MICRONUTRIENT REQUIREMENTS OF CHRYSANTHEMUMS GROWN ON PEAT SUBSTRATES

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In previous work (Smilde, 1972) the effects of minor nutrient supply and pH on chrysanthemums grown on peat substrates were mainly assessed in terms of dry weights of vegetative parts. No attempt was made to shorten the natural (summer) day lengths by darkening and, consequently, flowering was largely inhibited. Anomalies in flowering as a result of a deficiency or toxicity of minor elements such as copper and boron (Messing and Owen, 1954; Bunt, 1965; Penningsfeld, 1969 and 1972; Nelson, 1971; Adams et al., 1971; Boodley and Sheldrake, 1973; Gogne and Sanderson, 1973) could not be demonstrated therefore.

Further studies, conducted with reduced day lengths, mainly concentrated on the effects of added minor nutrients and lime on flower production of various spray and pot chrysanthemum cultivars. Further work was also undertaken to test the effectiveness of fritted trace elements (FTE) in controlling Fe deficiency, fairly commonly occurring in chrysanthemums cultivated on peat substrates. The results are reported here.

Experimental methods

All experiments were conducted in a glasshouse between mid-July and early in October, day and night temperatures varying from 20-30 and 15-20°C, respectively. Five rooted cuttings were planted in either 1.6 litre (pot chrysanthemums) or 5.2 litre (spray chrysanthemums) polythene pots and subjected to short-day conditions (8 a.m.-6 p.m.) from the end of July. Pot chrysanthemums were harvested when at least 90% of the flower buds of "normal" plants had opened. Spray chrysanthemums, because of their greater variability in flower size, were harvested with still about 30% of the flower buds unopened.

Pots contained 100 g of dry substrate per litre in the case of slightly decomposed Dutch or Finnish spagnum (moss) peat (pH 3.7 and 3.4, respectively; maximum water capacity about 1200 g per 100 g), or 160 g in the case of humified old Dutch spagnum peat ("black peat"; pH 3.7, maximum water capacity 625 g per 100 g). Pots were watered daily with demineralized water to about 80% of maximum water retention.

The following applications of reagent grade chemicals per litre substrate were standard in all treatments: 0.83 g NH_4NO_3, 0.63 g K_2HPO_4, 0.42 g $MgSO_4.7\ H_2O$, 10 mg $CuSO_4.5\ H_2O$, 2.0 mg $Na_2B_4O_7.10\ H_2O$, 4.0 mg $Na_2MoO_4.2\ H_2O$, 2.5 mg $MnSO_4.H_2O$, 5.0 mg $ZnSO_4.7H_2O$, 15 mg Fe-EDTA. In addition, pot chrysanthemums were given weekly 0.20 g NH_4NO_3 + 0.15 g K_2HPO_4 per pot and spray chrysanthemums double these amounts, as a liquid feed.

The experimental design was factorial, if not stated otherwise, with 3 randomized blocks (replications) and sub-blocks for micronutrient treatments, for each substrate or cultivar . Details for the various experiments are given below.

Experiment 1. Test plant was pot chrysanthemum, cv. Neptune. Micronutrient treatments (mg per litre substrate) included: copper (0, 2.5, 5.0, 10.0 $CuSO_4.5H_2O$), boron (0, 0.5, 1.0, 2.0 $Na_2B_4O_7.10H_2O$), molybdenum (0, 1.0, 2.0, 4.0 $Na_2MoO_4.2H_2O$), manganese (0, 12.5, 25, 50 $MnSO_4.H_2O$), zinc (0, 25, 50, 100 $ZnSO_4.7H_2O$), iron (0, 7.5, 15, 30 Fe-EDTA). In each of these treatments with micronutrients as variables the element in question was omitted from the standard dressing. The micronutrient effects were assessed at 4 pH levels: 4.4, 4.8, 5.5, 6.9 on Dutch moss peat, and 4.6, 5.3, 6.0, 7.0 on black peat, following additions of 1.67, 3.34, 5.00, 8.34 g reagent grade $CaCO_3$ per litre moss peat, respectively, and twice these quantities on the humified black peat with its higher bulk density.

Experiment 2. Test plant was pot chrysanthemums, cv. Neptune, grown on Dutch moss peat. Micronutrient treatments (mg per litre substrate) were: boron (0, 2.0, 4.0, 8.0, 16.0, 32.0 $Na_2B_4O_7.10H_2O$), molybdenum (0, 2.0, 4.0, 8.0, 16.0, 32.0 $Na_2MoO_4.2H_2O$); each treatment at 2 pH levels, viz. 4.8 or 6.1 following applications of 3.33 or 6.66 g $CaCO_3$ per litre substrate, respectively.

Experiment 3. Test plants were pot chrysanthemum, cv. Neptune, Princess Anne Supreme, Yellow Mandalay, and spray chrysanthemums, cv. Indianapolis White, Spider Super White, Pink Marble, all grown on Dutch moss peat. Treatments included: standard dressing (control), and standard dressings minus copper, boron, molybdenum or iron, respectively; each treatment at 3 pH levels, viz. 4.9, 6.0, 6.5, following $CaCO_3$ additions of 3.44, 5.94, 8.44 g per litre substrate, respectively.

Experiment 4. Test plants were spray chrysanthemums, cv. Indianapolis White and Spider Super White, grown on Finnish moss peat given 12 g $CaCO_3$ per litre (pH 6.7). The variable was iron, applied at rates of 0, 0.83, 1.66, 3.32, 4.98 mg per litre as either FTE 32 (1.89% Cu, 0.16% B, 1.26% Mo, 1.00% Mn, 1.86% Zn, 2.66% Fe) or iron chelate Fe-EDDHA (5% Fe). Single micro-element salts were applied at all chelate and at the lower FTE rates in the basic dressing to give total amounts of micronutrients corresponding with the second highest FTE rate. The experimental design was non-factorial, with 3 randomized blocks (replications) for iron additions, for each cultivar.

For the estimation of foliar micro-element concentrations leaf samples from harvested plants were wet-ashed with HNO_3, H_2SO_4 and $HClO_4$, and analysed spectrophotometrically (B, Mo) or by atomic absorption spectrophotometry (Cu, Mn, Zn, Fe). Shortly after terminating the experiments peat substrates were analysed for pH-H_2O in a 1:5 w/v extract.

The data on flower numbers, but not those on dry weights (except in experiment 2) were analysed statistically for significant effects.

Results

Experiment 1. Copper deficiency symptoms, i.e. severe chlorosis and desiccation of middle leaves and considerable suppression of flowering (Fig. 1) were observed in all nil copper treatments irrespective of pH. At the highest chalk rate (pH 6.9-7.0) slight chlorosis was general, more severely occurring though in plants given little or no iron or boron. Disorders were more pronounced on moss peat than on black peat.

Fig. 1. **Suppression of flowering in pot chrysanthemums** (cv. Neptune) grown on pure moss peat; on the left without, on the right with copper added.

On moss peat an increase in pH following chalk addition had no definite effect on total flower production, pH 4.8-5.5 being optimum, but delayed flowering as demonstrated (Fig. 2) by an increase in small flowers (1-4 cm) and a concomitant decrease in large flowers (> 4 cm). The linear pH effects on both small and large flowers proved highly significant ($P = 0.01$) in all minor nutrient treatments, and so was the negative quadratic pH effect on small flowers, except in the molybdenum, manganese and zinc treatments. Absence of added

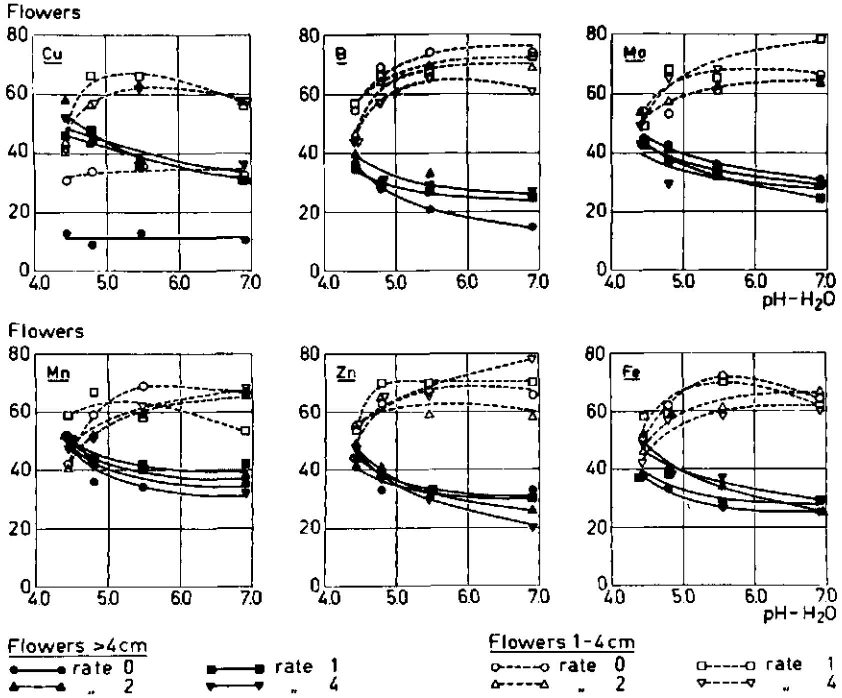

Fig. 2. Flower numbers of pot chrysanthemums (cv. Neptune) grown on pure moss peat as affected by micronutrients (rates as stated in Table 2) and pH.

copper, however, masked the pH effects in suppressing total flower production, most flowers remaining in the bud stage. Added boron and iron were found to advance flowering as indicated by a highly significant increase in large flowers and a concomitant decrease in small flowers. None of the other minor elements had any significant effect on flowering pattern.

Black peat displayed a distinct pH optimum (4.6-5.3) when adding various rates of chalk. Higher pH levels suppressed total flower production in all minor element treatments, the highly significant decreases in large flowers not being offset by marked increases in small flowers (Fig. 3). Added boron, iron and manganese all had a significant positive, and zinc a negative effect on large flowers, whereas the effects on small flowers were mainly opposite. Copper did not significantly affect flowering pattern.

On each substrate the medium rates of micronutrients added, i.e. 5 mg of copper sulphate, 1.0 mg of borax and 15 mg of iron-EDTA per litre, proved sufficient for optimum flower production. Apparently the large applications of manganese and zinc aimed at inducing phytotoxicity were still too low to induce such disorders, apart from a slight decline in the case of zinc on black peat.

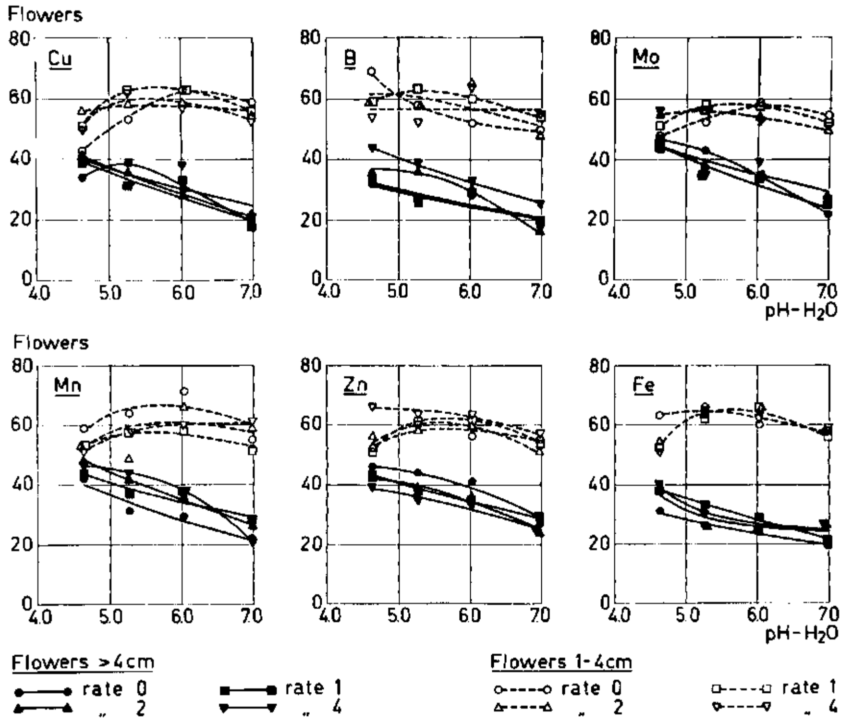

Fig. 3. As fig. 2, but for black peat.

Vegetative growth was little affected by minor element treatments but absence of applied copper tended to promote it. Summarized data on dry weights are presented in Table 1 as means for the various micronutrient rates at different pH levels. There appears to be an optimum at pH 5.3-5.5, higher values reducing growth, especially so on black peat.

Table 1. Dry weights (g per pot) of vegetative parts of pot chrysanthemums (cv. Neptune) grown on pure peat substrates. Results are means for 4 rates of micronutrients at various pH levels.

Treatment	Moss peat, at pH				Black peat, at pH			
	4.4	4.8	5.5	6.9	4.6	5.3	6.0	7.0
copper	21.8	24.6	26.5	24.2	21.8	23.2	21.0	18.1
boron	20.1	23.5	23.8	24.1	22.2	23.0	20.7	18.0
molybdenum	19.5	23.1	23.8	22.8	21.8	23.8	22.0	18.9
manganese	19.6	22.3	23.6	22.4	21.5	20.1	20.3	18.4
zinc	20.0	22.9	23.8	23.3	20.8	23.2	20.9	17.8
iron	20.3	22.4	23.6	23.0	21.2	23.4	21.1	18.8

Foliar analysis revealed an increase in leaf concentration following addition of the minor element in question. In the case of boron, manganese, zinc and iron responses were smaller with applied chalk, but trends for molybdenum were opposite. Data are presented for moss peat only (Table 2) as trends for black peat were very similar.

Table 2. Micronutrient concentrations (on dry-weight basis) in foliage of pot chrysanthemum (cv. Neptune), grown on moss peat, as affected by micronutrients and pH.

Treatment (mg/l substrate)	Cu (ppm), at pH				Treatment (mg/l substrate)	B (ppm), at pH			
	4.4	4.8	5.5	6.9		4.4	4.8	5.5	6.9
$CuSO_4.5\,H_2O$					$Na_2B_4O_7.10\,H_2O$				
0	4.7	4.5	4.7	5.0	0	19	16	14	10
2.5	8.4	6.0	8.1	7.1	0.5	21	20	17	14
5.0	7.1	6.7	8.1	8.9	1.0	23	22	19	16
10	9.8	8.7	10.3	9.3	2.0	25	23	21	19
	Mo (ppm)					Mn (ppm)			
$Na_2MoO_4.2\,H_2O$					$MnSO_4.H_2O$				
0	0.23	0.11	0.20	0.15	0	131	113	88	98
1.0	0.31	0.66	1.9	4.2	12.5	487	425	347	357
2.0	1.6	2.0	5.5	7.6	25	851	654	499	622
4.0	3.6	8.9	12.1	18.7	50	1510	857	748	921
	Zn (ppm)					Fe (ppm)			
$ZnSO_4.7\,H_2O$					Fe-EDTA				
0	135	210	224	136	0	281	262	252	280
25	301	298	204	242	7.5	518	446	318	280
50	472	356	319	344	15	578	449	308	237
100	880	635	378	605	30	789	686	358	280

The above results were confirmed in an identical experiment conducted a year later.

Experiment 2. This experiment was meant to study the tolerance of pot chrysanthemums to high levels of boron and molybdenum. Boron toxicity, characterized by necrotic spotting and curling of leaf edges, was displayed in plants given 16 mg per litre of borax on moss peat at pH 4.8 the symptoms becoming progressively severe with more borax added. Toxicity symptoms were associated with 115 ppm B in the leaf tissue. From their visual appearance and leaf boron concentrations (Table 3) it is concluded that chrysanthemums tolerate more than 16 but less than 32 mg of borax at pH 6.1 before toxicity symptoms occur. Boron reduced dry weights of vegetative parts significantly, but differences are rather small if not taking into account some

Table 3. Flowering pattern and growth of pot chrysanthemums (cv. Neptune), grown on moss peat, given various rates of borax.

	$Na_2B_4O_7.10\ H_2O$ (mg/l)					
	0	2	4	8	16	32
pH 4.8						
Number of 1–4 cm flowers	55	39	44	47	42	40
Number of flowers >4 cm	38	28	42	47	52	48
Dry wt. stems + leaves (g)	20.6	12.9	17.9	18.6	17.5	16.1
Leaf B (ppm)	36	41	48	57	115†	207†
pH 6.1						
Number of 1–4 cm flowers	54	51	46	57	42	50
Number of flowers >4 cm	29	40	45	36	24	41
Dry wt. stems + leaves (g)	22.4	19.5	19.2	19.3	12.8	17.7
Leaf B (ppm)	33	37	40	51	74	145†

†Visual B toxicity symptoms.

obviously erratic data (treatments 2 mg borax at pH 4.8 and 16 mg borax at pH 6.1). There is little evidence of boron reducing growth before visual toxicity symptoms appeared. Growth appeared to be promoted by the higher pH but the trend failed to reach significance.

The (significant) effects of boron and chalk on flowering pattern are in close agreement with those found in the first experiment, boron advancing and chalk delaying flowering as shown by the opposite trends for larger and smaller flowers (table 3). Apparently the boron rates applied were not sufficiently large to reduce flower production or to effect flower disorders.

High molybdenum rates produced no noxious effects, neither on growth nor on flower production, and the data will not be further discussed. It is noteworthy, however, that the higher chalk addition, although more than doubling leaf Mo concentrations reaching a high 116 ppm at the largest molybdenum rate, also significantly promoted growth.

Experiment 3. This experiment was intended to study the sensitivity of various pot and spray chrysanthemum cultivars to micronutrient deficiencies in moss peat. Omitting molybdenum from the basic dressing did not significantly affect flower numbers, nor did absence of copper, boron or iron, which was rather surprising. Neither could any significant effect of pH, ranging from 4.9 to 6.5, on flowering pattern be established. The data are not presented here. It is felt that a more comprehensive experimental design, including various micronutrient rates, might have revealed significant effects. It is noteworthy that Yellow Mandalay displayed quilling and twisting of the top half of petals following necrosis in the middle. This phenomenon was not restricted to any particular treatment, so its cause remains obscure.

Table 4. Leaf iron concentrations (ppm on dry weight) and chlorosis rating of various pot and spray chrysanthemum cultivars as affected by added iron and pH on moss peat.

pH	Pot chrysanthemums						Spray chrysanthemums					
	Mandalay		Princess Anne		Neptune		Indianapolis		Marble		Spider	
	Leaf Fe	Index[†]	Leaf Fe	Index	Leaf Fe	Index	Leaf Fe	Index	Leaf Fe	Index	Leaf Fe	Index
No Fe added												
4.9	218	10.0	264	10.0	295	10.0	198	10.0	154	10.0	204	10.0
6.0	202	9.3	256	9.3	298	10.0	185	7.0	150	10.0	183	9.0
6.5	190	7.0	250	8.3	284	9.7	176	4.7	151	8.7	194	7.0
Fe added												
4.9	256	10.0	312	10.0	341	10.0	293	10.0	432	10.0	332	10.0
6.0	195	10.0	248	10.0	319	10.0	200	10.0	216	10.0	211	10.0
6.5	188	10.0	222	10.0	294	10.0	181	10.0	188	10.0	188	10.0

† Visual chlorosis score (10 = dark green, 1 = yellow).

Without added iron leaf chlorosis was fairly common at the higher pH values (Table 4), but there is evidence of the various cultivars differing in sensitivity, as shown by chlorosis intensity and the earliness of its appearance. For example, Neptune and Marble did not show symptoms until twelve days after the other cultivars did. From Table 4 it is evident that leaf iron concentration and visual chlorosis score bear no close relationship. Although the response of leaf iron to iron treatment was virtually nil at pH 6.5, there was no incidence of chlorosis with iron added.

Experiment 4. Previous attemps to test the effectiveness of FTE's in controlling iron deficiency in chrysanthemums grown on humified ("black") peat failed as the disorder did not occur (Smilde, 1972). In the present experiment a further investigation was made, using Finnish moss peat as a substrate and raising its pH to 6.7. Severe chlorosis in middle and upper leaves developed in plants not given iron, specially so in Indianapolis. As shown in Table 5 this disorder could be prevented when including as little as 0,83 mg of iron per litre substrate as Fe-EDDHA in the basic dressing. By contrast, supplying up to about 5 mg of iron as FTE 32 remained largely (Spider) or completely ineffective. Leaf iron was elevated in the case of the chelate only.

Table 5. Leaf iron concentrations (ppm on dry-weight basis) and chlorosis rating of spray chrysanthemums, grown on Finnish moss peat at pH 6.7, given various iron compounds.

mg Fe/ litre	Spider				Indianapolis			
	Fe-EDDHA		FTE 32		Fe-EDDHA		FTE 32	
	Leaf Fe	Index†	Leaf Fe	Index	Leaf Fe	Index	Leaf Fe	Index
0	133	5.0			139	4.0		
0.83	161	10.0	134	5.7	173	10.0	127	3.7
1.66	209	10.0	117	6.7	176	10.0	96	3.7
3.32	206	10.0	107	6.3	176	10.0	113	4.0
4.98	281	10.0	106	6.7	169	10.0	118	4.0

† Visual chlorosis score (10 = dark green, 1 = yellow).

Added iron was found to significantly increase the number of larger flowers in Spider but to have no distinct effect on smaller flowers (Fig. 4). As for the larger flowers, the difference between iron sources just failed to reach significance at $P = 0{,}05$, Fe-EDDHA being the more effective material. Indianapolis responded differently to added iron in significantly raising the number of smaller flowers, and reducing larger flowers at the higher iron rates, mostly so with Fe-EDDHA. Applying 1.7 mg of iron per litre substrate as Fe-EDDHA would appear optimal for flower production of either cultivar. As shown in Fig. 4 trends

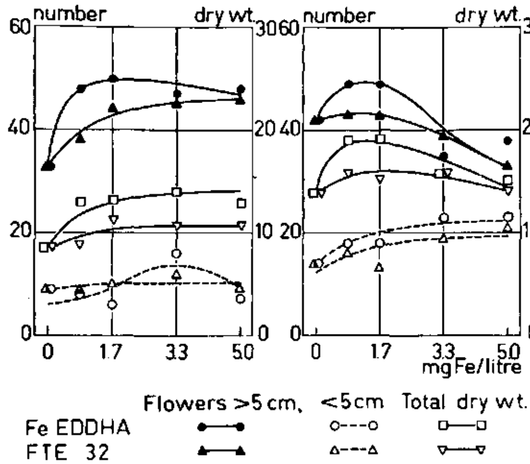

Fig. 4. Flower numbers and flower dry weights of spray chrysanthemums grown on Finnish moss peat given various iron rates as Fe-EDDHA or FTE 32; on the left cv. Spider, on the right cv. Indianapolis.

for (total) flower dry weights and numbers of larger flowers are rather similar. There was also found to exist a positive correlation between dry weights of flowers and of vegetative plant parts (data not presented here).

When terminating the experiment sprays were cut to study vase life for about two weeks. Keeping quality of the flowers in vases did not appear to be influenced by treatments during growth in pots.

In a supplemental experiment substitution of the trace element mixture FTE 32 for a straight iron frit (FTE 54, 27% Fe) could not control iron deficiency in Indianapolis grown on moss peat in the pH range 5.3 to 6.6.

Discussion

The symptoms of copper deficiency in chrysanthemums observed in this study agree with those described by Penningsfeld (1969), Adams et al. (1971) and Nelson (1971). However, as flower buds failed to open the phenomenon of lateral rolling or quilling of florets (Nelson, 1971) could not be verified. The observation that copper deficiency tended to promote vegetative growth is in line with data by Graves (1972). Leaf copper concentrations of copper deficient plants (Table 2) fit in with values reported by Nelson (1971) and Bunt (1973).

Bunt's (1971, 1973) finding that quilling of florets rather than a delay in flowering is typical of boron deficiency could not be confirmed. Boodley and Sheldrake (1973) report petal desiccation and necrosis instead of quilling. As far as vegetative growth is concerned they mention no distinct check which supports our data. Messing and Owen (1954) stressing the differences in symptom severity between varieties also noted a marked eliminating effect of day length. At the lower levels of applied boron leaves contained less than the 20 or 25 ppm B considered critical by Adams et al. (1972) and Boodley and Sheldrake (1973), respectively (Table 2).

Symptoms of boron toxicity in leaves were similar to those stated by Lunt et al. (1964), Adams et al. (1972), and others. Whilst it is apparent that boron deficiency primarily affects blooms, boron toxicity is first exhibited in vegetative plant parts. The maximum safe rate of borax application was found to lie around 16 $mg.l^{-1}$, depending on pH (Table 3). Bunt (1972) arrives at rather similar rates. Obviously these amounts are too low to reduce flower size as reported by Gogue and Sanderson (1973). Leaf boron concentrations exceeding 115 ppm and associated with boron toxicity fall within the range mentioned by Bunt (1972) and Gogue and Sanderson (1973) for poisoned plant the more so when allowance is made for seasonal and varietal fluctuations in boron tolerance and in foliar toxic levels as observed by the latter authors.

In general, iron deficiency symptoms were mild, the various cultivars differing in sensitivity though. Extreme symptoms like those reported by Bunt (1971) for pot chrysanthemums (cv. Mermaid), i.e. leaves devoid of chlorophyll and flower buds failing to open, were not encountered. Bunt's data, however, suggest an iron-copper deficiency syndrome alleviated by either added iron or copper, only their combined application giving full control. Fe-EDDHA, and straight and mixed iron frits proved equally effective as iron sources, which is in marked contrast with the results obtained here (Table 5). This discrepancy in results calls for further investigation. Bunt's observation that leaf iron content and chlorosis incidence are not closely related corroborates the data presented in Table 4.

The depressing effect of Fe-EDDHA (5% Fe) rates exceeding about 70 $mg.l^{-1}$ on dry weights of cv. Indianapolis White may be attributed to the chelate component, a finding which is substantiated by similar trends in lettuce plants given 60 $mg.l^{-1}$ of Fe-EDTA or more (unpublished data). FTE 32 at the rates applied here is unlikely to be noxious (cf. Smilde, 1972). Bunt (1972) using a more concentrated frit (e.g. 2% B as against 0.16% B) considers applications up to 350 $mg.l^{-1}$ safe.

Chrysanthemums proved rather indifferent to additions of molybdenum and zinc, and mainly to manganese as well, confirming reports by Penningsfeld (1969) and Adams et al. (1972). The lack of response to molybdenum is in marked contrast with the behaviour of other plant species on peat substrates (Smilde, 1972). Leaves supported levels up to about 1500 ppm Mn, 900 ppm Zn and 120 ppm Mo without showing toxicity symptoms (Table 2). No definite critical values for these elements are stated in literature, Bunt (1972) considering 900 ppm leaf Mn as being non-toxic

Summary

Responses in flowering and growth of pot and spray chrysanthemums grown on slightly decomposed sphagnum (moss) peat or humified ("black") peat to added micronutrients and calcium carbonate were studied in pot experiments. Main effécts for pot chrysanthemums were: copper increasing total flower production, boron and iron advancing flowering in increasing the proportion of larger flowers, chalk delaying flowering in decreasing the proportion of larger flowers. Application of 5 mg of copper sulphate (25% Cu), 1.0 mg of borax (11% B) and 15 mg of Fe-EDTA (15% Fe) per litre substrate is recommended for optimum flowering additions. Growth and flowering were not adversely affected by conditions of up to 32 mg of sodium molybdata (40% Mo), 100 mg of manganese sulphate (33% Mn) or 50 mg of zinc sulphate (22% Zn) per litre substrate, but 16 mg of borax may be toxic. The pH optimum for vegetative growth (pH 5.3-5.5) was not much beyond that for flower production but markedly higher than that required for early bloom.

Responses to iron were mainly studied in spray chrysanthemums grown on limed moss peat. Added iron was found to positively affect flower size and flower dry weight, Fe-EDDHA being a more effective iron source than mixed iron frit (FTE 32). Application of 1.7 mg $Fe.l^{-1}$ as Fe-EDDHA (5% Fe) proved optimal and doubling this rate detrimental (in one cultivar), probably because of a noxious effect of the chelate component. In this study both straight (FTE 54) and mixed (FTE 32) iron frit proved largely ineffective in controlling iron deficiency foliar chlorosis. Further work is needed to unravel the cause of this ineffectiveness.

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