) produced only 51% as many spears (19 vs. 37; $P = 0.05$) after the end of the harvest season as those spring-harvested.

Harvesting at greater cutting pressures may be stimulator to spear emergence after the harvest season. By experiment's end in Fall 1988, the number of live fern at the end of the experiment after the spring harvests was about the same for plants harvested at three, six, and 12 spears/plant, but there was more live fern on plants when nine spears were harvested per plant (Table 1). In contrast, 27% more fern survived to the end of the experiment for the summer harvest when 12 rather than three to nine spears were cut.

The lifespan of the fern emerging after the harvests ended varied with cutting season. Spring fern lived 63 days longer than fern emerging after summer harvests (121 vs. 58 days; $P = 0.05$). Cutting pressures in spring or summer had no effect on fern lifespan.

The percentage of all spears to emerge after summer harvest and survive until the experiment's end increased with cutting pressure. As cutting pressures increased from three to 12 spears per plant, there was a linear increase in the percentage of ferns to survive until the end of the experiment (Table 1). These percentages did not differ among spring-harvested plants.

Cutting pressure interacted with harvest season to affect fern weight measured at the experiment's termination (Table 1). Weight of fern produced after spring harvests was similar as cutting pressures increased from three to nine spears/plant; however, harvesting 12 spears/plant reduced fern weight. Fern weight was similar at all cutting pressures after summer harvesting.

Spring and summer harvesting or cutting pressure severity did not affect crown quality and fresh weight or fructose concentration per crown (data not shown). The number of

buds and bud clusters and size, the percentage of the rhizome considered dead or spent, the degree of segmentation, root vigor and quality, and the number of storage roots were similar among cutting pressure and harvest season treatments. Apparently, the plants compensated for buds used during summer harvest and postharvest fern production. Fructose content per milligram of dry root was 14% higher in plants harvested in summer than in spring (370 vs. 320 $\text{mg}\cdot\text{g}^{-1}$; $P = 0.05$). Therefore, forcing asparagus in summer apparently was not detrimental to crown vigor and enough time elapsed after each harvest period for the crowns to recover. Shelton and Lacy (1980) reported that soluble carbohydrates of 1-year-old asparagus harvested from 0 to 6 weeks were similar by the fall after spring harvests.

Recovery from harvest pressure was determined by counting the number of fern emerging throughout the 1989 growing season. Generally, recovery was similar among cutting pressure treatments throughout 1989. Significant differences between spring and summer harvesting became apparent by 7 July (10 vs. 13 ferns/plant; $P = 0.05$). Summer-harvested plants the previous year produced 21% more ferns by 9 Sept. than those spring-harvested (24 vs. 19; $P = 0.05$).

The highest cutting pressures evaluated during spring and summer in this study apparently did not hinder plant recovery. Although less time was available after summer harvesting than spring, the time was adequate for recovery. In fact, summer harvesting tends to stimulate growth. Kretschmer and Hartman (1979) reported that more frequent harvesting induces an increase of spear emergence. In our study, summer harvesting may have encouraged release of apical dominance, since none of the crown quality variables, especially number of buds and storage roots, was affected by summer forcing. This heightened growth response apparently compensated for biomass lost in harvesting. The summer-harvested plants may have stored more carbohydrate during the spring when left unharvested than spring-harvested plants. Since fern becomes photosynthetically inefficient ≈ 3 months after emergence (L. Hung, personal communication), the capacity of spring fern to elaborate carbohydrates after harvest may be less efficient than fern produced after summer harvests.

It is apparent that the harvest season and cutting pressures evaluated in this study should be studied in field tests. Although the ex-

perimental treatments imposed during the first harvest season were not detrimental, research is needed to clarify the impact of summer forcing in the field over many years.

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