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THE INFLUENCE OF NUTRITION ON PRODUCTION OF CONTAINER-GROWN ORNAMENTAL PEPPERS

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Abstract: Three experiments were conducted to study the influence of nutrition on the production of container-grown *Capsicum annuum* 'Fips' the first was a central composite design which examined the influence of five rates of N, P, K and lime 0 to 600 g N m^{-3}, 0 to 400 g P m^{-3}, 0 to 332 g K m^{-3} and 0 to 12 kg lime m^{-3} The second experiment was a 4 × 2 × 2 factorial with 4 rates of Mg from 0 to 450 g m^{-3}, 2 rates of P at 50 and 400 gm^{-3} and 2 rates of K at 83 and 415 g m^{-3}. The third experiment was a simple randomised block design with 5 rates of K from 300 to 700 g m^{-3} Strong responses to N and K were noted while P had a moderate influence. Lime had no apparent effect at low N rates but influenced growth significantly at high N by raising the pH from 4.2 to 5 8. There was no response to added Mg Foliage growth, plant quality and fruiting were optimal at 600 g N, 300 g P and 500 g K m^{-3} Lime at 6 kg m^{-3} was recommended (optimum pH 5 8 - 6.1). Suggested tissue composition of good quality ornamental pepper 'Fips' are given as 3 4 to 3 8% N, 0 4% P, 4 6% K, 3 4% Ca, and 1 4% Mg

INTRODUCTION

Ornamental peppers (*Capsicum* spp.) are popular pot plants providing colour for the autumn and winter months. A bonus of ornamental peppers in the home is the potential use of the fruits for making pepper sauce and flavoring food (4). The increased production of a wide range of pot plants emphasises the need for research on cultural requirements (23).

Previous studies on the nutrition of peppers were confined to chilli and sweet pepper cultivars (17). Recommended fertilizer rates in the potting medium and liquid feeding for ornamental peppers were based on standard responses of a range of container-grown plants rather than the specific requirements of *Capsicum* spp. (3,21). Studies of chillies and sweet peppers revealed a strong N response (13,20). Responses to P and K were dependent on existing soil P and K levels (6). Calcium deficiency in peppers resulting in blossom-end rots was indirectly caused by high Mg application (11) while high liming was considered beneficial (22). Magnesium deficiency is common among Solanaceous species and is often a result of high levels of applied K (3,21). Inclusion of $MgSO_4$ in potting mixes or in liquid feeds for ornamental peppers was advocated (8,21), although field studies found no response to Mg application (7). Studies of several Solanaceous flowering pot plants, also from tropical America, such as *Browallia speciosa*, *Brunfelsia* spp. and *Petunia* × *hybrida* revealed a strong demand for N and K, while the P requirement was relatively low (9,10,12,28).

The objective of this study was to examine the response of container-grown ornamental peppers to N, P, K, and Ca and Mg application, and to recommend appropriate rates of these nutrients in potting media used for production.

MATERIALS AND METHODS

Plant Material, Growing Environment, and Potting Media

Capsicum annuum 'Fips' plants were raised from seed in seed trays and pricked-out at the five to six-leaf stage, directly into 12.5 cm pots (0.8 liter) in Experiment A. Plants pricked-out from seed trays to 12.5 cm pots in Experiment B were older seedlings, with eight to ten leaves. Seedlings For Experiment C were raised in 5 cm pots and potted out directly into 12.5 cm pots, to minimise transplanting shock.

The experiments were conducted in a heated glasshouse equipped with automatic fan ventilation. The minimum glasshouse temperature was 15°C while the maximum was close to 5°C above the ambient outside temperature. Plants in experiment C, grown in the winter months, were given supplementary lighting from 4 p.m. to 11 p.m. daily to encourage growth during short-day conditions. The plants were hand-watered when required. Sprays against *Botrytis*, aphids, mites, and white flies were given when necessary. The plants were pinched at about 7.5 cm high to allow 4 to 5 shoots per plant to develop.

The potting medium used was equal parts (1:1, v/v) Mataura sphagnum peat and coarse sand (crushed shingle grit). The chemical and physical properties of this medium were described by Goh and Haynes.

Experimental Design and Fertilizer Rates

Experiment A: A central composite second order design with incomplete blocks for four factor response surfaces as described by Box and Hunter (2) was used. The factors N, P, K, and lime were applied in 30 treatments arranged in 10 blocks, each consisting of 3 sub-blocks and 10 replicates per treatment. Nutrients were supplied from Osmocote (26% N), superphosphate (8% P), sulphate of potash (39% K), and a mixture of dolomite and agricultural lime at 3:1. Nitrogen, P, K, and lime treatment additions were all applied as base dressings with the levels given in Figures 1,2, and 4, respectively. All treatments also received a basal dressing of the following: 360 g m^{-3} "Fetrilon" (35% EDTA chelate Fe with 5% Fe), and 150 g m^{-3} "Sporumix A" (containing 1.4% B, 0.05 % Co, 1.27% Cu, 9.78% Mg, 5.46% Mn, and 0.06% Mo). The experiment was started on December 8, 1979 and harvested on March 18, 1980.

Figure 1. The nitrogen response of ornamental peppers supplied with medium rates of P, K, and lime. *Left to right*: N (in g m^{-3}): 0, 300, 600

Experiment B: A 4×2×2 factorial randomised block design with 5 replicates per treatment was used. Magnesium in the form of magnesium sulphate (10% Mg), P as superphosphate, and K as sulphate of potash, were applied as basal dressings at the rates given in Table 1.

All treatments received 450 g N m^{-3} as Osmocote (26% N), 6 kg m^{-3} of agricultural lime, and 360 g m^{-3} of "Fetrilon". No dolomite lime or "Sporumix A" were added because of the 11-19% and 9.78% Mg in these fertilizers, respectively. This experiment was run from February 8, 1960 to May 6, 1980.

Experiment C: A simple design with five rates of K, in randomised blocks, was used. There were 4 replicates per treatment which commenced on May 3, 1985 and was terminated on October 7, 1981. Potassium in the form of sulphate of potash (39% K) was added at rates shown in Figure 9. All treatments were given a basal dressing of the following: 600 g N m^{-3} from Osmocote (26% N), 300 g P m^{-3} from superphosphate (8% P), 6 kg lime m^{-3} in a 3:1 mix of dolomite and agricultural lime, 360 g m^{-3} of "Fetrilon" and 150 g m^{-3} of "Sporumix A".

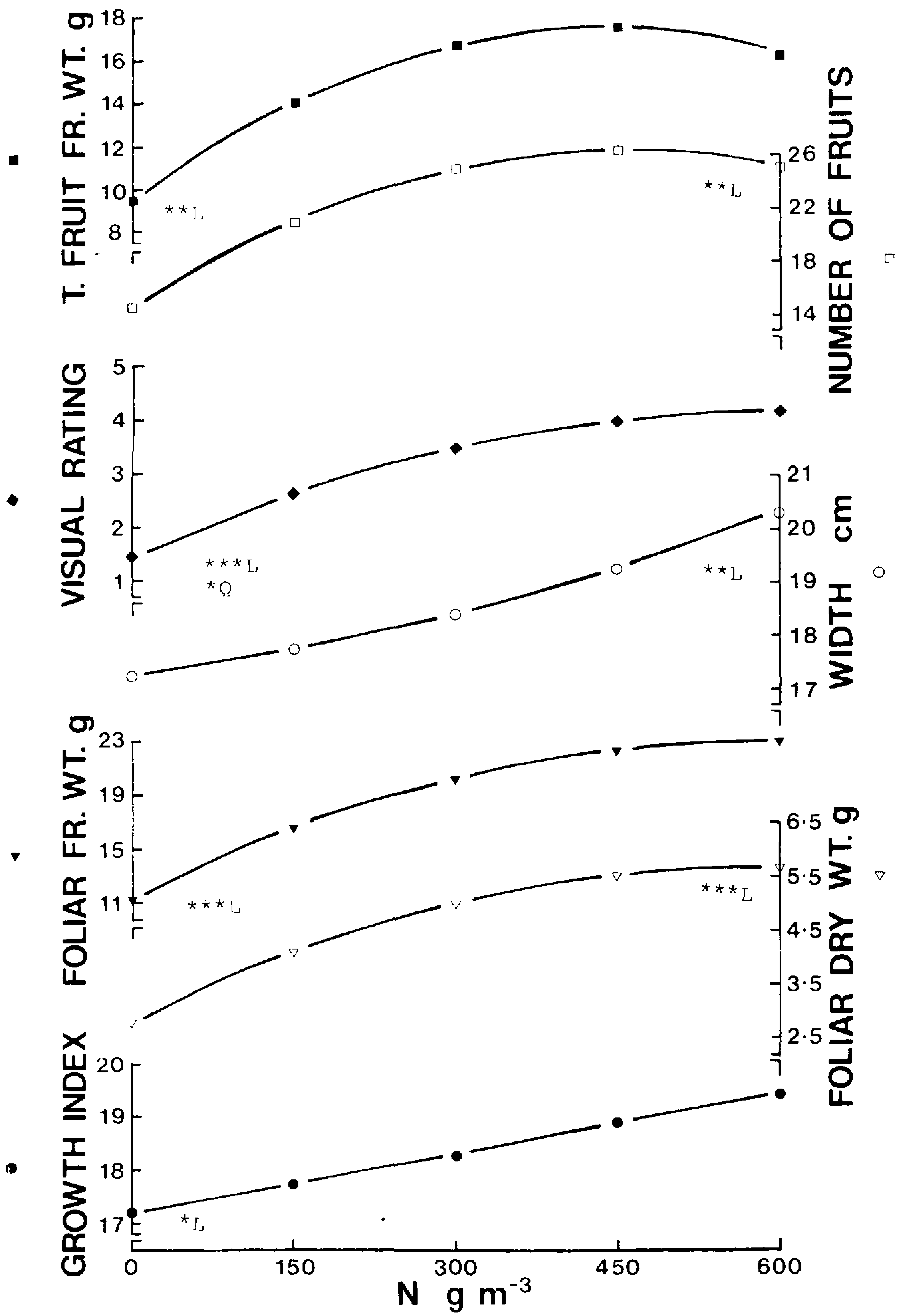

Figure 2. Experiment A Influence of low to medium N levels at medium P, K, and lime rates on foliage growth and fruiting.

(In all figures and tables L = linear and Q = quadratic with asterisks (*) used to give the level of significance.)

Table 1. Experiments A and B. Foliar analyses and media pH from composite samples of selected treatments taken at harvest and 2 months after potting, respectively.

Added Nutrients					Foliar Nutrients (% dry weight)					
$g\ m^{-3}$			$kg\ m^{-3}$	$g\ m^{-3}$						Media
N	P	K	lime	Mg	N	P	K	Ca	Mg	pH
Experiment A:										
0	200	166	6		1 90					6 4
150	100	83	3		2 92	0.27	3 0			
300	200	166	6		3 03	0.26	3 0	3 4	1.4	6 1
450	300	250	9		3 22	0 41	2 7			
600	200	166	6		3 38					5 9
300	0	166	6			0 14				
300	400	166	6			0.43				
300	200	0	6				1 5			
300	200	332	6							
300	200	166	0							4 8
300	200	166	12							6 4
Experiment B:										
450	50	83	6	0		0.25	3 5			
450	400	415	6	300		0 43	4.5			

Date Collection and Analysis

The plants were assessed for height, width, stem diameter, visual rating, total number of fruits per plant, and foliar dry weight. Plant height was measured from the soil surface to the highest point; plant width at the widest point, and stem diameter at the base of the plant at soil level. Visual ratings were obtained using a score of 0 for dead to 5 for quality plants with dark green foliage and a good display of colourful fruits. Two growth indices were calculated: growth index from the sum of height and width divided by two, and height growth index from the product of height and the square of the stem diameter (14,26). Additional assessments in some of the experiments included the total fresh weight of the fruits per plant, and the foliar fresh weight. Plants were harvested at the appearance of red fruits equivalent to when the crop would be marketed. Data collected were statistically analysed for analysis of variance and F test.

Foliar samples were taken from selected treatments in Experiments A and B to assess concentrations of N, P, K, Ca, and Mg using the methods described by Parkinson and Allen. A range of pH levels was also obtained for Experiment A.

RESULTS

Experiment A: The effects of N, P and K were highly significant as shown in Figures 1-8 and in Table 2. A strong positive response to N was observed (Figure 1). Characteristic

N deficiency symptoms of stunting and chlorosis were observed with plants receiving no N and having a foliar N content of 1.90% (Table 1). The optimum response in foliage growth and plant quality was at 600 g N m^{-3} (Figure 2) while fruiting was greatest at 450 g N m^{-3}. The foliar N content of plants receiving 600 g N m^{-3} levels was in the range of 3.22 to 3.38% (Table 1). The pH at this optimal N level was 5.9 (Table 1). Flowering commenced at the end of January.

A very marked response to P is shown in Figures 3 and 4. Plants receiving no P were severely stunted, with the young upper leaves showing an intensely dark green colouration while the lower leaves were paler with large yellow patches (Figure 5). Purple colouration of stems and leaves usually associated with P deficiency was not observed. The foliar P content of these P-deficient plants was 0.14% (Table 1). Foliage growth, plant quality, and fruiting were all optimal at 300 g P m^{-3} (Figures 3 and 4). Plants receiving this optimal P level would have a foliar P content of around 0.41% (Table 1).

Added K had a strong effect as indicated by Figures 6, 7 and 8. Potassium deficiency occurred on plants with no added K. Stunting and interveinal chlorosis leading to a bronzed colour, necrosis, and eventually loss of some leaves were observed. Such plants had a foliar K content of 1.5% (Table 1). Plant quality was apparently optimal at 250 g K m^{-3} but the responses in foliage growth and fruiting suggested a higher K requirement than supplied by 332 g K m^{-3}. It appears that plants receiving desirable K additions should have a foliar K content of greater than 4% (Table 2).

Lime had no apparent effect and plants receiving 6 kg m^{-3} lime seemingly had adequate foliar Ca and Mg and the pH of the medium was raised from 4.8 to 6.4 by lime application (Table 1).

Experiment B: Added Mg at from 0 to 450 g m^{-3} had no significant influence on either foliage growth, fruiting, or plant quality (data not shown). However, the responses to both P and K were highly significant and there was improved foliage growth, plant quality, and fruiting. Flowering was observed in early March, a month after the beginning of the experiment (as with Experiment A). Plants with optimum growth had foliar P and K contents of 0.43 and 4.5%, respectively, compared with 0.25 and 3.5%, respectively, for the plants with the poorest growth (Table 1).

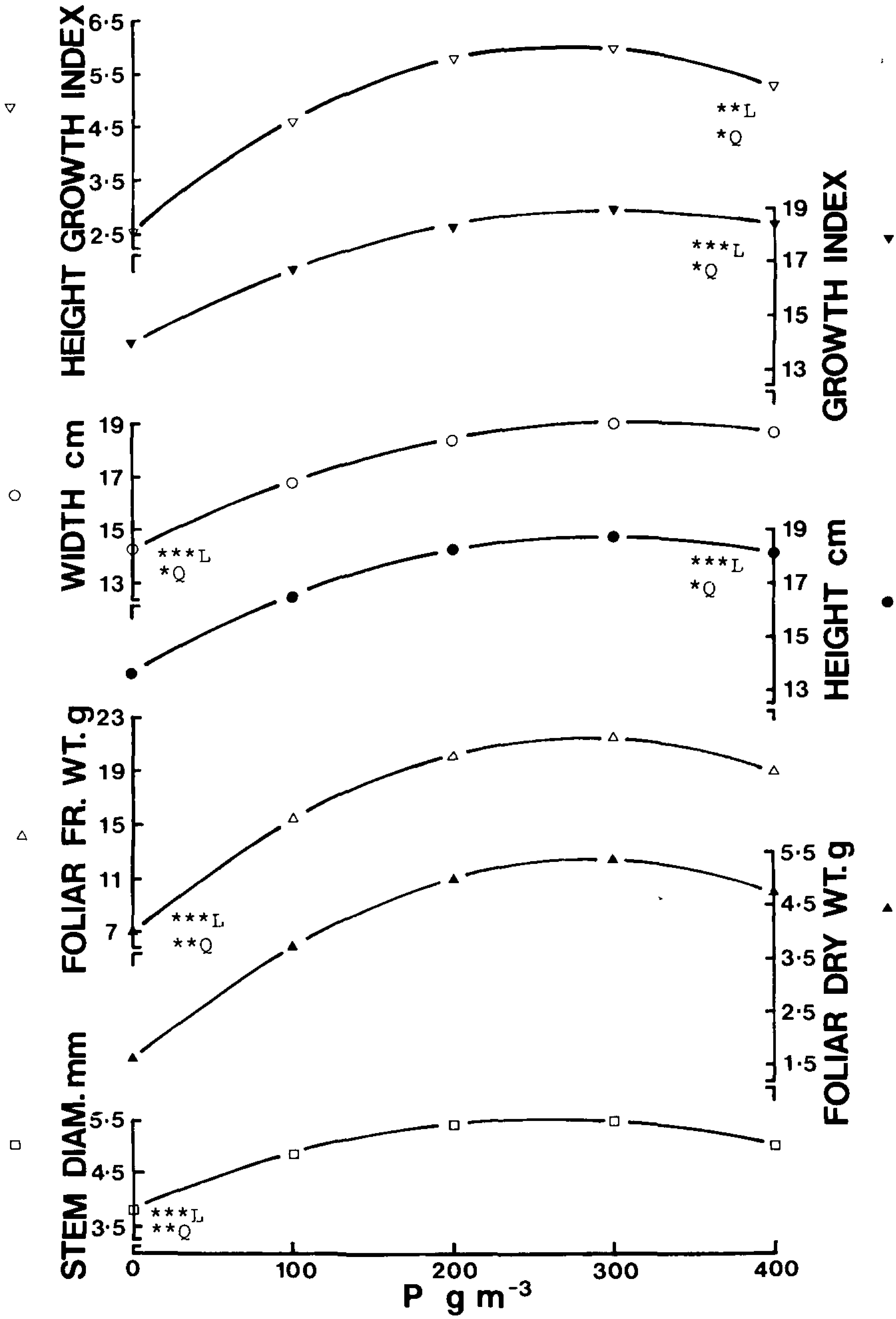

Figure 3. Experiment A: Influence of P fertilization at medium N, P, and lime rates on foliage growth.

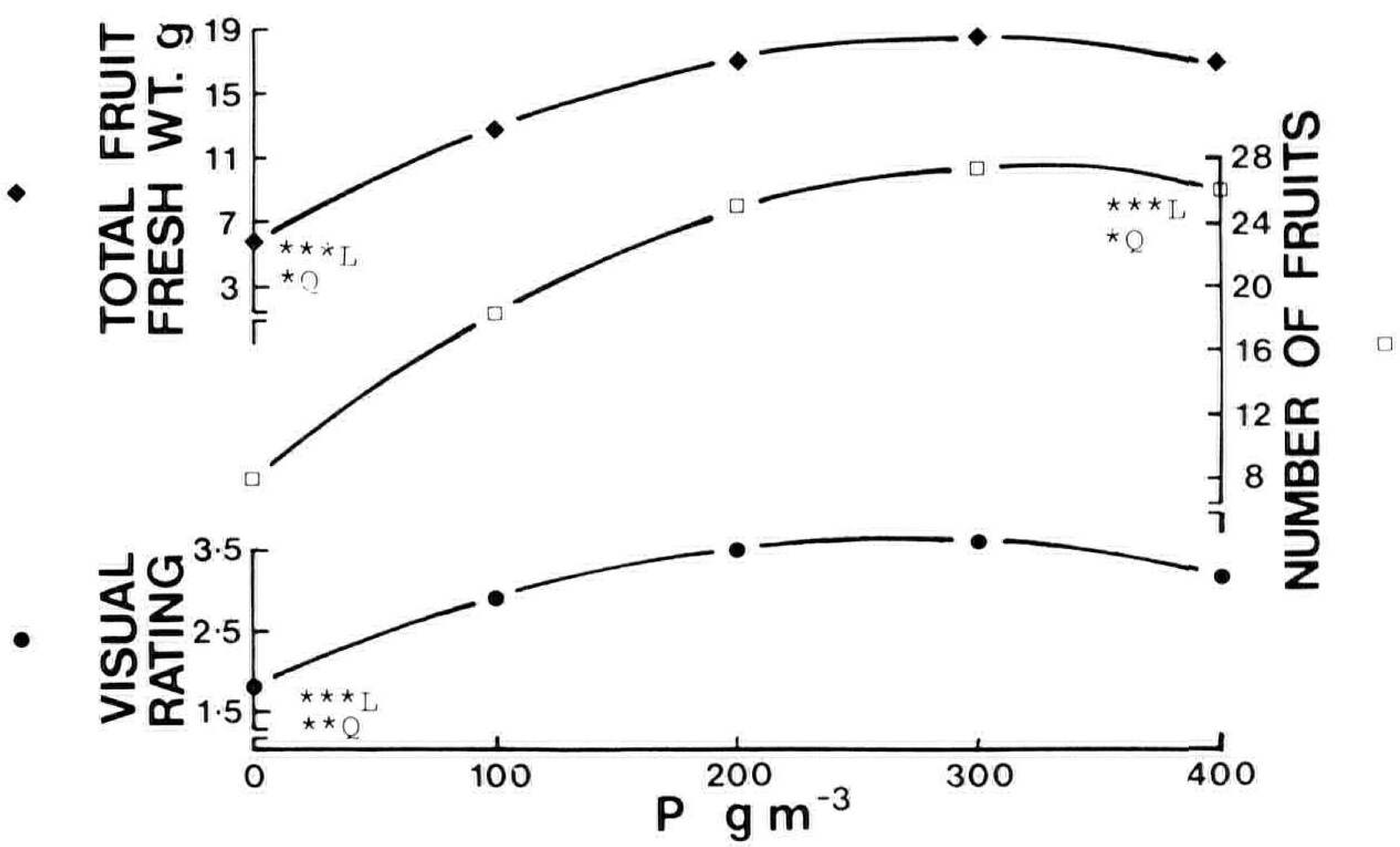

Figure 4. Experiment A: Influence of P fertilization at medium N, K, and lime rates on plant quality and fruiting.

Figure 5. The phosphorus response of ornamental peppers supplied with medium rates of N, K, and lime. *Left to right:* P (in g m^{-3}) 0, 200, 400

Table 2. Experiment B The effects of P and K on foliage growth and fruiting

Nutrient levels (g m-3	Height (cm)	Width (cm)	Stem diameter (mm)	Growth Index	Height growth index	Visual rating	Number of fruits per plant	Total fruit fresh weight per plant (g)	Foliar fresh weight (g)	Foliar dry weight (g)
P levels										
50	13 4*	13 6***	5 0**	13 5***	3 5**	2 6***	5 7***	3 1***	10 9***	2 6***
400	14 8	16 4	5 5	15 6	4 6	3 5	9 6	6 1	17 0	3 9
K levels										
83	13 1**	13 3***	5 0**	13 2***	3 5**	2 6***	7 0	4 0#	12 1***	2 9***
415	15 1	16 6	5 5	15 9	4 7	3 5	8 3	5 1	15 8	3 7
LSD (05) for P or K means	1 3	1 3	0 3	1 1	0 7	0 4	1 8	0 2	1 7	0 4
Significant interactions			P × K*							
CV (%)	20	19	13	17	39	26	52	58	27	28

Figure 6. The potassium response of ornamental peppers supplied with medium rates of N, P, and lime. *Left to right:* K (in g m-3) 0, 166, 322

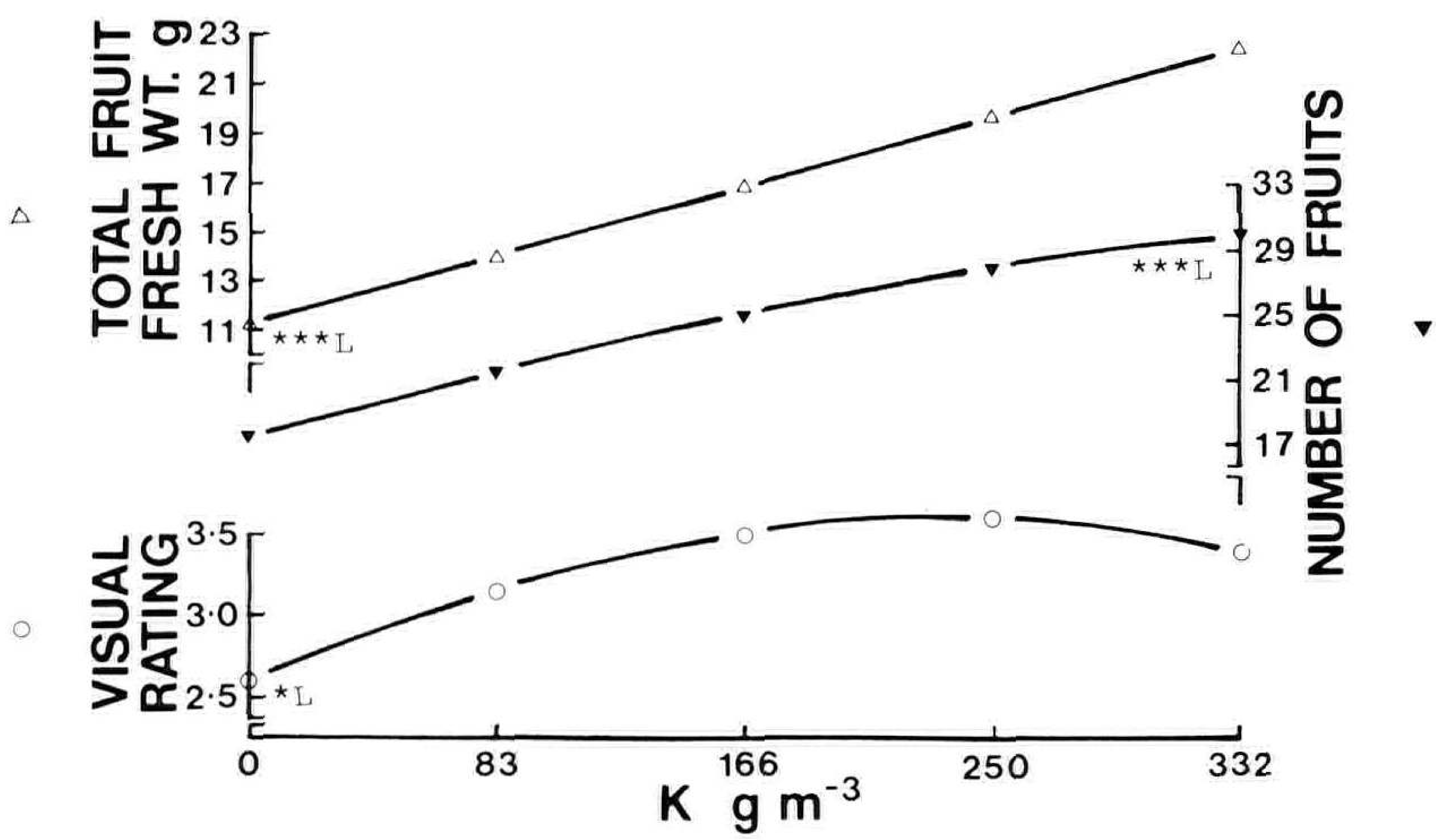

Figure 7. Experiment A: Influence of K fertilization at medium N, P, and lime rates on plant quality and fruiting.

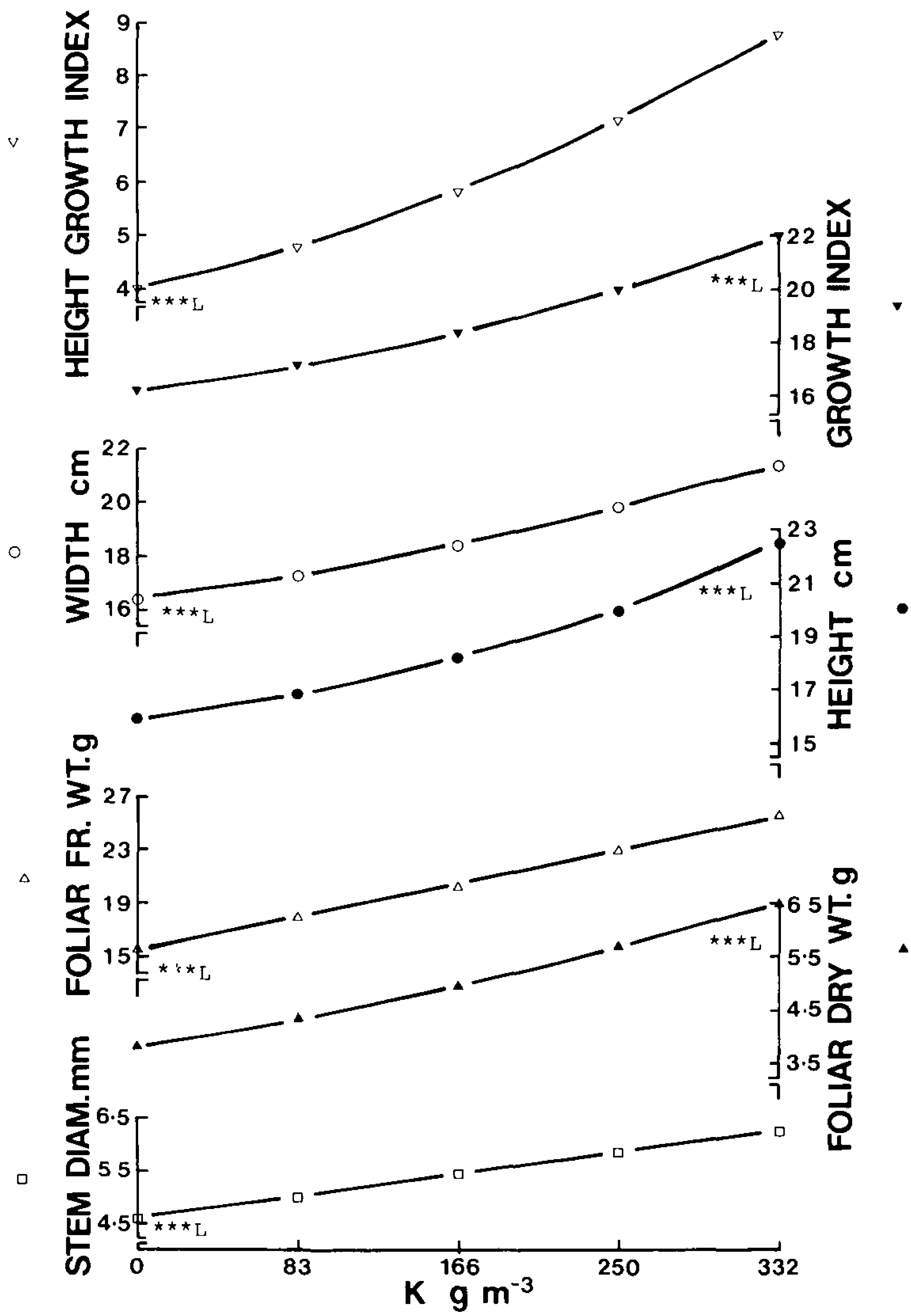

Figure 8. Experiment A Influence of K fertilization at medium N, P, and lime rates on foliage growth.

Experiment C: Responses to higher K levels confirmed the indication from the former two experiments that this species had a high K requirement; optimum foliage growth and fruiting was at 500 g K m^{-3} (Figure 9). This experiment was started in autumn and flowering was delayed until late July, taking nearly two months longer to flower than the trials conducted in summer. Growth was very slow from late May to early July and supplementary lighting was used from July onwards.

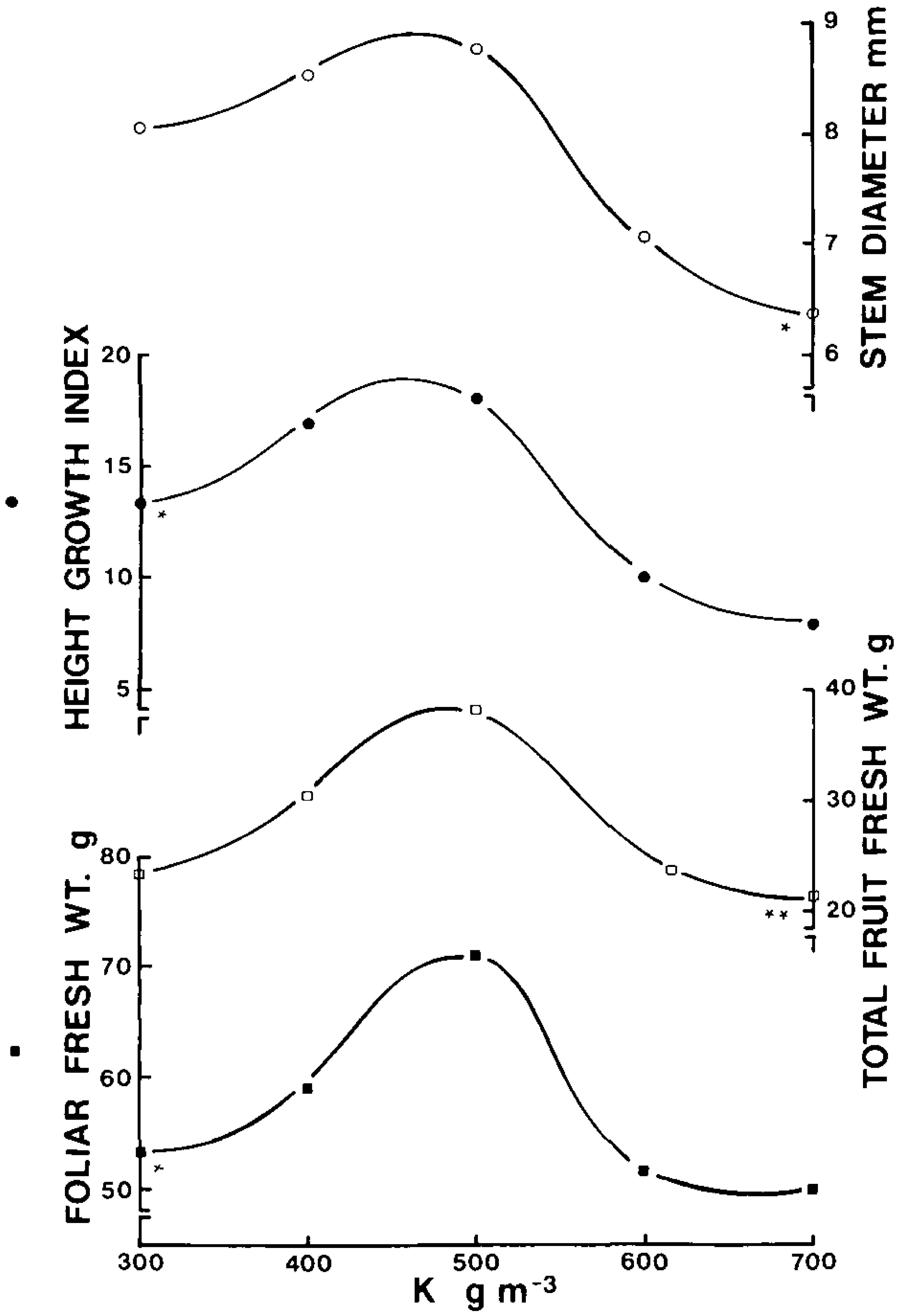

Figure 9. Experiment C Influence of medium to high K levels at medium N, P, and lime rates on foliage growth and fruiting

DISCUSSION

The strong nutritional response of ornamental pepper 'Fips' was not unexpected for *Capsicum* spp., like its Solanaceous relative, the tomato, they are vigorous plants with high nutrient requirements. Miller *et al.* (8) showed that the *Capsicum* plant could produce 54.5 g of total dry weight and absorb 1633 mg of N over a 10-week period. This compared favourably with the tomato and summer-grown pot chrysanthemum, both of which have very high N requirements (3). The loam-based John Innes No. 2 potting medium was recommended for growing ornamental peppers in Britain (8,21). This medium contained 308 g N, 190 g P, 534 g K m^{-3}, and magnesium. Supplementary liquid feed at rates of 190 to 240 ppm N and 220 to 250 ppm K, applied weekly, were suggested. The results of the present study agree generally with these recommendations, although the optimal P and K levels were higher and lower, respectively, and Mg requirements were not demonstrated.

Nitrogen fertilization consistently increased yields of field-grown sweet peppers and chillies (13, 28). However, above the optimal N levels, fruit yields were reduced. A similar observation was made in the present study (Figure 2). Maynard *et al.* (16) had shown that increasing N levels resulted in a corresponding increase in flowering and fruit set. The increase in fruit number and the total fruit fresh weight in Experiment A would be due to the increase in flowering and fruit set (Figure 2).

Knavel (15) reported that 16-week-old sweet pepper seedlings responded best to 240 g N m^{-3}. Plants receiving less N exhibited typical N deficiency symptoms. Plants receiving no N in the present study showed similar symptoms, while chlorosis was noted at 150 g, though not at 300 g N m^{-3} (Figure 1). Chlorotic plants of the present study had foliar N content of 2.92% and below (Table 1). This value was a lot higher than that given by Miller (17) but was closer to those given by Knavel (15) and Maynard *et al.* (16). Foliar N levels of plants with optimal response in the present study were more than double the value given by Miller (17) but corresponded with those given by Knavel (15) and Maynard *et al.* (16). Sweet pepper seedlings studied by Knavel (15), when grown to maturity after being transplanted to soil beds, yielded highest in fruit weights at N levels in the range of 400 to 500 g m^{-3}. The optimal response of fruit yield to 450 g N m^{-3} in the present study would be in agreement with Knavel's investigation.

Responses to P fertilization of field-grown chilli and sweet pepper plants were varied depending on the P status of the soils in which these plants were grown (19). The P status of mineral soils is diverse, accounting for negligible to good responses to P fertilization. However, with organic soils, a good response to P fertilization was ensured by the low P status inherent in peats (3). Hence, the good response in foliage growth and fruit yield in the present study was not unexpected. The corresponding increase of foliar P content with P additions in the present study, as illustrated in Table 2, agree with the findings of Ozaki and Iley (19) and Thomas and Heilman (28). Foliar P content of plants receiving no P in the present study was higher than the 0.09% value reported by

Miller (17) for P deficiency, but less than the 0.6% given by Thomas and Heilman (28).

Ozaki and Hamilton (20) reported a good K response while Iruthayaraj and Kulanaivelu (13) found no significant response to K application of *Capsicum* spp. grown in mineral soils. The very low K content in peats, according to Bunt (3) would account for the very good response to K fertilization of peppers grown in organic soils (1), hence the good response and high K requirement shown by the ornamental peppers in the present study. A marked reduction of foliar K at high N observed in the present study. A marked reduction of foliar K at high N observed in the present study was in accordance with results reported by Knavel (15) and Miller (17). Plants receiving optimum K had a higher foliar K value than that given by Miller (17).

Hamilton and Ogle (11) found that increasing Ca levels in liquid feed produced a significant increase in fruit yield followed by an equal reduction as high Ca level was added. Even at the low Ca level where deficiency symptoms of dwarfing, upturned leaf margins, and blossom-end rot of fruits were noted, good fruit yields were obtained. This could possibly explain the lack of response in Experiment A of the present study. *Capsicum* peppers were very tolerant of the low pH of 4.8 obtained from the medium which received no lime.

Field-grown peppers did not respond to Mg application even though Solanaceous species are prone to Mg deficiencies (7,19). The lack of response in the present study could be attributed to adequate Mg in the peat-based media. Peats, according to Bunt (3), have a greater percentage of Mg present than most mineral soils. Plants receiving no dolomite lime in Experiment A of the present study had foliar Mg content greater than the value given by Miller (17) for sufficiency level in the leaf tissues.

The combinations of high N, medium P, and high K fertilization for optimal growth and fruiting of ornamental peppers were comparable to the nutritional requirements of other Solanaceous species. Semeniuk (24) recommended liquid feed of N,P,K, of 20:8.7:16 fertilizer for producing *Browallia speciosa*. This ratio was very similar to the 6:3:5 N, P, K ratio obtained with the ornamental peppers in the present study. Czabajski *et al.* (5) reported that growth and dry matter yield of *Datura inoxia* were optimal with plants receiving N, P, K fertilizer with ratio of 6:1.3:5:1. The tomato, when grown with similar media, fertilizers, and environment, showed a requirement for 120 g N m^{-3} per month, 100 to 300 g P, 500 g K, and 6 kg lime m-3 (26). The N, P, K requirements of ornamental peppers appear close to that for other Solanaceous species.

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SEED PROPAGATION OF *GENTIANA SCABRA*

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INTRODUCTION

Although the genus *Gentiana* contains many hundred species, the cultivated cut flower cultivars have arisen principally from only three: *G. makinoi, G. triflora,* and *G. scabra,* all of which are native to Japan. *Gentiana* is a very popular flower in Japan where it blooms mainly between the months of July and October. In 1979 it was estimated that approximately 278 ha of *Gentiana* was cultivated in Japan. In 1982 this had increased to 449 ha.

Until recently most propagation has been by seed. Cutting propagation is used in some districts for white cultivars, which tend to have a poorer seed germination rate than the blue and purple ones. The tissue-cultured material which is now becoming available provides the advantages of clonal multiplication but is more expensive than seedlings. Seed, available