HortScience 32(1):75–78. 1997.

Nitrogen, Magnesium, and Boron Applications Affect Cauliflower Yield, Curd Mass, and Hollow Stem Disorder

K.M. Batal[1], D.M. Granberry[2], and B.G. Mullinix, Jr.[3]
Horticulture Research Department, University of Georgia, Coastal Plain Experiment Station, Tifton, GA 31793

Additional index words. *Brassica oleracea*, *Botrytis* group, plant nutrition, soil type, hollow stem

Abstract. **The effects of three rates of N, Mg, and B on cauliflower (*Brassica oleracea, Botrytis group*) yield, average curd mass, and hollow stem disorder were evaluated on sandy and clay loam soils. Cultivars White Empress and Stovepipe were tested on the sandy loam soil and 'White Empress' was tested on the clay loam soil. Maximum mean curd mass and maximum yields were obtained with the highest N rates (269 and 381 kg·ha^{-1}) applied to sandy loam and clay loam soils, respectively. Yield response to increased N rates varied with cultivar. Increasing Mg from 22.5 to 90 kg·ha^{-1} did not affect yield or curd mass on clay loam soil, but increased yield and mean curd mass on sandy loam soil. The Mg effect on curd mass was influenced by N and B rates. On both soil types, the higher Mg and B rates reduced the incidence of hollow stem, but the Mg effect was influenced by N applications. On clay loam soil, increasing B from 2.2 to 8.8 kg·ha^{-1} reduced hollow stem but had no effect on yield or curd mass. On sandy loam soil, B at 4.4 kg·ha^{-1} maximized yield and curd mass, but the hollow stem disorder continued to decrease as B rates were increased from 2.2 to 8.8 kg·ha^{-1}.**

Cauliflower production can be a viable potential for vegetable growers in the southeastern United States. However, high temperatures during the production season (Table 1) and low soil fertility in the coastal plain can result in low yields and poor curd quality.

The importance of N supply in enhancing cauliflower yield and average curd mass has been reported (Cutcliffe and Munro, 1976; Nilsson, 1980; Pimpini et al., 1971). Magnesium and B concentrations, particularly in the sandy soils, are low (Table 2), and the Univ. of Georgia Cooperative Extension Service recommendations advocate Mg and B applications to improve yields of various crops (Plank, 1989). Cauliflower yield has been increased by B applications in the field (Gilbert, 1953; Gupta and Cutcliffe, 1975) and in the greenhouse (Gupta and Cutcliffe, 1975). These reports cited that 20% to 30% of the cauliflower plants grown on acid soils with 0.28 mg·kg^{-1} B had typical B deficiency, such as chlorosis, cupping up of leaf edges, and purplish coloration of the curds. These symptoms are also associated with the hollow stem disorder (HSD) as described by Maier (1951) and English and Maynard (1978). English and Maynard (1978) have shown that B applications reduce HSD in cauliflower. However, Genkov and Georgeiva (1973) found that B applications did not affect yield or HSD in 'Erfurt Dwarf' cauliflower. Similarly, Gupta and Cutcliffe (1975) found that HSD in cauliflower was not related to a low (0.28 mg·kg^{-1}) B concentration in soil or >10.5 mg·kg^{-1} in tissue.

In this study, we investigated the effects of application rates of N, Mg, and B on cauliflower yield, head mass, and the incidence of hollow stem.

Materials and Methods

Tifton. This experiment was conducted on a Tifton sandy loam soil (fine loamy, siliceous thermic Plinthic Paleudults) (Perkins et al., 1978) in Fall 1980 at the Coastal Plain Experiment Station, Tifton, Ga. (Table 2).

Fertilizer at 45N–90P–133K kg·ha^{-1} was broadcast and incorporated into the top 15 cm of the beds just before transplanting. Soil N (0- to 15-cm depth) was monitored by weekly soil NO_3-N analyses, using the nitrate-specific ion electrode method of Gaines and Mitchell (1979). Additional N at 56 kg·ha^{-1} as KNO_3 was top-dressed in double bands (10 cm from plants) whenever soil NO_3-N concentrations fell below 5, 10, and 20 mg·kg^{-1} for low, medium, and high rates, respectively. Subsequently, these top-dressings were applied once for low (total N 101 kg·ha^{-1}), 3 times for medium (total N 213 kg·ha^{-1}), and 4 times for the high rate (total N 269 kg·ha^{-1}). The N application procedure was a modification of a

Table 1. Average monthly minimum and maximum temperatures and total rainfall for fall production seasons, 1976–80 (Tifton) and 1984–88 (Plains).

	1976–80			1984–88		
	Temp (°C)		Rain	Temp (°C)		Rain
Month	Min.	Max.	(mm)	Min.	Max.	(mm)
September	18.9	30.6	60	17.8	29.7	71
	(20.8)^z	(32.8)	(86)	(19.0)	(28.9)	(83)
October	15.8	26.9	85	10.8	24.7	33
	(12.2)	(24.8)	(82)	(9.6)	(23.8)	(61)
November	13.6	23.6	168	9.4	21.9	135
	(7.3)	(20.0)	(17)	(8.5)	(21.0)	(43)
December	4.7	16.3	138	2.7	14.7	68
	(2.6)	(15.8)	(30)	(1.7)	(16.4)	(29)

^{z}Values in parentheses are temperature and rainfall readings for the year and period the experiments were conducted.

Table 2. Chemical and physical properties of soils at the two experimental sites.

	Experimental site	
	Tifton	Plains
Property	(sandy loam)	(clay loam)
Element^z (mg·kg^{-1})		
P	44 medium	56 high
K	47 medium	84 high
Mg	26 low	71 medium
Ca	273 adequate	365 adequate
B	0.07 very low	0.21 low
CEC [mmol(+)·kg^{-1}]^y	25.55	34.10
Organic matter (%)	<1.0	1.50
Clay content (%)	10% to 15%	22% to 35%
pH^x	5.60	6.70

^{z}Elements P, K, Mg, and Ca were determined (soil samples, 0- to 15-cm depth) by the double acid (Mehlich-1) extraction method and inductively coupled plasma spectrograph (ICPS); B was determined by modified hot water (80 °C) extraction and ICPS.

^{y}Values are sums of cation exchange capacities (CEC) of Ca^{++}, Mg^{++}, K^+, Na^+, and H^+ elements; milliequivalents (meq) were converted to mmol(+)·kg^{-1} by multiplying meq by a factor of 5 for Ca^{++}, Mg^{++}, and by 10 for K^+, Na^+, and H^+.

^{x}pH at Tifton was adjusted to 6.5 with $CaCO_3$ 3 months prior to test.

Received for publication 20 Aug. 1996. Accepted for publication 24 Sept. 1996. This research was supported by State and Hatch funds allocated to the Georgia Agricultural Experiment Stations. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

[1]Horticulture Dept., Coastal Plain Experiment Station, Tifton, GA 31793-0748.
[2]University of Georgia Cooperative Extension Service, RDC, Tifton, GA 31794.
[3]Statistical and Computer Services, Coastal Plain Experiment Station, Tifton, GA 31793-0748.

similar method described by Batal and Smittle (1981). Potassium levels were equalized in all plots by applying muriate of potash with each KNO_3 top-dressing.

Magnesium oxide was applied at 22.5, 45, and 90 kg·ha^{-1} for low, medium, and high rates, respectively. Half of each amount was broadcast and incorporated in the soil 15 cm deep just before transplanting and half was banded on both sides (10 cm from plants) 6 weeks later, at curd formation.

Solubor (20.5% B) (Traylor Chemicals and Supply Co., Orlando, Fla.) in aqueous solution was applied in bands (10 cm from plants) at 2.2, 4.4, and 8.8 kg·ha^{-1} for the low, medium, and high rates, respectively. Two equal band applications were made, half at transplanting and the remainder at curd formation. Overhead irrigation (8 mm) was used immediately after each application.

Five-week-old plants of 'Stovepipe' and 'White Empress' cauliflower were transplanted to 2.1 × 1.8-m plots on 14 Sept. 1980. Plants were set 38 cm apart in rows 90 cm apart. Each test plot consisted of two rows, and plots were separated by rows of border plants. When needed, irrigation was used to ensure a minimum of 38 mm of water, applied in three irrigations per week, throughout the growing season.

The harvesting period was from 20 Nov. to 3 Dec. Individual heads were harvested 7 days from the time each head measured 10 cm in diameter. Only the marketable heads (minimum diameter ≥15 cm) were considered for yield analyses. All marketable heads were trimmed to market standards and weighed. Curd stems were examined for the presence or absence of hollow areas.

The design was a randomized complete block, consisting of 27 treatment combinations with three levels of N, Mg, and B for each cultivar with three replications. The cultivars were stripped across the 27 treatment combinations. The data were analyzed as a stripped split-plot.

Plains. This experiment was conducted in Fall 1988, at the Southwest Georgia Agricultural Experiment Station, Plains. The soil was clayey-kaolinite (thermic Rhodic Paleudults) (Perkins et al., 1978) (Table 2). Rates and methods for Mg and B applications were the same as at Tifton. The initial N application (45 kg·ha^{-1}) at transplanting (14 Sept. 1988) was also the same, but total N rates were predetermined by the number of applications rather than by soil NO_3-N concentrations, as was done at Tifton.

Beginning 3 weeks after transplanting, N at 56 kg·ha^{-1} was applied once every 3 weeks, once every 2 weeks, and once every week. The last application was made 8 weeks after transplanting. Thus, the total N applications, including the initial one, were 157, 213, and 381 kg·ha^{-1} for the low, medium, and high N rates, respectively.

Plot preparations, transplanting, and irrigation procedures also were similar to those used at Tifton. Only 'White Empress' was tested at Plains. Plots were 3 m long and 2 m wide. Individual heads were harvested based on general appearance of the curd surface (fully expanded, compact and smooth domed curds) from 16 to 30 Nov. 1988. Cauliflower heads were individually weighed and evaluated for HSD, as was done at Tifton. The design was a randomized complete block, consisting of four replications of a 3 × 3 × 3 factorial arrangement of N, Mg, and B, respectively.

Table 3. Effects of cauliflower cultivars and application rates of N, Mg, and B on yield, curd mass, and hollow stem disorder, Tifton (T) and Plains (P).

	Total yield (t·ha^{-1})		Mean curd mass (g)		Hollow stem disorder (%)	
Variable	T	P	T	P	T	P
Cultivar (cv)						
Stovepipe	7.7	---	561	---	27	---
White Empress	9.7	---	693	---	25	---
Significance (P > F)	NS	---	*	---	NS	---
Application rate (kg·ha^{-1})						
Nitrogen (N)						
101	7.0	---	501	---	30	---
157	---	10.4	---	494	---	14.7
213	9.1	12.0	667	573	22	13.8
269	9.9	---	712	---	25	---
381	---	12.9	---	614	---	9.6
Linear	***	**	***	***	NS	**
Quadratic	NS	*	**	*	NS	NS
Magnesium (Mg)						
22.5	7.2	11.4	533	548	32	15.4
45.0	8.7	12.0	623	566	25	13.1
90.0	10.2	11.9	724	567	21	9.7
Linear	***	NS	***	NS	**	**
Quadratic	NS	NS	NS	NS	NS	NS
Boron (B)						
2.2	8.0	11.7	579	567	38	18.2
4.4	9.0	12.0	651	561	29	11.8
8.8	9.0	11.6	649	553	10	8.1
Linear	**	NS	***	NS	***	***
Quadratic	*	NS	NS	NS	NS	NS
Interactions						
cv × N	**	---	***	---	NS	---
N × Mg	NS	*	**	**	**	*
Mg × B	NS	NS	**	NS	NS	NS
N × Mg × B	NS	NS	NS	NS	NS	*

NS, *, ** , ***Nonsignificant or significant at $P \le 0.05$, 0.01, or 0.001, respectively.

Results and Discussion

Cultivar and N effects. Mean curd mass and total yield at Tifton were affected by significant cultivar × N interactions (Table 3). Individual curd mass (Fig. 1A) and total yield (Fig. 1B) of 'White Empress' increased linearly ($P < 0.0001$) with increased N rate from 101 to 269 kg·ha^{-1}. Increase in yield of 'Stovepipe' was quadratic ($P < 0.05$), attaining its maximum gain of only 28% with N at 213 kg·ha^{-1} compared to a 61% gain for 'White Empress'. Cutcliffe and Munro (1976) reported a maximum increase in cauliflower yield with N application of 224 kg·ha^{-1}.

At Plains, both mean curd mass and total yield were increased by increasing N rates from 157 to 381 kg·ha^{-1} (Table 3). The increase in mean curd mass at Plains was slightly lower than at Tifton. However, the total yield at Plains was higher because more marketable heads were produced on the clay loam soil.

The cultivar response in the Tifton experiment may have resulted from the basic genotypic differences between the two cultivars. Leaves of 'Stovepipe' have an upright growth habit, while 'White Empress' is a semi-self-blanching type. 'Stovepipe' normally produces smaller curds and matures slightly earlier than 'White Empress'. These data show that specific N rates required to maximize yield may vary with each cultivar. Perhaps, yield of some cauliflower types can be improved on sandy soils by a continuous supply of N above the rates tested here.

Interaction effects of N and Mg. Total yield and curd mass increased linearly with increasing N and Mg rates at Tifton (Table 3). These results coincide with increased cabbage (*Brassica oleracea* Capitata Group)-head mass by 48 g/plant with increased Mg from 0 to 25 mg·L^{-1} in a culture solution with N concentration at 50 mg·L^{-1} (Hara and Sonoda, 1981). However, increased curd mass with increasing N depended on applied Mg rate at Tifton (Fig. 2) and Plains (Fig. 3A). At both locations, the changes in curd mass with increased N rates were linear with low (22.5 kg·ha^{-1}) and high (90 kg·ha^{-1}) Mg rates. The increase in curd mass was quadratic with Mg at 45 kg·ha^{-1}.

The combined effects of N and Mg on curd mass also was reflected in the total yield produced by the N–Mg combinations at Plains (Fig. 3B). These results indicate a strong positive yield response to N rates higher than 213 kg·ha^{-1} when applied with high Mg rates.

Boron effect on curd mass and total yield. At Tifton, B at 4.4 kg·ha^{-1} resulted in a higher yield ($P < 0.01$) than 2.2 kg·ha^{-1} (Table 3). Increasing B to 8.8 kg·ha^{-1} had no further

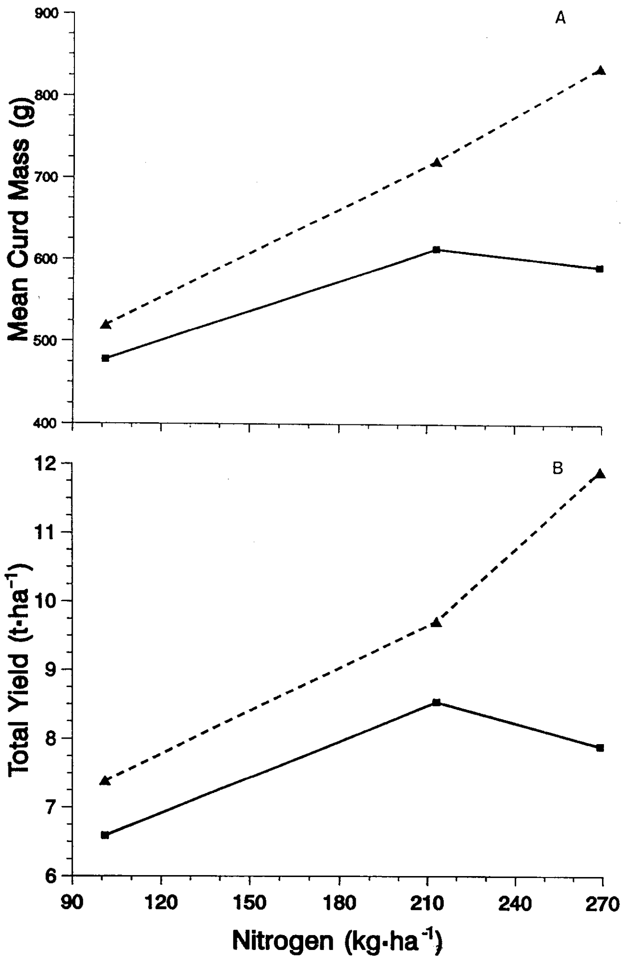

Fig. 1. Cauliflower mean curd mass (**A**) and total yield (**B**) as affected by cultivar × N rate interactions at Tifton. Changes in curd mass and total yield with differing N rates are quadratic (Q*) for 'Stovepipe' (—■—) and linear (L***) for 'White Empress' (--▲--). *,***Significant at $P \leq 0.05$ and 0.01.

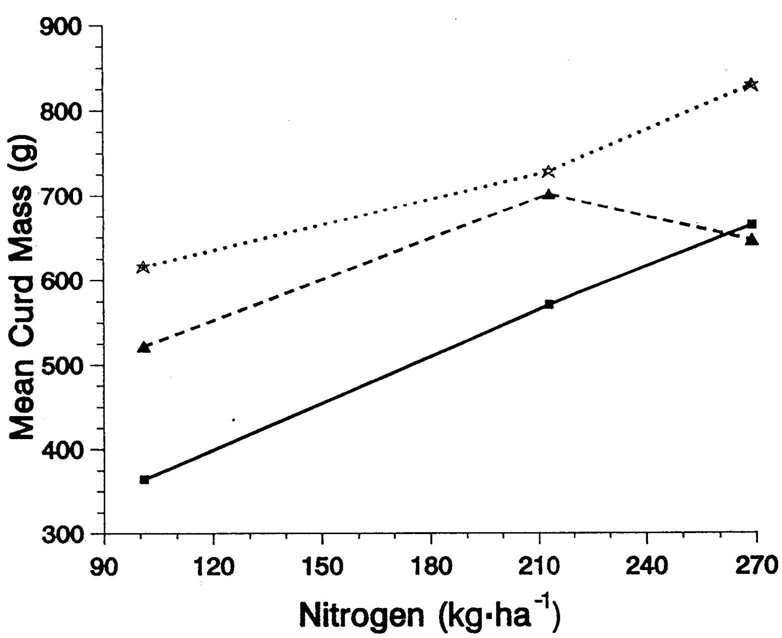

Fig. 2. Changes in mean curd mass as affected by an N rate × Mg rate interaction at Tifton. Linear changes (L***) in curd mass with Mg rates, 22.5 (—■—) and 90 (...★...) kg·ha^{-1}, and quadratic (Q**) with 45 (--▲--) kg·ha^{-1}. **,***Significant at $P \leq 0.01$ and 0.001.

effect on yield. The mean curd mass, however, was only slightly higher at 4.4 than at 8.8 kg·ha^{-1}. Boron applications have been shown to increase cauliflower plant growth by 3-fold in the greenhouse and increase yield by 20% in the field (Gupta and Cutcliffe, 1975). Gilbert (1953) also reported a significant yield increase by applying B at 11.2 kg·ha^{-1} to hot weather-type cauliflower grown during late summer in Hawaii.

Increasing B rates at Plains had no effect on total yield or average curd mass. The lack of response to B at Plains may have been due to the soil type (clay loam), higher cation exchange capacity, or the initial B concentrations (Table 2). These results suggest that response to B nutrition depends on cauliflower type and on soil and climatic conditions.

Effects on hollow stem. Boron deficiency symptoms associated with HSD as described by Maier (1951) and English and Maynard (1978) were absent at both locations. However, B was predominantly responsible for the significant ($P < 0.001$) reduction of HSD as B rates increased from 2.2 to 8.8 kg·ha^{-1} (Table 3). Results of this study indicate that, under certain conditions, increased levels of soil B can effectively reduce the HSD.

The interaction effect ($P < 0.01$) of N × Mg × B on HSD was evident at Plains (Fig. 4). For each Mg rate within the lowest or the highest N level, increasing B from 2.2 to 8.8 kg·ha^{-1} had no significant effect on HSD. However, with medium N and high Mg rates, increased B rates linearly ($P < 0.01$) reduced percentage of HSD. The nonsignificant change in HSD from increased B with the high N rate may have resulted from the possible effect of curd growth, which was influenced by the high N rate in both experiments (Table 3). Mean curd mass was negatively correlated with percentage of HSD ($r = -0.321$, $P < 0.001$ and $r = -0.466$, $P < 0.001$) for Tifton and Plains, respectively.

Percentage of heads with HSD also was influenced by significant interactions between N and Mg rates at Tifton (Table 3). With the low N rate (101 kg·ha^{-1}), increased Mg linearly reduced the HSD (Fig. 5). At the higher N rates (213 and 269 kg·ha^{-1}), increasing Mg had no effect on HSD.

Conclusions

Further evaluations of N, Mg, and B fertilization, along with a complete assessment of B composition in young and old leaves, in head tissue, and elemental recovery analyses are needed to better understand the interrelationships of these elements in curd growth and the development of HSD. This study demonstrated that HSD can be reduced by B and Mg, but the efficacy of these elements is influenced by N rates.

Cauliflower cultivars differentially responded to N rates. This probably resulted from the genotypic influence on growth and maturation of the two cultivars. Nitrogen and Mg were equally effective in improving average head mass and total yield of 'Stovepipe' and 'White Empress'. Boron also influenced

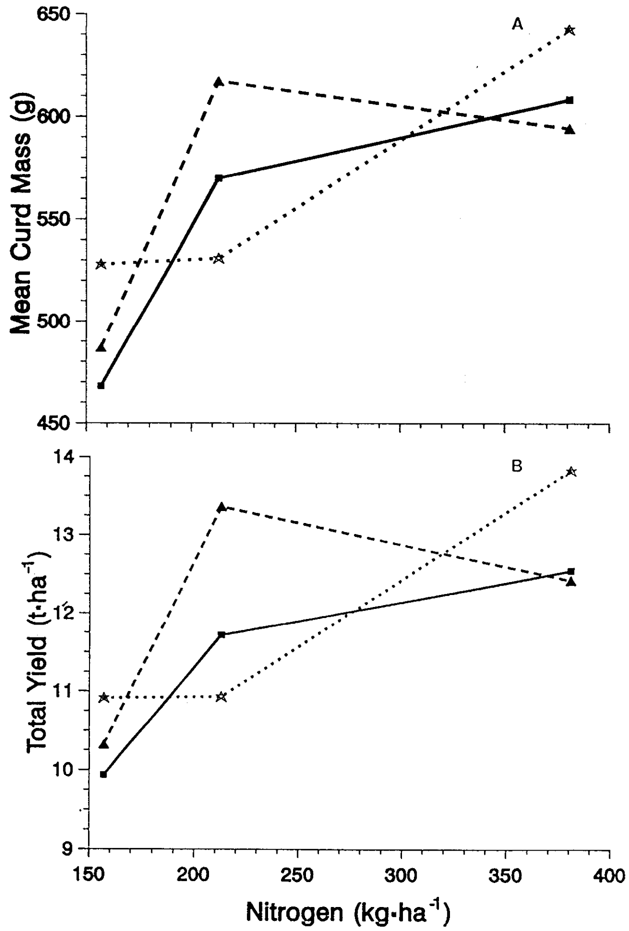

Fig. 3. Changes in curd mass (**A**) and total yield (**B**) as affected by N rate × Mg rate interactions at Plains. Linear (L^{**}) change for curd mass and total yield with Mg rates, 22.5 (—■—) and 90 (..★..) kg·ha^{-1}. Quadratic (Q^{*}) change with 45 (--▲--) kg·ha^{-1}. *,**Significant at $P \leq 0.05$ and 0.01.

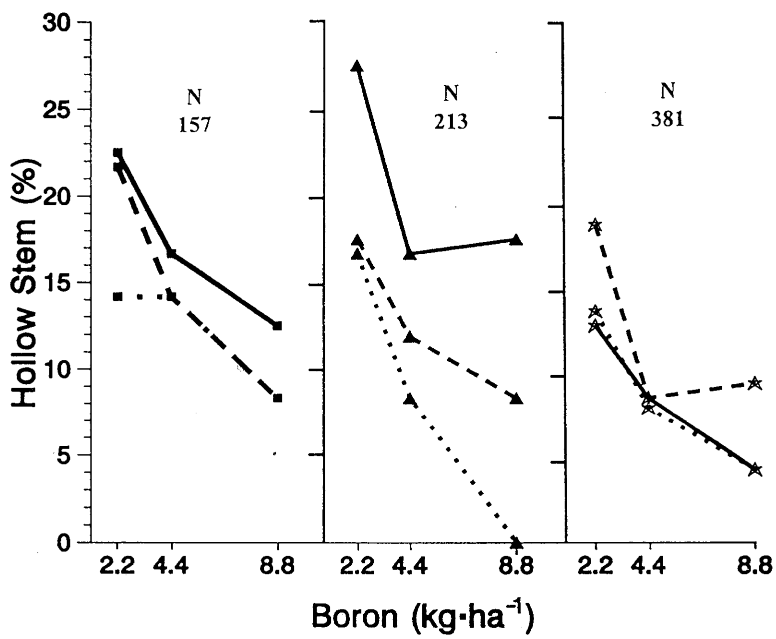

Fig. 4. Percentage of cauliflower heads with hollow stem disorder (HSD) at Plains as affected by N rate × Mg rate × B rate interactions. Reduction of HSD by B with Mg rates, 22.5 (____), 45 (----), and 90 (....) kg·ha^{-1} within each N rate, 157 (■), 213 (▲), and 381 (★) kg·ha^{-1}. Linear (L^{**}) changes in HSD for N, 157 with Mg 45 kg·ha^{-1} and for N, 213 with Mg 90 kg·ha^{-1}. Changes for all other combinations were nonsignificant. ^{NS,**,***}Nonsignificant or significant at $P \leq 0.01$ and 0.001.

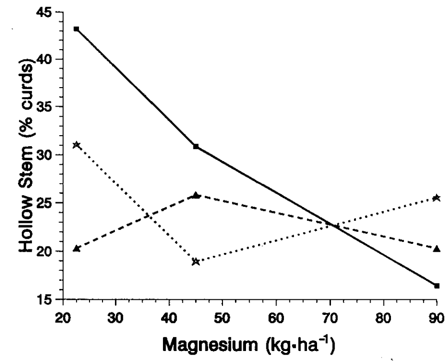

Fig. 5. Percentage of cauliflower heads with hollow stem disorder (HSD) at Tifton as affected by an N rate × Mg rate interaction. Linear (L^{***}) changes in HSD by Mg with N 101 kg·ha^{-1} (—■—); nonsignificant changes in HSD with N rates, 213 (—▲—) and 269 kg·ha^{-1} (..★..). ^{NS,***}Nonsignificant or significant at $P \leq 0.001$.

cauliflower growth, and maximized curd mass. Optimal rates of these elements and specific timing of application for different soil types and environmental conditions need to be determined.

Literature Cited

Batal, K.M. and D.A. Smittle. 1981. Response of bell pepper to irrigation, nitrogen, and plant population. J. Amer. Soc. Hort. Sci. 106:259–262.

Cutcliffe, J.A. and D.C. Munro. 1976. Effects of nitrogen, phosphorus and potassium on yield and maturity of cauliflower. Can. J. Plant Sci. 56:127–131.

English, J.E. and D.N. Maynard. 1978. A key to nutrient disorders of vegetable plants. HortScience 13:28–29.

Gaines, T.P. and G.A. Mitchell. 1979. Chemical methods for soil and plant analysis. Univ. of Georgia, Coastal Plain Expt. Sta., Agron. Hdbk., No. 1.

Genkov, G. and M. Georgieva. 1973. An attempt to determine the causes of hollow stem in cauliflower (in Bulgarian with Russian and English summaries). Rastenievudstvo 23:9–18.

Gilbert, J.C. 1953. Hot weather cauliflower culture. Hawaii Farm Sci. 2:1, 8.

Gupta, V.C. and J.A. Cutcliffe. 1975. Boron deficiency in cole crops under field and greenhouse conditions. Commun. Soil Sci. & Plant Anal. 6:181–188.

Hara, T. and Y. Sonoda. 1981. The role of macronutrients in cabbage-head formation. II. Contribution to cabbage-head formation of calcium, magnesium, or sulfur supplied at different growth stages. Soil. Sci. & Plant Nutr. 27:45–54.

Maier, W. 1951. Bormangelkrankheiten an Blumenkohl (*Brassica oleracea* L. var. *botrytis* L.) and Kohlrabi (*B. oleracea* L. var. *gongyloides* L.). Angew Bot. 26:3–12.

Nilsson, T. 1980. The influence of soil type, nitrogen and irrigation on yield, quality and chemical composition of cauliflower. Swedish J. Agr. Res. 10:65–75.

Perkins, H.F., A. Hutchins, and R.B. Moss. 1978. Soils of the Southwest Georgia Branch Expt. Sta., Univ. of Georgia, Res. Bul. 217.

Pimpini, F., F. Venter, and A. Wunsch. 1971. The influence of different nitrogen forms and increasing nitrogen doses on the content of total nitrogen and nitrate in cauliflower plants. Acta Hort. 29:307–318.

Plank, C.O. 1989. Soil test handbook for Georgia. Georgia Coop. Ext. Serv., Univ. of Georgia, Athens. June 1989.