Proc. Fla. State Hort. Soc. 114:318-322. 2001.

A PEER REVIEWED PAPER

SULFUR FERTILIZATION FOR POLYETHYLENE-MULCHED CABBAGE

ANAS D. SUSILA AND SALVADORE J. LOCASCIO
University of Florida
Horticultural Sciences Department
Gainesville, FL 32611

Additional index words. Drip irrigation, fertigation, *Brassica oleracea.*

Abstract. **Cabbage (*Brassica oleracea* L. Capitata) was grown with polyethylene mulch and drip irrigation on an Arredondo fine sandy soil testing very high in P and low in organic matter (0.9% to 1.6%) in four seasons to evaluate the effect of S rate and methods of application on yield and nutrient concentrations. Experiments were conducted with S rates of 0, 34, 68, and 102 kg·ha^{-1} from ammonium sulfate with two methods of application: preplant (100% broadcast in the bed) and drip (40% preplant and 60% injected). In each of four field studies, cabbage total yields were influenced by S application. Maximum cabbage yields were obtained with application of S at 34 kg·ha^{-1}. An interaction between method of application and S rate was significant for total yield. With 40% S applied preplant and 60% drip applied, cabbage yield was higher than with 100% S applied preplant. Leaf S concentrations were higher with S application than with no S application and were similar with S applications from 34 to 102 kg·ha^{-1}. Soil-extractable SO_4 increased linearly, and soil pH decreased ≈ 0.2 units at 6 and 9 weeks after transplanting with an increase in S rate.**

The sandy soils of northern and central Florida are low in available S. Soil extractable SO_4-S (with 0.01 M $Ca(H_2PO_4)_2 \cdot 2H_2O$) was less than 6 mg·kg^{-1} and considered very low throughout the profile of a Florida Spodosol (Mitchell and Blue, 1981). A lack of S in many fertilizer materials used for crops grown under intensive production systems may cause plant nutrient imbalances that reduce yield. Other researchers have demonstrated that crops such as white clover (*Trifolium repens* L.) (Monteiro and Blue, 1990), sorghum-sudan grass (*Sorghum* spp.) (Mitchell and Blue, 1981), and corn (*Zea mays* L.)) (Blue et al., 1981) growing in Florida sandy soils responded to S application. Also, responses of increased tomato (*Lycopersicon esculentum* Mill.) growth to S application were reported in a greenhouse (Susila and Locascio, 1999) and field studies (Susila and Locascio, 2000).

Extensive studies have been conducted with drip irrigation to determine the fertilizer requirements of polyethylene-mulched crops. In tomato, fruit yield was greater with 60% drip applied N + K than with 100% preplant applied N + K (Locascio et al., 1989). Locascio et al. (1997) reported that on a sandy soil, tomato yield was lowest with 100% N + K applied preplant, intermediate with 100% applied by fertigation, and highest with 40% applied preplant and 60% injected.

Florida is the leading state for winter and spring production of fresh market cabbage (*Brassica oleareca* L. Capitata group). During 1999-2000, the crop was grown on 3,321 ha with a value of $20.2 million and comprised 1.3% of the total vegetable production value in Florida (Witzig and Pugh, 2001). Schnug and Haneklaus (1994) reported that *Brassica* species have a particularly high demand for S nutrition compared with most other vegetables. Sulfur deficiencies have negative effects on yield and quality of *Brassica* species.

Minimal SO_4 adsorption occurs in coarse-textured, sandy soils. Mineralized sulfate or sulfate applied in fertilizer may be readily lost by leaching under high rainfall conditions, which exist during most of the growing season in Florida. Although intensive studies have been conducted on N and K nutrition, less attention has been focused on S nutrition in polyethylene-mulched drip irrigated crops. Studies reported here were conducted to evaluate the effect of S-rate and methods of application on yield and nutrient concentration of polyethylene-mulched cabbage.

Materials and Methods

These studies were carried out at the Horticultural Research Unit of the University of Florida in Gainesville, Fla. during Fall 1999, Spring 2000 (two experiments), and Fall 2000. Before fertilization, soil samples were taken with a soil probe from the top 15 cm of an Arredondo fine sand (loamy, siliceous, Hyperthermic, Grossarenic Paleudults) at each site. Soil was dried, sieved, and analyzed for nutrient content with Mehlich-I extraction procedure (Hanlon et al., 1994). Sulfate-S was extracted from 10 g of soil in a 25 ml 0.01m $Ca(H_2PO_4)_2 \cdot 2H_2O$ solution and determined by turbidity procedures (Jones, 1995). Soil organic matter content was determined in each season with the Walkey-Black methods (Hanlon et al., 1994). Results of preplant soil analysis are presented in Table 1. Fertilizer was applied at 224-56-168-34 (Fall 1999), 224-56-209-34 (Spring 2000A), 247-56-209-34 (Spring 2000B), and 196-56-140-34 (Fall 2000) kg·ha^{-1} of N-P-K-micronutrient mix. Nutrient sources were ammonium nitrate, phosphoric acid, potassium chloride, and FN 503 (Frit Industries, Ozark, Ala.). All micronutrients and 40% of N and K were applied preplant, and 60% of N and K were applied via fertigation in 10 weekly applications. Phosphorus was applied from phosphoric acid at 56 kg·ha^{-1} and was applied via fertigation weekly for five times from 1 to 5 weeks after planting.

Sulfur was applied as ammonium sulfate (24% S and 21% N) at 0, 34, 68, and 102 kg·ha^{-1} of S with two methods of application (preplant and drip). Preplant S fertilizers were applied broadcast and rototilled into raised beds approximately 0.9 m wide and 20 cm high. Drip S applications were applied 40% preplant and 60% via fertigation in 10 applications weekly with the N and K. Experiments were arranged as a 4 (rates) × 2 (methods) factorial using randomized complete block designs with five replications.

Beds were fumigated 2 weeks before planting with 98% methyl bromide—2% chloropicrin at 448 kg·ha^{-1}. Biwall drip irrigation tubing (orifice diameter, 0.025 cm; emitter spacing, 30 cm; 1.89 liters 30.5 m^{-1} min^{-1}) was placed on the soil surface at the bed center and covered with black polyethylene mulch

This research was supported by the Florida Agricultural Experiment Station, and approved for publication as Journal Series No. R-08188

Table 1. Preplant soil analysis with Melich I extraction (IFAS Soil Testing Lab).

Analysis	Fall '99	Spring '00A	Spring '00B	Fall '00
P (mg·kg^{-1})[z]	92 (vh)	117 (vh)	75 (vh)	114 (vh)
K (mg·kg^{-1})	22 (l)	18 (vl)	13 (vl)	27 (l)
Mg (mg·kg^{-1})	23 (m)	38 (h)	14 (l)	39 (h)
Ca (mg·kg^{-1})	234	260	263	522
Cu (mg·kg^{-1})	1.03	2.6	0.26	2.35
Zn (mg·kg^{-1})	1.06	2.8	1.03	4.07
Mn (mg·kg^{-1})	2.77	12.6	1.61	12.2
OM (%)[y]	1.2	0.9	1.6	1.0
SO_4 (mg·kg^{-1})[x]	1.86	0.75	0.15	1.49
pH[w]	6.1	6.7	6.0	5.8

[z]vh = very high, h = high, m = medium, l = low, vl = very low.
[y]Walkley-Black Methods.
[x]Turbidimetric.
[w]Water.

(Sonoco with 0.0038 cm thickness). 'Green Cup' cabbage plants were planted on plots 1.83 m wide × 3.66 m of bed length in a double row on 1 Sept. 1999, 16 Mar. 2000, and 16 Aug. 2000. Plants were spaced 30 cm between rows and 30 cm within rows (24 plants/plot). The volume of irrigation water applied daily was 75% of the mean daily volume of E pan for the previous 7 d.

Recently matured cabbage leaves and soil from the bed centers were sampled at 3 weeks after transplanting (WAT) on 16 Sept. 1999, 5 Apr., and 13 Sept. 2000), 6 WAT on 6 Oct. 1999, 26 Apr., and 27 Sept. 2000, and 9 WAT on 27 Oct. 1999, 17 May, and 18 Oct. 2000. Leaf tissue was dried in a forced-air oven at 70°C to constant weight and ground to a diameter of < 0.6 mm. Total Kjeldhal N was determined by using 100 mg samples digested in H_2SO_4 and analyzed by Rapid Flow Colorimetry (Hanlon et al., 1994). Phosphorus, K, Ca, and Mg leaf concentrations were determined by a dry-ash procedure using 500 mg samples dried at 500°C for 10 h, diluted in 1N HCl, and analyzed by IACPS -Inductively Argon Coupled Plasma Spectrophotometer (Spectrociros CCD, Spectro Analytical Instruments, Kleve, Germany).

Total leaf S concentration was determined on digested tissue by the turbidity procedure described by Jones (1995). Plant tissue samples of 500 mg were digested using $Mg(NO_3)_2$ solutions on a hot plate, followed by combustion of samples in a muffle furnace at 500°C for 4 h. Sulfate reagent powder (SulfaVer®4 from HACH Co., Loveland, Colo.) was used in the turbidimetry process. Total S was determined using a spectrophotometer (Spectronic-20D, Thermo Spectronic, Rochester, N.Y.).

Cabbage heads were harvested on 8 Dec. 1999, 6 June (both studies), and 28 Nov. 2000. Fifteen cabbage heads with four wrapper leaves each were harvested per plot from the center of the plot. Analyses of variance of data were calculated using SAS 6.12 (SAS Institute, Cary, N.C.). Polynomial regression was used to describe yield response to S rate (linear, quadratic, or cubic). Mean separation between seasons was performed using Waller-Duncan's multiple range test.

Results and Discussion

Sulfur deficiency symptoms of green-yellow color on the younger leaves were observed first at 4 weeks after transplanting on cabbage plants grown with 0 S. As the growing period progressed, these visible symptoms became more pronounced over the entire plant. Severely deficient cabbage did not produce marketable heads.

Main effect of season. Cabbage yield, leaf S, and leaf N concentrations at 3 WAT and 9 WAT were influenced by season (Table 2). Cabbage yields were also influenced by methods of S application and rate, and an interaction between season and S rate (Tables 2 and 3). Leaf S concentrations declined with an increase in plant age. Leaf S concentrations ranged between 0.52% to 0.71% at 3 WAT and were lower, with a range of 0.10% to 0.20%, at 9 WAT. Leaf N concentration at 3 WAT and 9 WAT (Table 2) and leaf P, K, Ca, and Mg concentrations at 3 WAT and 9 WAT were influenced by season (Table 4). At 3 WAT, the highest leaf concentrations were obtained for P in spring 2000B, for Ca in spring 2000A, and for Mg in fall 2000. At 9 WAT, the highest leaf P, K, Ca, and Mg concentrations were obtained in spring 2000A.

Interaction effect. Interaction between S rate and season occurred on cabbage total yield (Table 2). Interactions of S rate and season on cabbage total yield and average head weight are presented in Table 3. Cabbage yields were higher with S application than with no S in all seasons. However, cabbage yields were similar with application of S from 34 kg ha^{-1} to 102 kg·ha^{1} in all seasons except in fall 1999 where total yields decreased linearly with an increase in S rate above 34 kg ha^{-1}. The minimum cabbage head weight requirement for market-

Table 2. Main effects of season, S rate, and method of application on yield, leaf S, and N concentration of cabbage sampled at 3 WAT and 9 WAT in fall 1999, and spring and fall 2000.

		Leaf nutrient concentration (% dry wt)			
		S		N	
Treatments	Yield (t·ha^{-1})	3	9	3	9
Season (S)					
Fall '99	48.8	—	0.28	—	2.6 a[z]
Spring '00A	56.7	0.71	0.20	5.0 c	2.6 a
Spring '00B	35.8	0.66	0.10	6.8 a	2.2 b
Fall '00	51.6	0.52	0.21	5.5 b	2.1 b
Sig.	**	**	**	**	**
Methods (M)[y]					
Drip	49.6	0.47	0.26	4.39	2.4
Preplant	46.8	0.48	0.14	4.30	2.4
Sig.	**	NS	NS	NS	NS
S rate (kg·ha^{-1}) (R)					
0	37.5	0.26	0.04	4.27	2.7
34	53.0	0.55	0.14	4.35	2.2
68	51.4	0.52	0.23	4.39	2.3
102	50.8	0.56	0.38	4.47	2.3
Sig.	**	**	*	NS	C**
0 vs. S					**
S_L[x]					NS
S_Q[x]					NS
Interaction					
S × M	*	NS	NS	NS	NS
S × R	**	**	**	NS	NS
M × R	**	NS	NS	*	NS
S × M × R	NS	NS	**	NS	NS

[z]Mean separation (in column) by Waller-Duncan's multiple range test. NS, *, ** = nonsignificant and significant at $P \le 0.05$ and 0.01, respectively. S rate effects were cubic (C).
[y]Drip = 40% S preplant + 60% S drip applied, preplant = 100% S preplant.
[x]Polynomial regression for S rate of 34, 68, and 102 kg·ha^{-1}.

Table 3. Interaction effect of S rate and season on cabbage total yield and average head weight in fall 1999, spring and fall 2000.

S rate (kg ha^{-1})	Fall '99 Total (t ha^{-1})	Fall '99 Head wt (g head^{-1})	Spring '00A Total (t ha^{-1})	Spring '00A Head wt (g head^{-1})	Spring '00B Total (t ha^{-1})	Spring '00B Head wt (g head^{-1})	Fall '00 Total (t ha^{-1})	Fall '00 Head wt (g head^{-1})
0	44.07	1044	37.43	887	26.52	628	42.12	998
34	56.69	1343	60.27	1428	40.92	970	54.20	1284
68	48.29	1144	62.81	1488	38.50	912	56.19	1332
102	46.05	1091	66.36	1573	37.15	880	53.78	1274
Sig.	*		**		**		**	
0 vs. S	*		**		**		**	
S_L[z]	**		NS		NS		NS	
S_Q[z]	NS		NS		NS		NS	

[z]Polynomial regression for S rate of 34, 68, and 102 kg·ha^{-1}.
NS, *, **Nonsignificant or significant at $P \leq 0.05$ and 0.01, respectively.

able yield is 902 g head^{-1} (USDA, 1997). With no S application, average cabbage head weights were 887 and 628 g head^{-1} in spring 2000A and spring 2000B, respectively. Therefore, with no S application, no marketable yield was obtained in both seasons. Average head weight of 880 g head^{-1} also was obtained with S application of 102 kg ha^{-1} in spring 2000B. This small head size may indicate some toxicity of S at that higher S rate.

An interaction between S rate and methods of application occurred on total cabbage yield (Tables 2 and 5). Cabbage yields were higher with S application than with no S with both application methods. However, with S applied via drip, total yields were reduced linearly with an increase in S from 34 to 102 kg ha^{-1}. With a 100% preplant S application, a quadratic response in total yield was obtained with an increase in S application from 34 to 102 kg ha^{-1} with very little difference in yield above 34 kg ha^{-1}.

Leaf nutrient concentrations at 6 WAT were not influenced by S rate except leaf S and N concentrations (Table 6).

Table 4. Main effect of season, method of application, and S rate on leaf P, K, Ca, and Mg concentration of cabbage sampled at 3 WAT and 9 WAT in fall 1999, spring and fall 2000.

	Leaf nutrient concentration (% dry wt)							
	P		K		Ca		Mg	
Treatments	3	9	3	9	3	9	3	9
Season (S)								
Fall '99	—[w]	0.25	—	1.81 c	—	2.97		0.32
Spring '00A	0.68 b[z]	0.45	3.73	2.96 a	4.97 a	4.16	0.27 a	0.54
Spring '00B	0.78 a	0.43	4.31	2.31 b	2.94 c	3.27	0.55 b	0.47
Fall '00	0.63 c	0.42	4.00	2.86 a	4.05 b	2.30	0.58 b	0.31
Sig.	**	**	**	**	**	**	**	**
Methods (M)[y]								
Drip	0.52	0.40	3.11	2.52	2.98	3.16	0.46	0.41
Preplant	0.52	0.38	2.90	2.45	3.00	3.19	0.47	0.42
Sig.	NS	**	**	NS	NS	NS	NS	NS
S rate (kg·ha^{-1}) (R)								
0	0.55	0.38	2.97	2.42	3.13	3.32	0.50	0.43
34	0.53	0.39	3.04	2.46	2.89	3.07	0.44	0.40
68	0.50	0.40	2.98	2.55	2.99	3.24	0.46	0.42
102	0.50	0.38	3.04	2.52	2.95	307	0.45	0.39
Sig.	L**	NS	NS	NS	NS	NS	Q*	*
0 vs. S	**			NS	*	NS	**	
S_L[x]	NS			NS	NS	NS	NS	
S_Q[x]	NS			NS	NS	NS	NS	
Interaction								
S × M	NS	NS	NS	NS	NS	**	NS	NS
S × R	NS	NS	**	NS	NS	**	NS	**
M × R	NS	*	NS	NS	NS	NS	NS	NS
S × M × R	NS	**	NS	NS	NS	NS	NS	NS

[z]Mean separation (in column) by Waller-Duncan's multiple range test.
[y]Drip = 40% S preplant + 60% S drip applied, preplant = 100% S preplant.
[x]Polynomial regression for S rate of 34, 68, and 102 kg·ha^{-1}.
[w]Data were not taken.
NS, *, **Nonsignificant or significant at $P \leq 0.05$ and 0.01, respectively. S rate effects were linear (L) and quadratic (Q).

Table 5. Interaction effect of S rate and method of application on cabbage yield and average head weight in fall 1999, spring and fall 2000.

S rate (kg ha^{-1})	Drip S[z] Total (t ha^{-1})	Drip S[z] Head wt (g head^{-1})	Preplant S[z] Total (t ha^{-1})	Preplant S[z] Head wt (g head^{-1})
0	38.9	922	37.0	877
34	55.3	1311	50.7	1201
68	55.3	1310	47.6	1128
102	49.7	1178	51.9	1231
Sig.	**			**
0 vs. S	**			**
S_L[y]	*		NS	
S_Q[y]	NS		*	

[z]Drip S = 40% S preplant + 60% S drip applied, preplant S = 100% S preplant.
[y]Polynomial regression for S rate of 34, 68, and 102 kg·ha^{-1}.
NS, *, ** = nonsignificant and significant at $P \leq 0.05$ and 0.01, respectively.

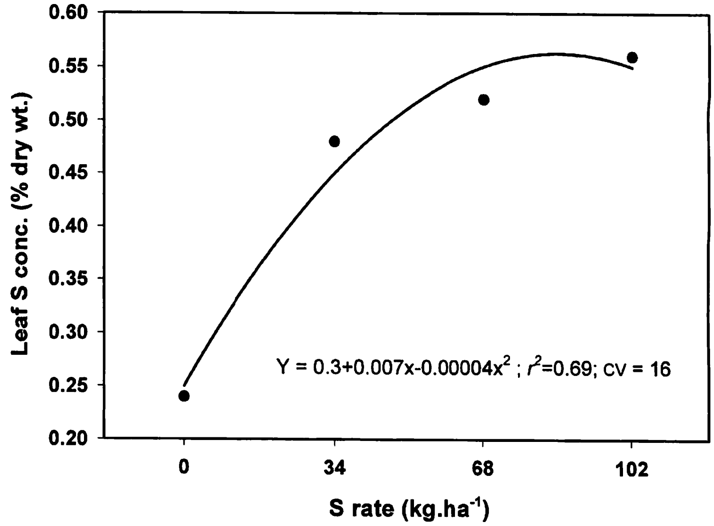

Figure 1. Relationship between S application rate and cabbage leaf S concentration at 6 WAT.

With S application, leaf S concentration was higher at 6 WAT than with no S application. A quadratic effect was obtained on leaf S concentration with an increase in S application from 34 to 102 kg·ha^{-1}. The relationship between S rate and leaf S concentration at 6 WAT was $Y = 0.3 + 0.007x - 0.00004x^2$; $r^2 = 0.69$; CV = 16 (Fig. 1). We attribute the S deficiency symptoms observed on plants grown at 0 S to low S concentration in the leaf. With 0 S applied, cabbage leaf S concentration was 0.24% at 6 WAT. In previous works, S deficiency symptoms occurred when leaf S concentrations were less than 0.18% dry weight on greenhouse tomatoes (Cerda et al., 1984) and from 0.12% to 0.18% dry weight on drip irrigated tomato in field studies (Susila and Locascio, 2000).

An interaction between season, S rate, and methods of application affected leaf S concentration at 9 WAT (Tables 2 and 7). With preplant S applications in fall 1999, spring 2000A, and fall 2000, leaf S concentrations were higher with S than with no S but no response to S application was obtained in spring 2000B. With an increase in S application from 34 to 102 kg ha^{-1} S leaf concentration increased linearly in all seasons except in spring 2000B. With drip S applications, leaf S concentrations were higher than with preplant applications (Table 7). With S applied by drip, S leaf concentrations were higher than with no S in all seasons. However, with drip S application from 34 to 102 kg ha^{-1}, leaf S concentrations at 9 WAT increased linearly in spring 2000A, spring 2000B, and fall 2000, but were not different in fall 1999.

The effects of season on soil nutrient concentrations were significant, but were not influenced by methods of S application (data not presented). The effects of S rate on soil nutrient concentration are presented in Table 8. Sulfur application

Table 6. Main effects of method of application and S rate on leaf P, K, Ca, and Mg concentration of cabbage sampled at 6 WAT in fall 2000.

Treatments	S	N	P	K	Ca	Mg
	Leaf nutrient concentration (% dry wt)					
Methods (M)[z]						
Drip	0.48	4.0	0.68	4.7	2.9	0.4
Preplant	0.44	4.4	0.56	4.5	2.9	0.4
Sig.	NS	**	**	NS	NS	NS
S rate (kg·ha^{-1}) (R)						
0	0.24	4.2	0.68	4.5	2.7	0.4
34	0.48	4.3	0.68	4.7	3.0	0.4
68	0.52	4.5	0.56	4.7	2.8	0.4
102	0.56	4.0	0.56	4.7	3.0	0.4
Sig.	C*	Q*	NS	NS	NS	NS
0 vs. S	*	NS	NS	NS	NS	NS
S_L[y]	NS	NS	NS	NS	NS	NS
S_Q[y]	**	*	NS	NS	NS	NS
Interaction						
M × R	NS	NS	NS	NS	NS	NS

[z]Drip = 40% S preplant + 60% S drip applied, preplant = 100% S preplant.
[y]Polynomial regression for S rate of 34, 68, and 102 kg ha^{-1}.
NS, *, **Nonsignificant or significant at $P \leq 0.05$ and 0.01, respectively. S rate effects were Q = quadratic, C = cubic.

Table 7. Interaction effect of S rate, season, and method of application on cabbage leaf S concentration at 9 WAT in fall 1999, spring and fall 2000.

S rate (kg·ha^{-1})	Fall '99	Spring '00A	Spring '00B	Fall '00
	Leaf S nutrient concentration (% dry wt)			
Preplant S[y]				
0	0.05	0.03	0.01	0.04
34	0.06	0.05	0.03	0.11
68	0.23	0.11	0.02	0.20
102	0.58	0.25	0.11	0.31
Sig.	**	**	NS	**
0 vs. S	**	*	NS	**
S_L[z]	**	**	NS	**
S_Q[z]	NS	NS	NS	NS
Drip S[y]				
0	0.06	0.04	0.02	0.08
34	0.38	0.20	0.10	0.21
68	0.34	0.41	0.23	0.33
102	0.55	0.51	0.26	0.42
Sig.	**	**	**	**
0 vs. S	**	**	**	**
S_L[z]	NS	**	**	**
S_Q[z]	NS	NS	NS	NS

[z]Polynomial regression for S rate of 34, 68, and 102 kg·ha^{-1}.
[y]Drip = 40% S preplant + 60% S drip applied, preplant = 100% S preplant
NS, *, ** = nonsignificant and significant at $P \leq 0.05$ and 0.01, respectively.

Table 8. Main effect of S rate on soil nutrient concentration for cabbage experiments at three sampling times in fall 1999, and spring and fall 2000.

S rate ($kg \cdot ha^{-1}$)	Soil nutrient concentration ($mg\ kg^{-1}$ soil)								
	pH	SO_4	P	K	Ca	Mg	NH_4	NO_3	Cl
3 WAT									
0	5.7	3.6	110	82	356	32	7.5	8.3	11.1
34	5.9	8.8	113	71	354	31	7.4	7.0	8.1
68	5.8	9.9	115	84	368	32	8.7	6.1	11.4
102	5.8	14.4	114	83	355	30	10.1	5.3	10.4
Sig.[z]	NS	L**	NS	NS	NS	NS	L**	L**	NS
6 WAT									
0	5.9	3.7	108	59	366	30	4.4	5.3	7.7
34	6.0	6.3	106	48	361	34	5.0	4.8	8.9
68	5.8	9.0	114	55	345	28	5.2	4.7	7.3
102	5.8	9.8	104	52	339	27	5.5	4.8	7.1
Sig.[z]	L**	L**	NS	NS	NS	NS	NS	NS	NS
9 WAT									
0	6.0	5.2	105	32	385	39	3.0	3.9	6.7
34	5.9	8.8	101	29	362	30	3.3	5.2	7.8
68	5.9	9.3	104	32	373	30	3.5	4.8	7.6
102	5.8	12.5	104	28	350	26	3.5	3.9	7.6
Sig.[z]	L**	L**	NS	NS	L**	C*	L*	NS	NS

[z]*, ** = Significance at 0.05 and 0.01 probability level, respectively, and NS = not significant at $P \leq 0.05$, L = linear, C = cubic.

increased soil extractable sulfate at all sampling times. At 9 WAT, S application reduced soil pH by about 0.2 units. The decreased soil pH may correlate with the reduction in soil Ca content with an increased rate of S. Soil nitrate concentrations 3 WAT also were reduced with an increase in S rate and were highest with the 0 S rate. With an increase in soil nitrate with no S fertilization, an increase in soil nitrate leaching may occur. Schung et al. (1993) reported that a reduction in S caused increased ecological problems because of the reduction of efficiency of N uptake in S-deficient crops, which increased leaching of nitrate into the groundwater.

In the four field studies, cabbage total yields increased with S application from 0 to 34 kg ha^{-1}. With S drip applications, total yields increased with an increase in S rate from 0 to 34 kg ha^{-1}, but yields were reduced linearly with S applications from 34 to 102 kg ha^{-1}. With preplant S applications, total yield increased with S to 34 kg ha^{-1}, but yields were similar with S rate above 34 kg ha^{-1}. Without S application, cabbage heads did not reach marketable size in two of the four seasons studied on soils with organic matter content between 0.9% and 1.6%. Total yields were significantly higher with drip than all preplant application of S. Thus, highest cabbage yields were obtained with drip application of S at 34 kg ha^{-1}.

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