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Article

Distribution of Micronutrients in Plastic Film House Soils of Yeongnam Province

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For better management of micronutrients in crop cultivation, the availability of micronutrients in the soils must be updated and evaluated as a first step. This study was conducted to investigate the distribution of micronutrients in soils of plastic film houses. Total 396 soil samples were collected from the plastic film houses of various crops in Yeongnam province (strawberry, 96; red pepper, 66; tomato, 74; oriental melon, 97; cucumber, 63). Total and available contents of B, Cu, Zn, Fe, and Mn in the soils were determined. Available B was extracted with hot water and available Cu, Zn, Fe, and Mn were extracted with 0.1 N HCl. Mean values of total contents of B, Cu, Zn, Fe, and Mn in the plastic film house soils were 25, 32, 74, 21,316, and 420 mg kg^{-1}, respectively. Total contents of micronutrients in the plastic film house soils were similar to those found in the open fields nearby, while they were different among the locations investigated. Mean contents extractable B, Cu, and Zn in the plastic film house soils were 2.1, 7.5, and 35 mg kg^{-1}, respectively. The contents of extractable B, Cu, and Zn in the plastic film house soils were higher than those found in the open fields nearby with exceptions of B in soils of strawberry and Cu in soils of red pepper and oriental melon. However, mean contents of extractable Fe and Mn in the plastic film house soils were 156 and 146 mg kg^{-1}, respectively, and the mean content of extractable Fe was much lower than that found in open fields nearby. The contents of extractable Zn, Fe, and Mn were higher than the sufficient levels for the crop requirements in most of the plastic film house soils investigated. Contents of extractable Cu in most soils of strawberry, tomato and cucumber cultivations were higher than the sufficient level. However, extractable Cu contents were below the sufficient level in about 30% of investigated soils of red pepper and oriental melon cultivation. Soils containing higher contents of extractable B than the sufficient level were relatively fewer in comparison to the other micronutrients.

Key words : Micronutrients, B, Cu, Zn, Fe, Mn, Plastic film house

Introduction

The area coverage under plastic film house crops is 100,000 ha in 2003 as compared to 58,000 ha in 1992, and it grows larger every year (Ministry of Agriculture and Forestry, 2004). Since year-round crop cultivation is possible in the plastic film houses, multiple cultivations of crops in a year are common and relatively larger amount of chemical fertilizers and composts are disposed in the soil.

Considering input of chemical fertilizers in plastic film houses since 1999, average inputs of N, P, and K in the plastic film house soils are 21, 52, and 34% higher, respectively, as compared to the input of those nutrients in the open field soils. Jung et al. (1998) reported that average levels of available P (P_2O_5) and N (NO_3-N) in plastic film house soils were 1,092 and 155 mg kg^{-1}, respectively, with high EC of 2.94 dS m^{-1}. Such input of nutrient materials causes a serious slat accumulation in soils under the environment of limited leaching potential in the plastic film house.

Farmers also use large amounts of compost (40-89 Mg ha^{-1}) and various kinds of micronutrient fertilizers in plastic film houses for better crop quality and productivity and soil management. Although those problems related to the accumulation of major nutrients and higher EC in the plastic film house soils are well acquainted, current information and knowledge about the availability of micronutrients in the plastic film house soils are insufficient.

Every plant requires micronutrients, and these nutrients

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must be available in the correct proportions, and they must be administered at the right intervals. While specific needs vary according to climate, soil, and choice of crop, it is vital that the proper balance is maintained. If a plant lacks any of the micronutrients it requires, its development, growth or reproduction will be affected, resulting in lower yields (Romheld and Marschner, 1991; Graham and Webb, 1991). Typical ranges in critical levels for soil micronutrients for common crops are 0.1-2.0, 1.0-2.0, 1.0-5.0, 10.0-16.0, and 1.0-4.0 mg kg^{-1} for B, Cu, Zn, Fe, and Mn, respectively (Sims and Johnson, 1991). Jung et al. (1997) reported that contents of Cu and Zn in the soils of plastic film house were relatively higher than those found in the paddy and upland soils of open fields. In the southern area of Korea, the levels available B, Zn, and Cu were found to be 8.4-15.4, 8.4-12.7, and 21.1-50.7 mg kg^{-1}, respectively (Ha et al., 1997).

Although farmers apply various micronutrient fertilizers through foliar spray and fertigation systems for the plastic film house crops, they do not have enough information about the optimum application levels and/or the availability of those nutrients in their soils. Therefore, for better management of micronutrients in the cultivations of plastic film house crops, the availability of micronutrients in the soils must be updated and evaluated as a first step.

This study was conducted to investigate the distribution of micronutrients in the soils of plastic film houses in Yeongnam province.

Materials and Methods

Collection of soil samples Total 396 samples of soil were collected from plastic film houses of various crops including strawberry, red pepper, tomato, oriental melon, and cucumber in Gyeongnam and Gyeongbuk area. Also 14 soil samples were collected from the open fields near the plastic film houses to compare the micronutrient status with those in plastic film houses. Soil samples were collected from top 20 cm with a bi-partite gouge auger. The sampling locations and numbers of soil samples for different crops are presented in Table 1.

Analysis of micronutrients The soils were air-dried, passed through a 2 mm sieve and stored in a covered plastic container at room temperature until the analysis was initiated.

Total contents of micronutrients, B, Cu, Zn, Fe, and Mn, were analyzed after sample digestion in aqua regia (a mixture in 3:1 ratio of 12 M HCl and 16 M HNO_3) as described by McGrath and Cunliffe (1985). Soil sample was ground to pass 0.18 mm sieve, and 3 g of the soil was digested in 15 mL aqua regia for 1 hr at 70℃. The digest was filtered with Whatman No. 42 filter paper and after rinsing the digest several times with water, the filtrate was combined and transferred quantitatively to a 50 mL volumetric flask and diluted to volume with water.

As potential indicators of plant-available micronutrients, contents of hot-water extractable B and

Table 1. Locations of soil sampling and numbers of soil sample for different crops

Crop	Gyeongnam		Gyeongbuk		Total
Strawberry	Geochang	22	Goryeong	20	96
	Gimhae	21			
	Miryang	18			
	Changwon	9			
	Yangsan	6			
Red pepper	Miryang	17	Yecheon	49	66
Tomato	Gimhae	11	Nongong	20	74
	Hamyang	2	Daegu	13	
	Sacheon	4	Gunwi	11	
			Angang	12	
			Seongju	1	
Oriental melon	Gimhae	23	Seongju	40	97
	Hapcheon	15	Gyeongsan	19	
Cucumber			Gunwi	31	63
			Andong	10	
			Dalseong	14	
			Chilgok	8	
Total		148		248	396

0.1 N HCl extractable Cu, Zn, Fe, and Mn in the soil samples were measured (Bingham, 1982; Baker and Amacher, 1982; Cox, 1987). The following procedure was used for B extraction. Soil sample was ground to pass 1 mm sieve, and 20 g of the soil was placed in a 250 mL low-B flat-bottom flask and 40 mL of water was added. The flask was heated until initiation of boil and the suspension was refluxed for precisely 5 min, and after cooling the flask the suspension was filtered with Whatman No. 6 filter paper. For determination available Cu, Zn, Fe, and Mn, 10 g of the air-dried soil sample was placed in 100 mL flask and 50 mL of 0.1 N HCl was added. After shaking the suspension for 1 hr at 30℃ the suspension was filtered with Whatman No. 2 filter paper.

Quantitative determination of micronutrients in the extracts was carried out using inductively coupled plasma-atomic emission spectrophotometer (ICP-AES, Varian Liberty Series II, Mulgrave, Australia).

Results and Discussion

Total and extractable contents of micronutrients in the soils of plastic film houses are presented in Table 2. Also

Table 2. Contents of total and extractable micronutrients in soils of plastic film houses

	B		Cu		Zn		Fe		Mn	
	Ext†	Total	Ext	Total	Ext	Total	Ext	Total	Ext	Total
	mg kg^{-1}									
					Strawberry					
Minimum	nd‡	11	0.1	8	2	28	48	9,407	18	77
Maximum	2.7	37	25.2	76	101	148	896	35,641	314	936
Mean±SE§	0.5±0.1	21±1	9.2±0.4	39±2	44±2	76±3	173±15	18,258±518	135±7	570±21
					Red pepper					
Minimum	nd	20	nd	3	3	45	20	16,231	14	152
Maximum	5.3	54	15.8	58	84	128	746	43,485	355	1,012
Mean±SE	0.8±0.1	36±1	3.2±0.5	15±1	22±2	80±2	181±17	27,069±754	158±8	506±20
					Tomato					
Minimum	nd	13	0.5	5	2	36	2	11,194	13	161
Maximum	10.1	35	108.0	193	131	156	904	46,217	330	2,695
Mean±SE	2.3±0.2	22±1	11.3±1.8	35±4	41±3	74±3	136±18	19,399±712	161±7	577±53
					Oriental melon					
Minimum	nd	14	nd	5	2	18	3	11,773	27	123
Maximum	11.7	46	17.9	54	60	127	983	49,876	318	4,506
Mean±SE	2.4±0.2	30±1	2.5±03	22±1	19±2	61±2	118±12	25,562±672	138±6	747±65
					Cucumber					
Minimum	0.1	11	1.7	9	8	37	9	8,521	12	118
Maximum	9.2	34	91.9	189	171	206	727	28,708	310	804
Mean±SE	2.7±0.3	19±1	11.5±1	46±4	51±4	78±4	170±14	16,293±545	139±7	398±18
	2.1	25	7.5	32	35	74	156	21,316	146	420

† Extractable : B in hot water, and Cu, Zn, Fe and Mn in 0.1 N HCl.
‡ Not detected.
§ Standard error.

Table 3. Contents of total and extractable micronutrients in soils of open fields near the plastic film houses

	B		Cu		Zn		Fe		Mn	
	Ext†	Total	Ext	Total	Ext	Total	Ext	Total	Ext	Total
	mg kg^{-1}									
Minimum	nd‡	17	0.4	6	2	5	86	15,463	9	128
Maximum	1.3	34	15.7	39	63	131	764	32,573	332	1,815
Mean±SE§	0.4±0.1	26±1	5.0±0.7	17±1	12±3	54±5	397±49	23,572±978	150±20	549±77

† Extractable : B in hot water, and Cu, Zn, Fe and Mn in 0.1 N HCl.
‡ Not detected.
§ Standard error.

contents of micronutrients in soils of open fields near the plastic film houses investigated are shown in Table 3.

Overall mean values of total contents of B, Cu, Zn, Fe, and Mn in the plastic film house soils were 25, 32, 74, 21,316, and 420 mg kg^{-1}, respectively. In the composition of the surface of the continental crust as an approximation of the average soil parent material, the contents of B, Cu, Zn, Fe, and Mn are 15, 25, 71, 35,000, and 600 mg kg^{-1}, respectively (Taylor and McClennan, 1985). Comparing to the average soil parent material, the contents of B and Zn were slightly higher and the contents of Fe and Mn were lower in the plastic film house soils. In soils of open fields near the plastic film houses, mean values of total contents of B, Cu, Zn, Fe, and Mn were found to be 26, 17, 54, 23,572, and 549 mg kg^{-1}, respectively. The mean total contents of micronutrients in the plastic film house soils and open field soils were not much different. The contents of micronutrients were quite different among the locations investigated (detail data not shown), and this difference would be due to the differences in the mineral composition and fertility management of the soils (Chesworth, 1991).

Overall mean values of extractable contents of B, Cu, and Zn in the plastic film house soils were 2.1, 7.5, and 35 mg kg^{-1}, respectively. And in soils of open fields near the plastic film houses, mean values of extractable B, Cu, and Zn contents were found to be 0.4, 5.0, and 12 mg kg^{-1}, respectively. The mean contents of B, Cu, and Zn in the plastic film house soils were higher than those found in the soils of open fields with exceptions of B in soils of strawberry and Cu in soils of red pepper and oriental melon. Frequent applications of micronutrient fertilizers and composts would be the reason for the higher contents of those nutrients in the plastic film house soils. Otherwise, the mean contents of Fe and Mn in the plastic film houses were 156 and 146 mg kg^{-1}, respectively, and mostly lower than those found in the soils of open fields. Most of the plastic film houses are located in the former paddy fields. And Fe and Mn are reduced and more soluble in the paddy environment. Most of the open fields where soil samples were taken were paddy, and this would be the reason for the higher contents of extractable Fe and Mn in the soils (McLaren and Cameron, 1996). Ha et al. (1997) reported that the average contents of hot water extractable B and exchangeable Cu and Zn in seventy-one plastic film house soils of Gyeongnam area were 1.44, 1.13, and 25.7 mg kg^{-1}, respectively, and these values are lower than those found in this investigation.

Mean contents of extractable micronutrients in soils of

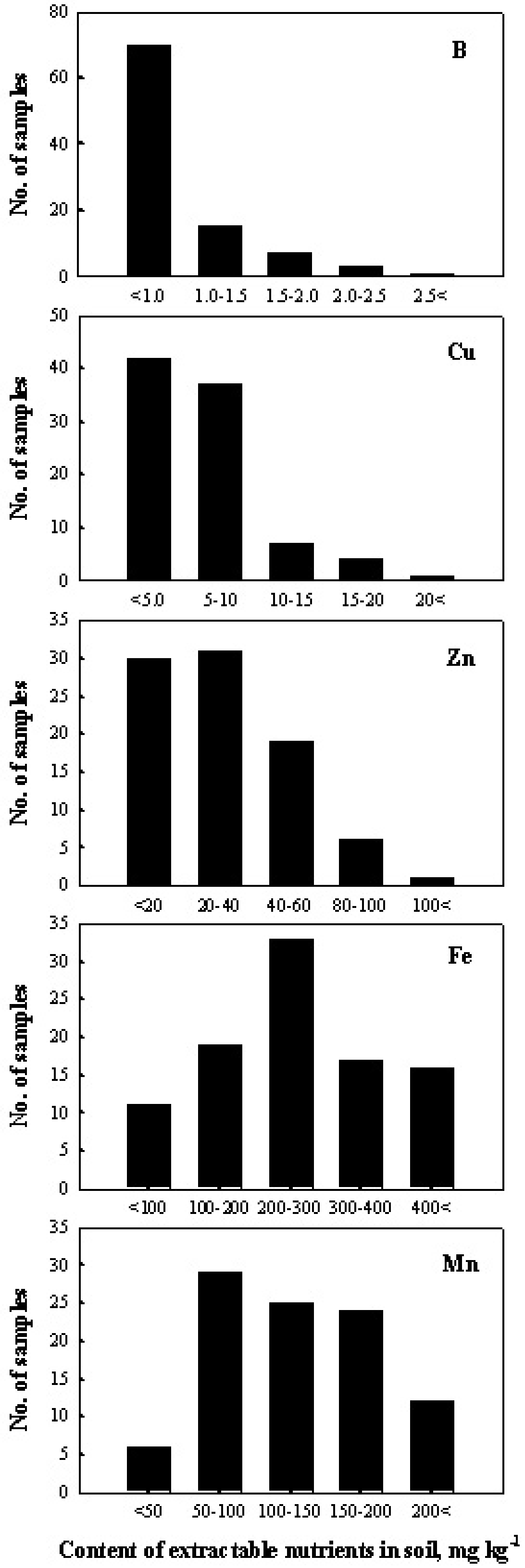

Fig. 1. Frequency distribution diagram for the contents of extractable micronutrients in the plastic film house soils of strawberry.

the plastic film houses of different crops were quite different (Table 2). Mean contents of extractable B, Cu, and Zn were highest in the plastic film house soils of cucumber, and average contents of extractable Fe and Mn

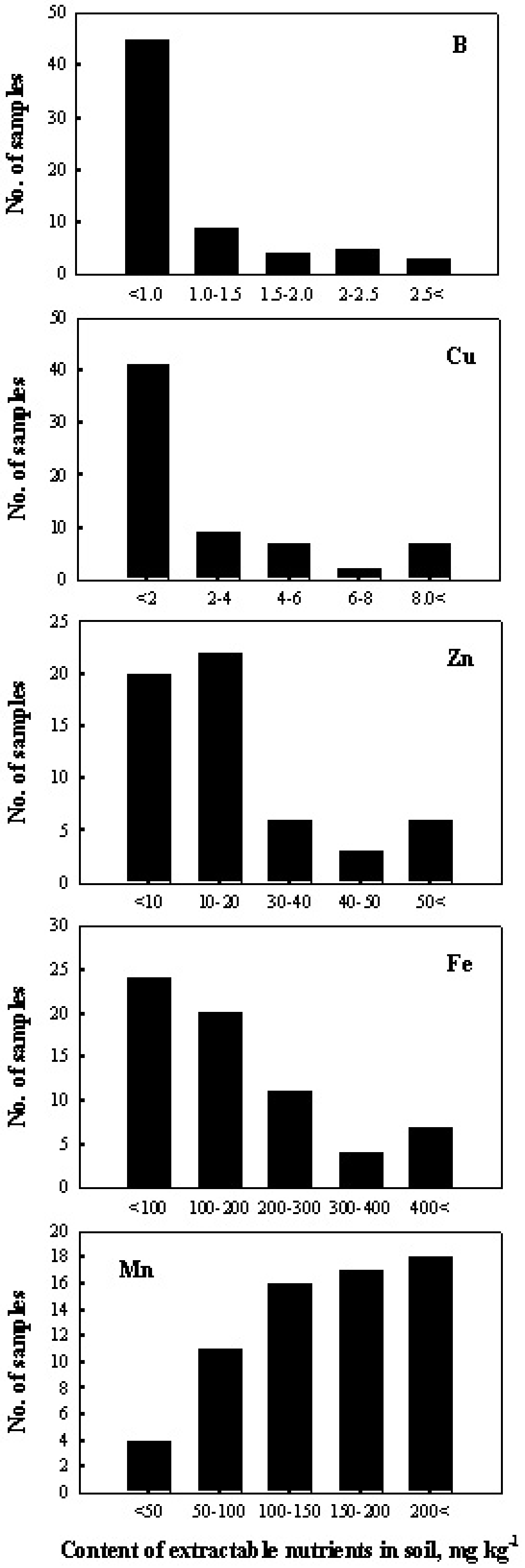

Fig. 2. Frequency distribution diagram for the contents of extractable micronutrients in the plastic film house soils of red pepper.

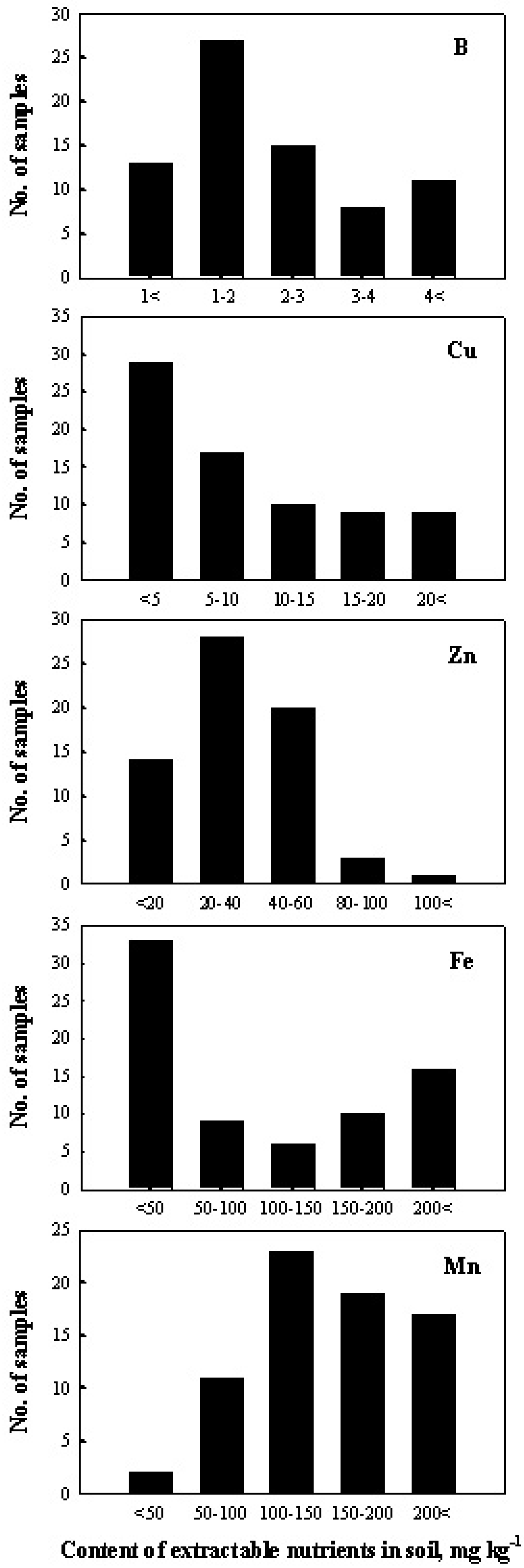

Fig. 3. Frequency distribution diagram for the contents of extractable micronutrients in the plastic film house soils of tomato.

were highest in the plastic film house soils of red pepper and tomato, respectively. Contents of extractable micronutrients in arable soils, as Shuman (1991) reported, could be influenced by soil moisture and

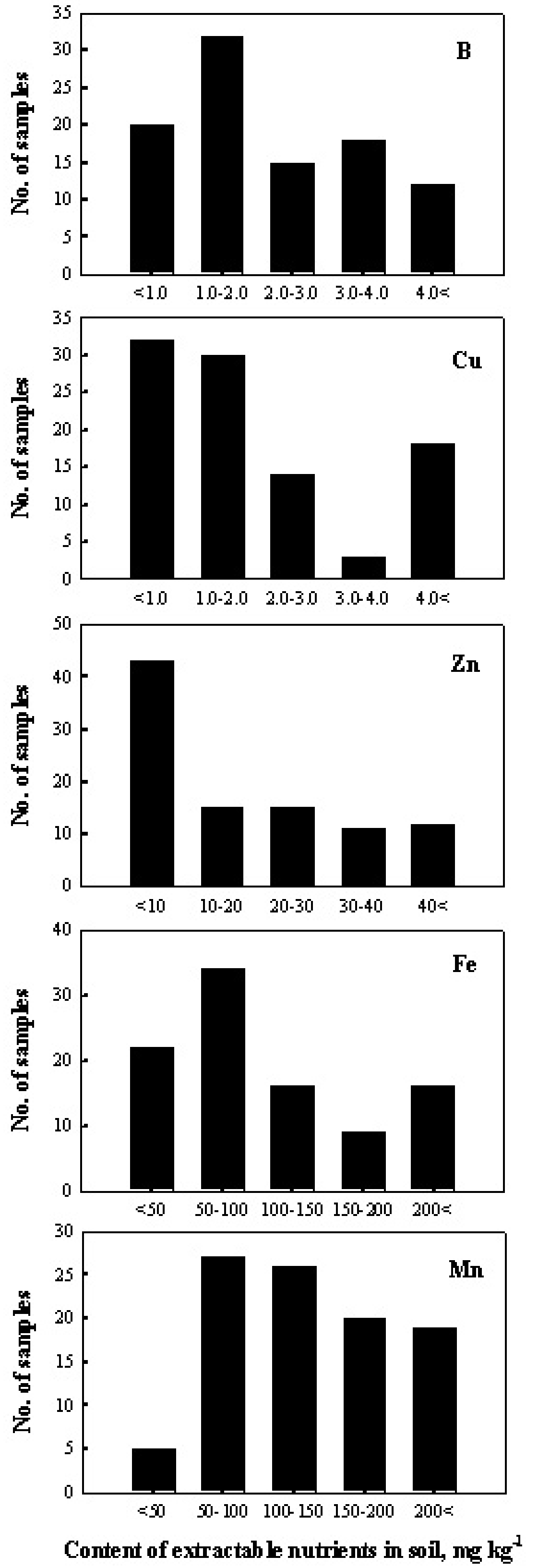

Fig. 4. Frequency distribution diagram for the contents of extractable micronutrients in the plastic film house soils of oriental melon.

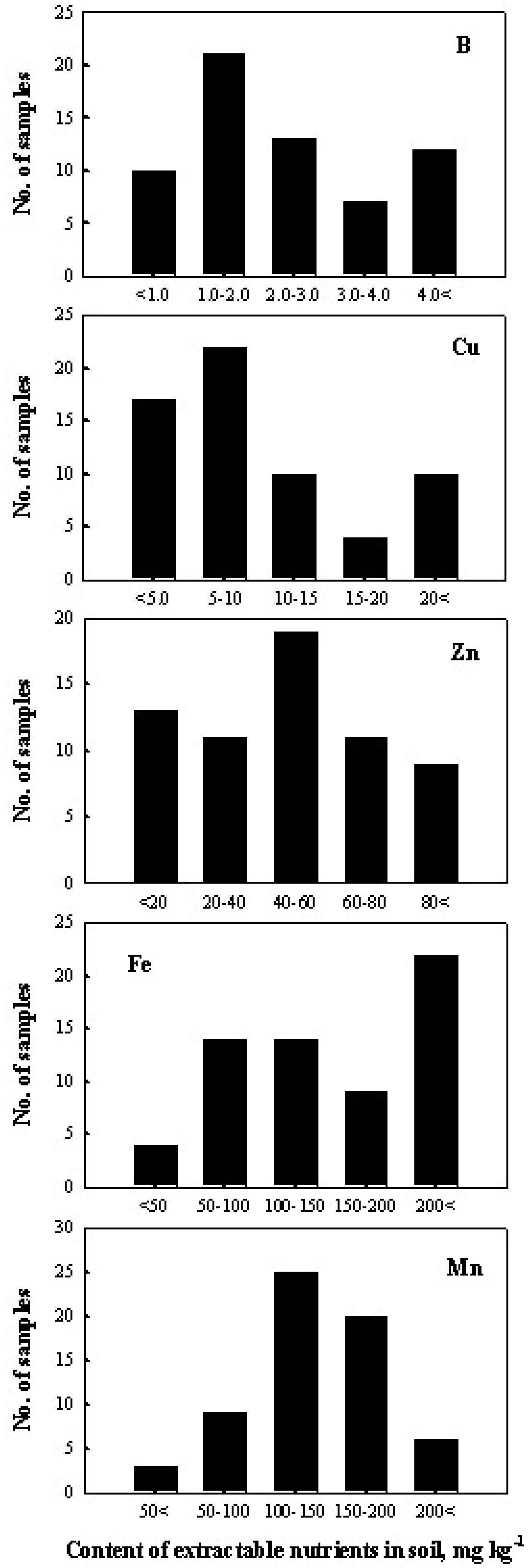

Fig. 5. Frequency distribution diagram for the contents of extractable micronutrients in the plastic film house soils of cucumber.

organic matter contents and fertility managements, and these factors would be the reasons for the differences of extractable micronutrient contents in the plastic film house soils of different crops.

Distributions of extractable micronutrients in the plastic film house soils of various crops are presented in Fig. 1, 2, 3, 4, and 5. Among the soils cultivated with the same crop, the contents of extractable micronutrients were quite various. Relationships between soil properties and extractable micronutrient contents in plastic film house soils were presented in Table 4. Generally as soil pH increases the solubility of Cu, Zn, Fe, and Mn decrease. Such relationship was found for Fe in soils of strawberry, red pepper, and tomato and for Cu in soils of strawberry and tomato. And such relationship was found for Mn only in soils of strawberry but extractable Mn content was increased as pH increased in soils of red pepper, tomato, and cucumber. Extractable B content was increased as soil EC increased with exception of strawberry soils, and such relationship was also found for Zn in strawberry and red pepper soils. As soil organic matter content increased the content of extractable Zn was increased in soils of the investigated crops except oriental melon, and such relationship was found for Cu only in soils of red pepper. The relationships between extractable Zn and Cu and organic matter contents in soils indicates that compost application could be the reason for the accumulation of those micronutrients in soil. However, the overall relationships between soil properties and extractable micronutrient contents in plastic film house soils were not consistent. The results indicate that the extractable micronutrient contents in soil could be controlled by various factors including soil physical and chemical characteristics and soil fertility managements as mentioned by Shuman (1991) and Jung et al. (1997), and such factors might be quite different among the investigated plastic film houses. Therefore, for better management of micronutrient in plastic film house soils, further detail individual farm based investigations in soil characteristics and fertility management practices should be carried out in relation to the soil micronutrient availability.

Typical ranges of critical levels for B, Cu, Zn, Fe, and Mn in most crop plants are 0.1-2.0, 1.0-2.0, 1.0-5.0, 10-16, and 1.0-4.0 mg kg^{-1}, respectively (Sims and Johnson, 1991). Considering these critical levels, the contents of

Table 4. Statistical summary of effects of soil properties on the extractable micronutrient contents in plastic film house soils

Crop cultivated	Extractable micronutrient	Correlation coefficient		
		pH	Electrical conductivity	Organic matter
Strawberry	B	ns	ns	ns
	Cu	-0.539**	ns	ns
	Zn	ns	0.450*	0.562**
	Fe	-0.663**	0.588**	ns
	Mn	-0.475**	ns	ns
Red pepper	B	ns	0.465**	ns
	Cu	ns	ns	0.369*
	Zn	ns	0.412*	0.570**
	Fe	-0.524**	ns	ns
	Mn	0.330*	ns	ns
Tomato	B	ns	0.529*	ns
	Cu	-0.529**	ns	ns
	Zn	ns	ns	0.523*
	Fe	-0.542**	ns	-0.568**
	Mn	0.686**	ns	ns
Oriental melon	B	ns	0.337*	ns
	Cu	ns	ns	ns
	Zn	ns	ns	ns
	Fe	ns	ns	ns
	Mn	ns	ns	ns
Cucumber	B	0.718**	0.588**	ns
	Cu	ns	ns	ns
	Zn	ns	ns	0.546**
	Fe	ns	ns	ns
	Mn	0.466*	0.485**	ns

extractable micronutrients were found to be above the critical levels in most plastic film house soils investigated.

Using the critical levels of Sims and Johnson (1991), frequency distribution of the plastic film house soils under the conditions of deficiency, sufficiency and excess levels in the micronutrients for each crop cultivation were evaluated and the results are presented in Table 5. In most of the investigated soils of various crop cultivations, the contents of 0.1 N HCl extractable Zn, Fe, and Mn were found to be higher than the upper limits of the critical levels for common crops. Extractable Cu contents were higher than the upper limit of critical range in 38 and 35% of the plastic film house soils of red pepper and oriental melon cultivation, respectively. However, in most (>80%) of the plastic film house soils of strawberry, tomato and cucumber cultivation the extractable Cu contents were higher than the upper limit of critical range. Otherwise, the percentage of soils contained extractable Cu lower than the lower limit of the critical range was relatively high (about 30%) in the plastic film houses of red pepper and oriental melon cultivation. The percentage of soils contained extractable B higher than the upper limit of the critical range was relatively lower as compared to the other nutrients, especially in the plastic film houses of strawberry and red pepper cultivation. And the percentage of soils contained extractable B lower than the lower limit of the critical range was 32 and 48% in the plastic film houses of red pepper and oriental melon cultivation, respectively.

The high contents of extractable Fe and Mn in the soils would be due to the fact that most of the plastic house soils are formerly rice paddy. Also in some plastic film houses paddy rice is included in their cropping system. In the case of Cu and Zn, the application of various biosolids and manure based composts can cause the elevated contents in the soils (Zubillaga and Lavado, 2002; Ozores-Hampton et al., 2005; Sukkariyah et al., 2005; Vidal-Vazquez et al., 2005). Continuous plastic film house crop cultivation increased Cu and Zn contents in the soils and higher contents of Cu and Zn were found in the soils where poultry or pig manure was applied (Jung et al., 1997). Lim et al. (2004) found that the application of pig manure (20 Mg ha^{-1}) could significantly increase the contents of total and 1 N HCl extractable Cu and Zn in the soil of red pepper. Also the frequent applications of micronutrient fertilizers could be one of the reasons for the high contents of extractable Cu, Zn, Fe, and Mn in the soils of plastic film houses. In one extreme case, soils contained extractable Cu higher than 50 mg kg^{-1}, the contamination warning standard in agricultural soils (Ministry of Environment, 2005), were found in two of the plastic film houses of tomato cultivation and in one of the plastic film houses of cucumber cultivation.

Conclusion

Since available micronutrients are in sufficient or even in excessive levels in terms of crop requirements in most of the investigated plastic film house soils of Yeongnam area, the effect of micronutrient fertilizer applications for those plastic film house crops is uncertain. However, in those plastic film houses where available B and Cu are in deficient levels, appropriate treatments are recommended to supply crop requirements of those nutrients. During the investigation, apparent toxicity and deficiency symptoms of the micronutrients in the crops were not found. However, a loss in crop productivity without any apparent toxicity and deficiency symptoms is always possible. For the best management of micronutrients in the cultivation of plastic film house crops, soil

Table 5. Frequency distribution for the soils of plastic film houses under the condition of deficiency, sufficiency and excess of extractable micronutrients for the different crops.[†]

Crop cultivated	B			Cu			Zn			Fe			Mn		
	D	S	E	D	S	E	D	S	E	D	S	E	D	S	E
	-------- % --------														
Strawberry	32	66	2	14	2	84	0	2	98	0	0	100	0	0	100
Red pepper	48	31	11	32	30	38	0	6	94	0	0	100	0	0	100
Tomato	1	56	43	4	8	88	0	1	99	5	10	85	0	0	100
Oriental melon	21	34	45	33	32	35	0	8	82	2	0	98	0	0	100
Cucumber	2	52	46	0	2	98	0	0	100	2	0	98	0	0	100

[†] D, S, and E represent deficiency, sufficiency, and excess, respectively. The status of soil micronutrients was evaluated using the critical levels suggested by Sims and Johnson (1991).

availability and crop requirements of micronutrients should be carefully determined before application of micronutrient fertilizers. And also the effect of interactions among soil characteristics and compost application on the availability of micronutrients in soils should be further examined.

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영남지역 시설재배지 토양중의 미량원소 함량 분포

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집약적으로 재배하는 시설작물의 품질과 생산성을 향상시키기 위해서는 적절한 미량원소의 관리가 필요하며, 따라서 시설재배지 토양중의 미량원소의 유효도에 대한 평가가 우선적으로 이루어져야한다. 본 연구에서는 영남지역 주요 시설재배지 토양중의 미량원소 함량을 조사하였다. 딸기 재배지 96개소, 고추재배지 66개소, 토마토 재배지 74개소, 참외 재배지 97개소, 오이 재배지 63개소 등 총 396개소의 비닐하우스 토양 시료를 채취하였고, B, Cu, Zn, Fe 및 Mn에 대하여 총 함량과 가용성 함량을 조사하였다. 가용성 함량의 경우 B는 열수로 추출하였으며 Cu, Zn, Fe, Mn은 0.1 N HCl로 추출하였다. 비닐하우스 토양중 B, Cu, Zn, Fe, Mn의 총 함량 평균값은 각각 25, 32, 74, 21,316, 420 mg kg^{-1}으로 조사되었다. 이들 값은 비닐하우스 주변 노지 토양중의 총 함량과 크게 다르지 않았다. 조사지역별 그리고 재배작물별로 비교하면 비닐하우스 토양중의 각 미량원소들의 총 함량은 매우 다양하게 나타났다. 가용성 B, Cu, Zn의 함량은 전체 조사 토양에 대한 평균값으로 각각 2.1, 7.5, 35 mg kg^{-1}으로 나타났으며, 주변 노지 경작토양에 비하여 대부분 그 함량이 높았다. 가용성 Fe와 Mn의 경우에는 전체 평균값이 각각 156 및 146 mg kg^{-1}이었으며, 가용성 Fe의 함량은 주변 노지 경작토양에 비하여 그 함량이 낮았다. 조사된 시설재배 토양중의 가용성 Zn, Fe, Mn의 함량은 모든 지역에서 대부분 일반작물 재배에 적정한 수준 또는 그 이상의 과잉 수준인 것으로 나타났다. Cu의 경우 딸기, 토마토 및 오이 재배지에서는 가용성 함량이 대부분의 조사 토양에서 적정수준 이상인 것으로 나타났으며, 고추와 오이 재배지에서는 조사토양의 약 30%에서 적정함량에 미달하는 것으로 나타났다. B의 경우 딸기, 고추, 참외 재배지에서 가용성 함량이 적정수준에 미달하는 토양이 많았으며, 전체적으로 가용성 B의 함량이 과잉 수준인 토양은 다른 원소의 경우에 비하여 상대적으로 적은 것으로 조사되었다.