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Growth and Development of Young Asparagus Plants in Response to N Fertilization

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Abstract. **One-year-old crowns of *Asparagus officinalis* L. cv. Princeville were grown for up to 2 years in pots containing a mineral soil. Nitrogen concentrations ranged from O to 340 kg N/ha. Increasing N fertilizer level resulted in a decrease in total crown fructose concentration and an increase in fern growth, both leveling off at higher N levels. Crown growth was maximized at intermediate N levels. To obtain maximum crown growth and total fructose concentration, while avoiding the excessive fern growth associated with higher N fertilizer levels, ≈57 kg N/ha should be applied to asparagus during the 2nd and 3rd years of growth.**

Various investigators (Hartmann and Wuchner, 1979; Huang, 1979; Morse, 1916; Mullins and Swingle, 1979; Scott et al., 1939) have reported that maximum asparagus yield has been obtained with Nat 54 to 600 kg·ha^{-1}. Others (Benson and Takatori, 1980; Dufault and Greig, 1983; Ellison and Scheer, 1959; Ellison et al., 1960; Morse, 1916; Scott et al., 1939; Tiedjens, 1924) noted positive correlations between crown weight and number of buds; number of fern and number of buds; size of fern and yield, and number of fern and yield; N fertilizer level and crown weight and numbers of roots and spears.

The effect of N fertilization on organic constituents of the asparagus plant has also been investigated. Early studies (Morse, 1916; Nightingale and Schermerhorn, 1928; Scott et al., 1939; Tiedjens, 1924) concentrated on the nature of the carbohydrate storage material (total fructose) present in the root and its role in the production of marketable spears. Morse (1916) and Scott et al. (1939) reported no apparent effect of fertilizer treatment level on carbohydrate reserves, but did report an increase in the concentration of N in roots receiving high N levels. We studied the effect of N fertilizer levels on growth, total crown fructose concentration, and mineral nutrients of asparagus plants in their 2nd and 3rd years of growth in pots to determine the N fertilization rate that maximized growth in terms of potential yield.

One-year-old certified crowns of 'Prince-

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Table 1. Mineral concentrations in asparagus crowns under six levels of N fertilization for 2-year-old (1982 data) and 3-year-old (1983) plants.

N applied (kg·ha⁻¹)	Mineral concn (%)									
	P		K		Ca		Mg		N	
	1982	1983	1982	1983	1982	1983	1982	1983	1982	1983
0	0.214	0.224	1.88	1.48	0.156	0.109	0.089	0.063	1.08	0.92
57	0.199	0.174	1.81	1.15	0.151	0.104	0.102	0.066	1.73	1.29
113	0.210	0.176	1.79	1.15	0.151	0.112	0.106	0.071	2.23	1.76
170	0.196	0.166	1.74	1.08	0.181	0.119	0.119	0.071	2.47	1.83
227	0.200	0.172	1.78	1.05	0.180	0.123	0.124	0.069	2.72	1.96
340	0.175	0.165	1.64	1.06	0.204	0.132	0.131	0.074	2.80	2.23
SE[z]	0.0059	0.0062	0.043	0.037	0.0060	0.0062	0.0033	0.0029	0.071	0.092
Significance[y]	**	**	**	**	**	*	**	NS	**	**
Regressions[x]										
Intercept	0.213	0.199	1.87	1.42	0.146	---	0.089	---	1.11	0.95
Linear coefficient	−1.07E-04*	−1.49E-04+	−0.0007**	−0.0036*	0.00018**	---	0.00023**	---	0.0132**	0.0080**
Quadratic coefficient	---	---	---	8.26E-06+	---	---	−3.12E-07+	---	−2.55E-05**	−1.28E-05+

[z]Standard error of a N treatment mean.
[y]Significance level from ANOVA test for equality of N treatment means, using +, *, and ** for $P = 0.10$, 0.05, and 0.01, respectively.
[x]Parameter estimates and levels of significance from quadratic regressions when the quadratic term was significant, or linear regressions when only the linear term was significant (X = N level)

Table 2. Mineral concentrations in asparagus fern under six levels of N fertilization for 2-year-old (1982 data) and 3-year-old (1983) plants.

N applied (kg·ha⁻¹)	Mineral concn (%)									
	P		K		Ca		Mg		N	
	1982	1983	1982	1983	1982	1983	1982	1983	1982	1983
0	0.226	0.415	0.39	0.60	0.46	0.49	0.16	0.30	1.02	1.03
57	0.183	0.314	0.49	0.51	0.54	0.55	0.18	0.29	1.28	1.05
113	0.194	0.271	0.62	0.45	0.59	0.63	0.23	0.29	1.53	1.21
170	0.208	0.216	0.61	0.42	0.67	0.63	0.27	0.27	1.75	1.24
227	0.212	0.297	0.69	0.44	0.71	0.67	0.28	0.31	1.77	1.39
340	0.222	0.215	0.66	0.47	0.79	0.69	0.33	0.32	1.97	1.32
SE[z]	0.0135	0.0291	0.037	0.049	0.019	0.037	0.012	0.016	0.067	0.075
Significance[y]	NS	**	**	+	**	**	**	NS	**	**
Regressions[x]										
Intercept	---	0.359	0.39	0.59	0.46	0.50	0.16	---	1.03	1.05
Linear coefficient	---	−5.35E-04+	0.0026**	−0.0019**	0.0016**	0.0014**	0.00058*	---	0.0059**	0.0012*
Quadratic coefficient	---	---	−5.47E-06*	4.85E-06**	−1.46E-06*	−2.38E-06*	---	---	−9.13E-06*	---

[z]Standard error of a N treatment mean.
[y]Significance level from ANOVA test for equality of N treatment means, using +, *, and ** for $P = 0.10$, 0.05, and 0.01, respectively.
'Parameter estimates and levels of significance from quadratic regressions when the quadratic term was significant, or linear regressions when only the linear term was significant (X = N level).

vine' asparagus were planted in a randomized complete-block design. Treatments were six N levels: O, 57, 113, 170, 227, and 340 kg N/ha. There were six blocks and within each block each treatment was replicated four times for a total of 24 plots per treatment, with each plot containing 10 crowns.

In June 1982, crowns were weighed and planted one per pot in 21-liter black plastic pots with bottom drainage holes and containing ≈23 kg loamy sand with 0.5% organic matter. Each pot received 1.5 g P and 4.2 g K as superphosphate and potassium chloride, respectively. Pots were set above ground in four double rows on black plastic; drainage from one pot did not flow to neighboring pots.

Ten days after the crowns were potted, treatment levels were established by topdressing the pots with NH_4NO_3 (33.5% N) in the following amounts: 0, 4.6, 9.3, 13.8, 18.4, or 27.7 g. Irrigation was provided as needed using biwall line-source drip irrigation tubing laid out upside-down over the pots. Insects were controlled as necessary using carbaryl at the manufacturer's recommended rate.

From Ott, through Nov. 1982, when the fern began to die back, the height of the tallest fern was recorded for each plant. All ferns were cut -2 cm above soil level, bagged, and weighed. For each plot, fern samples from the 10 plants were cut into 15-cm-long segments, combined, and a random 50-g subsample per plot was dried in a forced-draft oven at 70C for 3 days. Dried fern was ground to 20-mesh in a Wiley mill (Jones and Steyn, 1973). A 0.5-g portion of each subsample was analyzed for K, Ca, and Mg by atomic absorption spectrophotometry. Phosphorus was determined using the Murphy-Riley (blue phosphorus) method (Murphy and Riley, 1962). Optical density was read at 882 nm with a Perkin-Elmer Lambda 3 uv/vis spectrophotometer. Nitrogen was determined by the North Carolina State Univ. Soil Science Dept. Analytical Services Lab, analyzing 0.5 g dried ground tissue using a modified micro-Kjeldahl method that included recovery of nitrate (Technicon, 1974).

In Jan. 1983, five of the 10 crowns in each plot were harvested. They were washed free of soil, weighed, and crown growth was determined by difference from initial weight. They were then quartered; one-quarter of each crown (including associated roots) was cut into segments 5 to 10 cm long and mixed with the segments of quarters of other crowns from the same plot. A 100-g subsample was taken for nutrient analysis and a 5-g subsample taken for total fructose determination.

The subsample taken for nutrient analysis was rinsed in tap water, rinsed in distilled water, dried in a forced-draft oven at 70C for 3 days (Jones and Steyn, 1973), and then ground to 20-mesh in a Wiley mill. A 0.5-g portion of each subsample was prepared and analyzed for N, K, Ca, Mg, and P as described above.

The segments taken for total fructose determination were cut longitudinally into lengths of 2 to 3 cm, placed in a 473-ml

Table 3. Asparagus crown growth, fern height and weight, and crown fructose concentration under six levels of N fertilization for 2-year-old (1982 data) and 3-year-old (1983) plants.

N applied ($kg \cdot ha^{-1}$)	Crown growth (g)		Fern Wt (g)		Fern Ht (cm)		Fructose concn ($mg \cdot g^{-1}$)	
	1982	1983	1982	1983	1982	1983	1982	1983
0	169	510	4.6	40.3	62.0	102.1	113	105
57	202	760	9.0	62.6	65.8	103.7	104	110
113	193	741	10.5	68.3	64.7	96.4	95	101
170	189	739	11.8	72.3	64.0	95.2	82	100
227	195	755	14.1	87.8	62.8	91.7	92	96
340	169	665	12.8	77.4	60.8	91.7	92	99
SE[z]	7.0	42.1	0.87	8.48	1.03	2.32	4.57	5.06
Significance[y]	*	**	**	+	*	*	**	NS
Regressions[x]								
Intercept	176	561	4.9	41.8	---	---	113.8	---
Linear coefficient	0.290	2.543+	0.075*	0.363*	---	---	−0.260*	---
Quadratic coefficient	−0.001067*	−0.007479+	−0.000162**	−0.000805*	---	---	0.000632+	---

[z]Standard error of a N treatment mean.
[y]Significance level from ANOVA test for equality of N treatment means, using +, *, and ** for P = 0.10, 0.05, and 0.01, respectively.
[x]Parameter estimates and levels of significance from quadratic regressions when the quadratic term was significant, or linear regressions when only the linear term was significant (X = N level).

Mason jar with ~ 100 mg of $CaCO_3$, and extracted with 70% ethanol by boiling in a water bath for 5 min. Contents were blended for 5 min and then filtered over a Buchner funnel (BeMiller, 1976; Shiomi et al., 1976). The filtrate was brought up to 100 ml, and a 25-ml aliquot was then centrifuged at 7000 rpm for 10 min in a Sorvall Superspeed SS-3 automatic centrifuge. The resulting supernate was used for analysis.

Total fructose was determined using a modified partial anthrone method (Furnholmen et al.; 1964; Johnson et al., 1964; Ough, 1964). After 20 min in a 50C water bath, tubes were cooled in ice water for at least 10 min (Dufault and Greig, 1983). Optical density was read at 620 nm with a Beckman DB-6 spectrophotometer. Total fructose concentration was determined from a standard curve derived from fructose.

Five of the original 10 asparagus plants in each plot remained in the experiment after the Jan. 1983 harvest. In Mar. 1983, these pots were topdressed with NH_4N0_3 at the same concentrations as used in 1982. No additional K or P was applied. Irrigation continued unchanged. Plants were allowed to grow normally, without harvest of spears, throughout the growing season.

From Oct. through Nov. 1983, the fern harvest and analysis procedures used in 1982 were repeated for the remaining plants. In Jan. 1984, the remaining crowns were removed, weighed, prepared, and analyzed as in the previous year. The 5-g subsamples of crown and root segments taken for total fructose determination were also prepared and analyzed as in 1983. Optical density for total fructose was read at 620 nm with a Perkin-Elmer Lambda 3 uv/vis spectrophotometer.

Data were analyzed using analysis of variance (ANOVA) to establish treatment differences. Follow-up regression analyses were used to characterize N dose-response relationships using linear and quadratic equations.

Crown P concentration in both 2-year-old (1982 data) and 3-year-old plants (1983 data) and Kin the 2-year-old plants decreased with increased N fertilizer level over the range of N treatments considered (significant negative linear coefficients from regressions) (Table 1). In the 3-year-old plants, K concentration decreased sharply between O N and the low N rates, then leveled off at higher N rates (positive quadratic coefficient). In the 2-year-old plants, Ca and Mg concentrations increased with N fertilizer level (positive linear coefficients), with Mg concentration beginning to level off at the higher N rates (negative quadratic coefficient); there were no significant trends in Ca or Mg concentrations of the 3-year-old plants. Crown N concentration in both 2- and 3-year-old plants increased with N treatment level, leveling off at the higher treatment levels.

Fern P concentration was unrelated to N treatment level in the 2-year-old plants, but decreased as N rate increased in the 3-year-old plants (Table 2). The concentration of K increased, then leveled off, as N rate was increased in 2-year-old plants, but K decreased, then leveled off, as a function of N rate in 3-year-old plants. Fern Ca concentration increased with increasing N rate, beginning to level off at the higher N rates in both years. Magnesium concentration increased with the N treatment level in the 2-year-old plants, but did not appear to be affected by N rate in the 3-year-old plants. Fern N concentration increased with increasing N treatment level in both years, beginning to level off at the higher treatment levels in the 2-year-old plants.

Crown growth was maximized at 57 kg N/ha in both 2- and 3-year-old plants (Table 3). The quadratic equations fit to the data provide estimates of the optimum N rates for maximizing crown growth at 136 kg N/ha for 2-year-old and 170 kg N/ha for 3-year-old plants; however, the treatment means (Table 3) suggest that 57 kg N/ha may, in fact, be sufficient.

Fern weight was maximized at higher N treatment levels. The fitted quadratic equations estimate maximum fern weight to be realized at 231 kg N/ha in 2-year-old and 225 kg N/ha in 3-year-old plants. Fern weights for ≈ 230 kg N/ha were two to three times higher than the means at 0 kg N/ha. There were no significant linear or quadratic trends in fern height with increased N treatment level, although treatment means were found to differ significantly in the ANOVAs.

In the 2-year-old plants, fructose concentration in the crowns declined, then leveled off, as the N rate was increased; the fitted quadratic had fructose concentration minimized at 206 kg N/ha. No trends in fructose concentration were found for the 3-year-old plants.

In most cases, the increase or decrease in nutrient concentrations in the fern paralleled that in the crown. Increases in N, Ca, and Mg concentrations and decreases in P and K concentrations with increasing N fertilizer levels were expected. Increasing Ca and Mg concentrations may be due to an increase of NO_3^- at higher N fertilizer levels and the resultant increase in nonspecific uptake of cations.

Increasing N fertilizer levels increased fern weight and decreased total crown fructose concentration in 1982. Crown growth was maximized at intermediate N fertilizer levels. An abundance of N is known to stimulate fern growth (Morse, 1916) at the expense of crown growth, and to deplete carbohydrate reserves. Where N levels are limiting, photosynthates are not fully used in the synthesis of organic N compounds and sugars are accumulated (Mengel and Kirkby, 1978).

Studies with sugar beets and sugar cane have shown that high N fertilizer levels produce low sugar concentrations, high concentrations of amino compounds and minerals (Mengel and Kirkby, 1978), and more vegetative growth. Greater fern growth was not translated into greater crown growth or total fructose concentration at N concentrations >57 $kg \cdot ha^{-1}$.

Crown growth is the average increase in weight of the crown between the times of planting and removal from the experiment. Crown growth, fern growth, and total fructose concentration are important indicators of future yield because a larger crown has a greater capacity to store fructose and more potential for subsequent spear production (Benson and Takatori, 1980). Benson and Takatori (1980), comparing higher- and lower-yielding cultivars, found the greatest differences in growth to be in the root system. The higher-yielding cultivar had a higher percentage dry weight of root per plant and a lower percentage dry weight of fern per plant than did the lower-yielding cultivar.

When buds break dormancy, carbohydrates and amino compounds are supplied to growing tissues from the storage roots. Once photosynthates are produced, depletion from the storage roots is decreased. Thereafter, throughout the growing season, there must be sufficient N fertilizer to maximize both crown growth and total fructose concentration without stimulating excess fern growth. Considering crown and fern growth and total crown fructose concentration as important indicators of future yield, there appeared to be no beneficial effect of applied N fertilizer >57 kg N/ha on 1- and 2-year-old asparagus plants.

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