Response in Green and White Asparagus to Supplemental Nitrogen and Harvest Date

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Abstract. ‘Jersey Giant’ asparagus (*Asparagus officinalis* L.), grown in an Enders silt loam mineral soil, was given 80 kg supplemental N/ha either before or after the harvest season. Neither N application timing affected spear yield, objective color, or pigment concentration. Early supplemental N application decreased K concentration in white spears and Ca concentration in green spears. Green asparagus contained higher total-N, K, P, S, Ca, Mg, Fe, Zn, Al, Mn, and Cu concentrations but a lower soluble solids concentration (SSC) and NO₃ than did white asparagus. As the cutting season progressed, spear SSC and S, Ca, NO₃ (NO₃ in white spears only), Zn, Mn, and Cu (Cu in white spears only) concentrations decreased, but spear K and Al (Al in white spears only) increased on a dry-weight basis. Fall residual soil NO₃ levels were not affected by N application timing, but organic matter (percent) was lower in soil that received early supplemental N.

The response of asparagus crowns to supplemental N fertilizer is influenced by soil type and other edaphic factors (Ledgard et al., 1992; Pitman et al., 1991; Roth and Gardner, 1989). In mineral soils, the response to soil N is generally poor; however, spear quality attributes, such as color, might benefit by supplemental N applications.

Asparagus is one of 20 vegetables currently affected by the 1990 Food Labeling and Education Act that requires documentation of the percent reference daily intake (for humans) for Ca, Fe, and other nutrients found in fresh fruit, vegetables, and raw fish at the point of retail sale. The mineral nutrient values used by the Food and Drug Administration (FDA) may not accurately reflect the mineral nutrient levels found in asparagus grown on mineral soils of the mid-South because much of the asparagus entering the local and domestic markets are grown in other soil types.

The fate of residual soil NO₃ from N fertilizers is also a potential concern in asparagus production. My objectives were to determine if supplemental N enhances the production of asparagus grown in an upland mineral soil, to examine mineral nutrient levels in green and white asparagus and any changes in these

levels as the harvest season progresses, and to determine residual soil NO₃ levels at the end of the growing season.

Material and Methods

A 1986 planting of ‘Jersey Giant’ asparagus, planted in an Enders stoney, silt loam soil testing 130 and 285 kg·ha⁻¹ for P and K, respectively, and located at the Agriculture Research Service Unit near Booneville, Ark., was used as the experimental site. Single-row plots were 7.3 m long on 1.4-m centers (23,919 crowns/ha) and were replicated 4 times for each fertilizer level and spear type combination. Soil samples, taken at 0 to 15 cm on 17 Mar. 1993, were air-dried at 70°C and stored at room temperature until analyzed for soil pH, NO₃, and major nutrients. On 17 Mar. after soil sampling, single, 15-cm, banded N applications were made over the row center with 0 or 80 kg N/ha (as NH₄NO₃), and on 24 May, 80 kg N/ha was applied to plots that did not receive N fertilizer on 17 Mar. On 19 Mar., opaque rowcovers were installed for white asparagus production (Makus and Gonzalez, 1991); plots for green spears were left uncovered. Spears of both colors were harvested three times each week, beginning on 29 Mar. and ending on 21 May. Yield weights are based on a 15-cm

trimmed spear with a diameter of >9 mm at the base (butt end).

Samples used for nutrient analysis were collected during weeks 3, 5, and 7 of the harvest season. Spears were washed, and a 5-cm mid-spear segment (5 to 10 cm from the spear tip) was removed. Objective color was determined with a chromameter (model CR-100; Minolta, Ramsey, N.J.) standardized against a white plate with values of L = 94.8, a = -0.6, and b = 0.8. Then the segment was frozen in liquid N₂, freeze-dried, and ground through a 40-mesh (0.36 mm²) screen. Samples were stored in a freezer at -20°C until analyzed. A second set of samples were left unground and used for soluble solids concentration (SSC) determination.

Spear pigments were determined by Welburn and Lichtenthaler's (1984) method. SSC in juice expressed from thawed samples was read with a hand-held refractometer (model N1t; Atago Co., Japan). Tissue N and S were analyzed by the Leco combustion method, NO₃ and P colorimetrically, and mineral nutrients by atomic absorption spectrometry (Plank, 1992). After a killing frost on 4 Nov., a second set of soil samples was taken and dried at 70°C. The March and November samples were analyzed at the same time.

The analysis of variance was based on N level and spear color as main plots and harvest weeks as subplots in a randomized complete-block design. Means were compared by *t* tests using the probability of the difference option of the least square means statement of the general linear model of SAS version 6.04.

Results and Discussion

Harvest weeks 3, 5, and 7 received daily irradiance at means of 2.6, 4.5, and 2.3 W·m⁻²; rain at 35.6, 16.5, and 4.8 mm; and weekly mean air temperatures were 12.6, 13.3, and 12.6°C, respectively.

Spear color. Preharvest application of supplemental N fertilizer did not affect average spear weight, yield distribution, total yield, or number of spears per hectare of green or white asparagus spears throughout the season, compared to crowns that received no early supplemental N (data not shown). Although total spear counts per hectare were similar, yields of white asparagus were higher than those of green spears because white spears had ≈22% higher average spear weight (Table 1). This response is generally in agreement with past research comparing green and white spear counts and size (Makus and Gonzalez, 1991),

Table 1. Agronomic response of green and white asparagus given 0 and 80 kg N/ha on 17 Mar. 1993.²

Spear color	Yield			Spear count/ha (100,000s)
	Avg spear wt (g)	% Season by 3rd week	Total season (t·ha ⁻¹)	
Green	10.9	4.9	4.10	3.77
White	13.3	3.4	4.99	3.73
	**	0.06 ²	*	NS

²Supplemental N did not affect any of the responses, and there was no spear color × supplemental N interaction.

³Probability of a greater F value.

ns, *, **Nonsignificant or significant at *P* ≤ 0.05 or 0.01, respectively.

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although soil temperatures also can affect mean spear weight of green asparagus (Fieldhouse et al., 1968). The decrease in spear size over the three sampling weeks was linear in green spears and quadratic in white spears, with the fifth week having the highest average white spear weight (data not shown).

Spear SSC was higher in white than green spears (6.3% vs. 5.8%, $P \leq 0.001$). However, as expected, green spears were higher in total chlorophyll and carotenoids than white spears (Table 2). Objective color attributes between spear types were similar to those reported by Makus and Gonzalez (1991).

Green asparagus spears were higher in protein-N, K, S, P, Ca, Mg, Fe, Zn, Al, Mn, and Cu (in order of descending concentration on a dry-weight basis), but lower in NO_3 than white

spears (Table 3). The Fe levels found exceed the FDA published U.S. recommended daily allowance (RDA) of <2% for a 93-g serving of asparagus by 5-fold and are equivalent to 9.9% of the RDA for Fe for this serving size (Government Printing Office, 1991).

Supplemental N. Spear objective color and pigments were not significantly affected by N application (data not shown). The only mineral nutrients to show a response to applied N vs. no N were Ca (0.15% vs. 0.17% in green spears) and K (2.66% vs. 2.88% in white spears), respectively, which both decreased when N was applied. Total protein-N concentration (Table 3) and SSC (data not shown) were not affected by N application. Pitman et al. (1991) observed increases in cladophyll (fern) K, Ca, and N in 3-year-old, greenhouse-

grown 'Princeville' plants given NH_4NO_3 at $\leq 340 \text{ kg} \cdot \text{ha}^{-1}$. The differences in the K response between the two studies may be related to differences in the mineral nutrition of young stems (spears) vs. older leaves (cladophylls).

Harvest week. Spear chlorophyll and carotenoid concentrations (Table 2, only in green spears), and those of protein-N and P (Table 3) were highest during week 5, the period of highest light intensity of the three sampling periods. The objective Color Gardner (color difference meter) values for 'a' (greenness), 'b' (yellowness), color (hue), and color intensity (chroma) of green spears were enhanced by the higher light levels during the fifth week, whereas white spear objective color values were less affected by harvest week (Table 2). Changes in weekly irradiance would not be expected to affect white spear color; however, rowcover opaqueness can affect objective white spear color (Makus, 1992). Spear chlorophyll, and to a lesser extent spear carotenoids, were not affected by harvest season in white spears.

As the harvest season progressed, tissue S, Ca, NO_3 (NO_3 in white spears only), Zn, Mn, and Cu (Cu in white spears only) decreased and K and Al (Al in white spears only) levels increased in spears (Table 3). At the third and fifth harvest weeks, P levels were higher in green than in white asparagus spears. The fluctuation in mineral nutrient concentration of spears over the harvest season may be influenced by soil temperature and moisture (neither were measured in this study), canopy temperature, and the presence or absence of a photosynthetically active sink. Row-covered asparagus had an average canopy temperature 3°C higher but an average soil temperature 0.6°C lower (both measured 15 cm above and below the soil line, respectively) than uncovered (green) asparagus (Makus and Gonzalez, 1991). Because asparagus has a deep root system, soil temperature would not likely con-

Table 2. Effect of spear color and harvest week on objective spear color and pigments.^z

	Gardner color difference meter			Hue (a/b)	Chroma (a ² + b ²)	Total chlorophyll (mg·g ⁻¹) ^y	Total carotenoids (mg·g ⁻¹) ^y
	('L')	('a')	('b')				
Spear color (C)							
Green (Gr)	48.4 b	-11.3 b	27.7 a	-0.404 b	30.0 a	0.77 a	0.26 a
White (Wh)	74.7 a	0.3 a	17.2 b	0.029 a	17.3 b	0.09 b	0.03 b
	**	**	**	**	**	**	**
Harvest week (W)							
3 (12 Apr.)	62.0	-4.6 b	21.6 b	-0.136 a	22.8 b	0.36 c	0.13 c
5 (26 Apr.)	61.4	-7.3 a	25.0 a	-0.256 b	26.4 a	0.50 a	0.17 a
7 (10 May)	61.3	-4.5 b	20.8 b	-0.171 a	21.7 b	0.42 b	0.14 b
	NS	**	**	**	**	**	**
C × W interactions ^x							
Gr × week 3	49.9 c	-11.1 e	28.1 a	-0.392 d	30.2 a	0.66 c	0.23 b
Gr × week 5	48.0 d	-13.5 f	29.3 a	-0.459 e	32.3 a	0.92 a	0.30 a
Gr × week 7	47.1 d	-9.3 d	25.7 b	-0.361 d	27.3 b	0.74 b	0.24 b
Wh × week 3	74.0 b	1.8 a	15.1 d	0.121 a	15.2 d	0.07 d	0.02 d
Wh × week 5	74.7 ab	-1.1 c	20.6 c	-0.052 c	20.6 c	0.09 d	0.04 c
Wh × week 7	75.5 a	0.3 b	16.0 d	0.019 b	16.0 d	0.10 d	0.03 cd
	**	**	**	**	*	**	**

^zNitrogen application did not affect any of the responses (means not shown).

^yTotal chlorophyll and carotenoids on a dry-weight basis.

^xOther interactions not significant.

NS, *, ** Mean separation within columns nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

Table 3. Mineral nutrients in green and white asparagus^z, with and without supplemental N fertilizer, at three harvests in 1993.

	Protein											
	N	K	S	P	Ca	Mg	NO ₃	Fe	Zn	Mn	Cu	Al
Main effect	(%)						(μg·g ⁻¹)					
Spear color (C)												
Green	4.75 a	2.98 a	0.692 a	0.692 a	0.160 a	0.184 a	1530 b	191 a	69 a	19 a	16 a	29 a
White	4.00 b	2.77 b	0.603 b	0.583 b	0.132 b	0.176 b	1650 a	126 b	61 b	17 b	11 b	19 b
	**	**	**	**	**	*	**	*	**	*	*	**
Nitrogen rate (kg·ha ⁻¹)												
0	4.37	2.93 a	0.658	0.612	0.152	0.183	1598	164	66	18	15	24
80	4.38	2.82 b	0.638	0.602	0.140	0.177	1582	154	64	18	12	23
	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Harvest week (W)												
3 (12 Apr.)	4.33 b	2.56 b	0.701 a	0.595 b	0.165 a	0.178 b	1653 a	196	69 a	19	15 a	19 b
5 (26 Apr.)	4.68 a	3.08 a	0.691 a	0.629 a	0.166 a	0.176 b	1559 b	145	68 a	18	14 ab	22 b
7 (10 May)	4.12 c	3.98 a	0.551 b	0.598 b	0.108 b	0.187 a	1558 b	136	58 b	17	11 b	30 a
	**	**	**	**	**	*	**	NS	**	NS	**	**
Polynomial fit	L ^{**y} , Q ^{**}	L ^{**} , Q ^{**}	L ^{**} , Q ^{**x}	L [*] , Q [*]	L ^{**} , Q ^{**}	Q ^{**y}	L ^{**x} , Q ^{**x}	---	L ^{**} , Q ^{**x}	---	L ^{*x}	L ^{**y} , Q ^{**y}
Interactions ^y												
C × N	NS	**	NS	NS	*	NS	NS	NS	NS	NS	NS	NS
C × W	**	NS	**	*	**	NS	*	NS	NS	NS	NS	**
N × W	*	NS	**	NS	**	NS	NS	NS	NS	NS	NS	NS
C × N × W	*	NS	**	NS	**	NS	NS	NS	NS	NS	NS	NS

^zMidspear segments 5 to 10 cm from spear tip.

^yGreen only.

^xWhite only.

NS, *, ** Mean separation within columns nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

tribute to the differences in mineral nutrients between spear type found in this study.

The spear color $\times$ harvest week interaction is reported for protein-N, S, P, Ca, NO_3 , and Al in Table 3 (see polynomial fits). Weather, perhaps the much higher light intensity during the third harvest week, appeared to modulate spear protein-N and S levels more in green than white spears (Fig. 1A–B). Green spears that were supplied supplemental N were higher in protein-N and lower in S during the third harvest week compared to Ca levels in spears given supplemental N declined little over the harvest season compared to Ca levels in spears from other spear color-supplemental N combinations (Fig. 1C). As the season progressed, average SSC were 6.3%, 6.2%, and 5.6% for sampling weeks 3, 5, and 7, respectively. The decrease was linear and quadratic in both spear types ($P \leq 0.01$).

In other work, harvest date was reported to affect spear moisture (percent), SSC (percent), and ascorbic acid in 'Registered Washington' asparagus, but there were no significant seasonal trends (Shewfelt and Mohr, 1960). Fernandez et al. (1991) found that location, but not season, affected water-soluble vitamins in white asparagus spears. As the season progressed, postharvest storage life decreased and chilling injury increased in 'UC 157' (Klieber and Wills, 1992). Their results suggest that compositional changes may occur later in the harvest season, such as those reported here [e.g., reductions in simple carbohydrates (SSC), protein levels (protein-N), and Ca], which can shorten postharvest life.

Spring application of supplemental N, either before or after the harvest period, had no effect on residual soil NO_3 level, but a preharvest N application reduced soil organic matter ($P \leq 0.01$) and P ($P \leq 0.05$) test levels and increased Mn ($P \leq 0.001$) soil test values (data not shown). The use or absence of rowcovers to produce white and green spears, respectively, had no effect on any soil nutrient tested. Soil pH dropped 0.6 units (6.6 vs. 6.0, $P \leq 0.01$) over the growing season from both pre- and postcutting season N applications. Levels of soil NO_3 tested $6.4 \text{ kg} \cdot \text{ha}^{-1}$ before the initial spring N application and $12 \text{ kg} \cdot \text{ha}^{-1}$ after the fall killing frost.

Supplemental N fertilizer had no effect on green or white asparagus spear count or yield per hectare in the year of application or spear greenness. With the exception of K and Ca, supplemental N fertilizer also did not affect or reduce spear mineral nutrients. Major factors contributing to differences in spear color, SSC, and mineral nutrients were associated with spear type (green or white) and harvest week.

Literature Cited

- Fernandez, M.C., E. Llanos, O. Martin, and M.C. Ancin. 1991. Variaciones en el contenido de vitaminas B₁, B₂, B₆ y C del espárrago en función de la zona de producción, época de recolección, elaboración y almacenamiento de su conserva. *Revista de Agroquímica y Tecnología de Alimentos* 31:532–538.
- Fieldhouse, D.J., F.D. Moore, III, and E.P. Brasher. 1968. Soil temperature, ridging and asparagus

Fig. 1. (A) Protein-N, (B) S, and (C) Ca concentrations in white and green asparagus spears sampled during weeks 3, 5, and 7 of an 8-week harvest season in 1993. Spears were grown with and without supplemental N. Lowercase letters designate significant spear color $\times$ N application $\times$ harvest week differences at $P \leq 0.01$.

production. Agr. Expt. Sta. Bul. 373. Newark, Del. Government Printing Office. 1991. Congressional Record 58(229):60889. Government Printing Office, Washington, D.C.

Klieber, A. and R.B.H. Wills. 1992. Optimisation of storage conditions for 'UC 157' asparagus. *Austral. J. Expt. Agr.* 32:529–534.

Ledgard, S.F., J.A. Douglas, J.M. Follett, and M.S.

- Sprosen. 1992. Influence of time of application on the utilization of nitrogen fertilizer by asparagus, estimated using ^{15}N . *Plant & Soil* 147:41–47.
- Makus, D.J. 1991. An update on white asparagus production, p. 35–48. In: C. Cantiluppi (ed.). *Proc. 1992 Ohio Asparagus School*. Ohio State Univ. Misc. Publ. 92-1.
- Makus, D.J. and A.R. Gonzalez. 1991. Production and quality of white asparagus grown under opaque rowcovers. *HortScience* 26:374–377.
- Pitman, B.C., D.C. Sanders, and W.H. Swallow. 1991. Growth and development of young asparagus plants in response to N fertilization. *HortScience* 26:109–112.
- Plank, C.O. 1992. Plant analysis reference procedures for the Southern Region of the United States. Southern Coop. Serv. Bul. 368. Georgia Agr. Expt. Sta., Athens.
- Roth, R.L. and B.R. Gardner. 1989. Asparagus yield response to water and nitrogen. *Trans. Amer. Soc. Agr. Eng.* 32:105–112.
- Shewfelt, A.L. and W.P. Mohr. 1960. Effect of spear length, spear portion and harvest date on the composition and quality of asparagus. *Can. J. Plant Sci.* 40:371–374.
- Welburn, A.R. and H. Lichtenthaler. 1984. Formulae and program to determine total carotenoids and chlorophyll a and b of leaf extracts in different solvents, p. 9–12 In: C. Sybesma (ed.). *Advances in photosynthesis research*. vol. 2. Kluwer, The Hague, The Netherlands.