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Domestic System Development of Automatic Nutrient
Solution Controller and Equipment for Expanding
Nutriculture

1995

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SUMMARY

I. Title

Domestic System Development of Automatic Nutrient Solution Controller and Equipment for Expanding Nutriculture

II. Importance and Objects of the Study

Since the conclusion of world trade organization, opening of the agricultural field has also been rapidly progressed in all its aspects. Thus the Korean agriculture is to face the limitless competition. It is urgently needed to orient Korean agriculture by technology, of high quality and for exportation for strengthening the constitution of Korean agriculture and supporting the subsistence of Korean farmers.

The countries developed in agriculture, such as Netherlands, France, Belgium, Japan, the United States of America, etc., have exerted their efforts for several decades through the innovation of production and marketing technologies to promote the competitive ability of their agriculture for the preparation against its internationalization. Korea, on the other hand, has only recently started horticulture in the structures along with hydroponics, the prime of agricultural technologies, out of traditional rice-oriented agriculture. For the existing types of nutrient solution management systems and fertigation instruction devices, those by ventury tube, quantified pump, magnetic pump, diaphragm and flow meter for the former, and those by amount of solar radiation, moisture in rhizosphere and time-dependent control for the latter are utilized singly or in combinations : At present the

equipment and devices related to fertigation are imported extensively from Netherlands, Japan and Israel, but several domestic companies make their efforts to develop their own, including nutrient solution diluter.

In hydroponics the supply and drainage of nutrient solution differ by cultural systems, culture solutions substrates and equipments and devices for fertigation. The temperature, concentration and pH of the nutrient solution also vary greatly by crop species and growth stages. In addition, the systems should be compatible to the stature of most Korean farmers and their farming. These emphasize the careful choice and localization of equipments and devices related to hydroponics.

Crop production by hydroponics, though differs by crop species to some extent, brings about labor saving efficiency by 5 to 15 times and elevation of land productivity by 3 to 20 times, especially it can make available the quantity and quality of products year-around depending on scale and sophistication of the systems. To make the best utilization of hydroponics in Korea, the hydroponics-related equipments, devices and systems, above all, should be localized and standardized. This will bring about the effects that would substitute the whole quantity depended on importation, and at the same time induce the manufacturer's investment on ground build-up for agricultural production.

The purpose of this study was to develop a nutrient solution diluter and its incidental equipments, which is one of the important components of the hydroponic systems. In addition, a hydroponic system which is least polluting environment and harmonized with the stature and logic of Korean farmers was developed. Softwares for managing nutrient solution by types and scales of hydroponic systems were constructed and verified on-the-spot. A field manual on the production of vegetables and flowers in hydroponics was prepared and distributed to growers, researcher and extension agencies.

III. Contents and Range of Research

We developed an automatic diluter, an automatic temperature adjuster and a sterilizer of nutrient solution and control device for fertigation, and then, after on-the-spot verification, distributed them to growers in order to promote hydroponics in Korea.

1. Development of Nutrient Solution Diluter

The main characteristics of the diluter is to control the individual fertilizer components at will by growing stages. It so was designed that emergency measures against physiological disorders can be easily taken. In addition, this diluter utilize a cheap magnetic pump instead of an expensive quantified pump, and it was linked to 3-way valves to precisely control the solution concentration. It can also automatically regulate the amount and composition of the nutrient solution supplied by crop species and growth stages, once the background data of the underground water is input.

2. Development of Nutrient Solution Temperature Adjusting System

The temperature of nutrient solution greatly influences root zone environment. For the maintenance of optimum temperature in the rhizosphere, a temperature adjuster of nutrient solution was developed. The temperature adjuster is energy-saving, multi-functional and can be installed along with heat sterilizer.

3. Development of Nutrient Solution Sterilizer

Sterilization aims to kill harmful microorganisms in the nutrient solution, but different types of sterilizers have been used as non-selective ones. Sterilization of nutrient solution has been yet practiced in Korea due to lack of understanding its benefits. The nutrient solutions are sterilized by various agents such as ozone, heat,

chemicals and filters. The sterilizers developed in this research are those using heat and ultra-violet. An integrated sterilization using microorganisms was also intended.

IV. Results and Suggestions for Their Applications

The results of the research project are summarized as follows :

1. The present status of hydroponics in Korea, with the helps of provincial offices of rural administration and agricultural extension stations, including acreages, culture methods, crop species, cultural types of hydroponics by individual growers throughout the country was surveyed, and the data were analyzed to predict a prospect of hydroponics in Korea.

2. Nutrient Solution Diluter

The solution diluter can control the integrated supply of water and nutrient solutions at various conditions to different types of nutrient culture systems such as pure hydroponics and cultivation on solid substrates. The diluter is capable to automatically control the amount and time of supply in relation with pH and electric conductivity of the nutrient solution. By connection of its main control device to a personal computer, it is able to check up the functioning condition of the system, readjust the conditions, change to manual operation, and output or store various data. Low prices, simplification of operation and language for programming were emphasized in developing the diluter. The diluter can control the nutrient solution by crop species, growth stages and seasons, and by individual components of fertilizers. A control package by main computer for large scale operations was also prepared.

3. Nutrient Solution Temperature Adjuster

The temperature adjuster can maintain the temperature of a certain amount of solution at a target temperature. Heating and cooling can be accomplished by separate operations. Heating is done by circulation of underground water through heat exchanging pipes, and cooling by connecting the pipes to the boiler equipped with a burner. Pipes can be of either stainless steel or polyethylene depending on the control capacity, though the former is preferred. Either light oil or liquidified petroleum gases can be used for the burner. The exhaust gas, when the latter was used for heating, can be utilized as CO₂ source to the crops. The heat from the boiler can also be utilized for sterilization.

4. Nutrient Solution Sterilizer

With the ever-increasing emphasis of environmental protection, the solution sterilizer for hydroponics is also recognized as an important component along with augmentation of recycle system. One heat sterilizer connected to the temperature adjuster and another ultra violet sterilizer were developed. The heat sterilizer which shares with the temperature adjuster the same heat source can control the temperature within the range from 60 to 95 °C. For ultra violet sterilization, the lamps of easy purchase were installed apart from the solution canals so that it would not contaminate nutrient solution in case of breakage. It is easy due to its simple structure to change the lamps and to parallel the lamps for extension.

5. Fertilization Instruction Device

This device was designed to control the diluter function independently without connecting to a computer. The device works based on inputs of actual measurement for the last 3 weeks of aerial and root zone environment, predicted data and growing state of crops. Type, concentration and pH value of nutrient solution, and state of vegetative growth or fruit set are the other items of input. In addition, a

program will be prepared, which enables taking emergency measure against physiological disorders, when the kind of disorder and extent of its incidence are input, during operation. The Data based program will be prepared by using the predicted values by species, predicted microelement within the structure by seasons, and environment of the nutrient solution by types of hydroponics. Those expected values were catalogued for the convenient reference of the users.

6. Publication of a Manual on Hydroponics

Principles and techniques of hydroponics for major vegetables and flowers are arranged, laying stress on the actual practices. Two books titled, "Growing Fruit Vegetables by Hydroponics" and "Cut Flower Production by Hydroponics", were written primarily based on the field data collected for this project, which are now under distribution to vegetable and flower growers, agricultural research, education, extension and administration agencies.

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3	101
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software, controller

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(coconut peat), (peat moss)

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 technique, NFT) .
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4. . 1993. . -
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1860 1844 6

1860 Sachs . 1961 Knop

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1929 Gericke , 1 ha Count

Salm- Horstmar(1849) 가

McCall(1916) 가

. Robbins(1928)

, Laurie(1931)

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Robbins(1937), Chapmann Liebig(1938)

Temperman Watson(1938)

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Cooper

(1973) DeStiger

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16.36ha가 96 95 100ha가

277.9ha , 93 94 95 36ha

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68.1ha 24.5%

42.58ha 2

39ha 가 .

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257,120 30%

가

1 : 3

NFT DFT가

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NFT DFT가

가 13

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	-	-	-	-	-	0.06	0.11	0.17
	0.8	-	0.06	0.5	0.43	-	0.24	2.03
	0.8	-	0.06	0.5	0.43	0.06	0.35	2.20
	-	-	-	-	0.5	2.03	0.67	3.2
	-	-	0.26	0.3	0.1	-	0.01	0.67
	-	-	0.26	0.3	0.6	2.03	0.68	3.87
	-	-	-	-	0.006	-	-	0.006
	-	-	0.01	-	0.006	0.2	0.26	0.476
	-	-	0.01	-	0.012	0.2	0.26	0.482
	-	-	-	-	-	0.25	0.28	0.53
	-	-	-	-	0.26	-	0.27	0.53
	-	-	-	-	0.26	0.25	0.55	1.06
	-	0.4	-	-	0.78	0.35	4.96	6.49
	-	-	0.13	0.45	0.36	-	0.06	1.00
	-	0.4	0.13	0.45	1.14	0.35	5.02	7.49
	-	-	-	-	0.86	0.4	0.76	2.02
	-	0.43	0.06	-	-	-	0.01	0.5
	-	0.43	0.06	-	0.86	0.4	0.77	2.52
	-	-	0.3	0.15	5.01	4.42	24.12	34
	0.78	0.63	0.35	1.42	0.46	0.06	1.34	5.04
	0.78	0.63	0.65	1.57	5.47	4.48	25.46	39.04
	-	-	2.0	-	-	2.91	3.7	8.61
	-	0.1	-	-	-	-	-	0.1
	-	0.1	2.0	-	-	2.91	3.7	8.71
	0.16	0.55	-	1.48	1.32	0.88	4.98	9.37
	0.16	0.16	-	-	0.1	-	0.01	0.43
	0.32	0.71	-	1.48	1.42	0.88	4.99	9.80
	-	-	-	0.46	6.8	4.1	16.47	27.83
	-	-	-	-	-	-	-	-
	-	-	-	0.46	6.8	4.1	16.47	27.83
	-	-	0.1	1.0	0.73	4.03	21.46	27.32
	-	-	0.9	0.36	-	-	0.97	2.23
	-	-	1.0	1.36	0.73	4.03	22.43	29.55
	0.3	1.4	1.9	4.19	10.03	0.33	22.87	41.02
	0.23	0.15	0.46	0.98	0.33	0.03	0.62	1.56
	0.53	1.55	2.36	5.17	10.36	0.36	22.25	42.58
	-	-	0.06	-	1.90	3.92	5.31	11.19
	0.4	2.67	0.66	-	0.66	1.4	2.39	8.18
	0.4	2.67	0.72	-	2.56	5.32	7.70	19.37
	-	-	-	1.07	3.07	6.78	45.14	56.06
	-	-	0.01	0.7	0.31	1.33	9.69	12.04
	-	-	0.01	1.77	3.38	8.11	54.83	68.10
	-	-	0.5	0.1	1.4	0.3	3.64	5.94
	-	-	0.26	3.15	0.49	2.4	3.11	9.41
	-	-	0.76	3.25	1.89	2.7	6.75	15.35
	0.46	2.35	4.86	8.45	32.4	30.76	154.47	233.756
	2.37	4.14	3.16	7.86	3.51	5.42	17.74	44.196
	2.83	6.49	8.02	16.31	35.91	36.18	172.21	277.952

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		NFT, DFT				,			
		6,100	-	-	-	-	500	-	6,600
	가	9	-	-	-	-	2	-	11
		2,000	-	-	7,900	-	1,700	-	11,600
	가	4	-	-	6	-	2	-	12
		1,418	-	-	-	-	18	-	1,436
	가	5	-	-	-	-	1	-	6
		1,600	-	-	1,600	-	-	-	3,200
	가	2	-	-	1	-	-	-	3
		-	3,010	-	-	4,100	15,360	-	22,470
	가	-	6	-	-	3	26	-	35
		-	1,500	-	-	600	4,400	-	6,500
	가	-	3	-	-	1	7	-	11
		15,130	-	-	21,700	600	79,397	300	117,127
	가	21	-	-	18	2	80	1	122
		300	-	-	12,980	-	11,650	1,200	26,130
	가	1	-	-	7	-	15	4	27
		1,300	-	-	9,007	-	14,150	4,950	29,407
	가	3	-	-	8	-	20	7	38
		-	-	-	10,800	-	72,710	-	83,510
	가	-	-	-	11	-	105	-	116
		6,700	-	-	54,660	-	27,315	-	88,675
	가	9	-	-	48	-	24	-	81
		200	3,900	570	33,720	40,270	47,076	2,000	127,736
	가	2	6	1	25	38	57	1	130
		21,121	3,400	30	5,973	7,950	19,650	-	58,124
	가	40	3	1	8	10	23	-	85
		10,920	25,200	-	86,640	-	54,840	26,700	204,300
	가	18	27	-	79	-	52	28	204
		4,900	23,330	-	12,140	-	700	5,000	46,070
	가	8	25	-	10	-	1	4	48
		71,689	60,340	600	257,120	53,520	349,466	40,150	832,885
	가	122	70	2	221	54	415	45	929

: 1996 12 2 , ()

2-3.

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	400	-	-	-	-	3,200	1,800	-	1,200	6,600
	-	2,500	-	300	-	900	-	7,900	-	11,600
	-	-	30	18	-	1,388	-	-	-	1,436
	2,350	-	-	-	-	850	-	-	-	3,200
	10,600	7,220	-	-	1,000	-	-	2,600	1,050	22,470
	700	-	3,100	600	-	1,500	-	600	-	6,500
	25,275	3,600	20,372	9,350	-	11,230	2,910	31,370	13,020	117,127
	15,440	3,800	4,340	1,200	-	1,350	-	-	-	26,130
	-	11,140	7,917	3,600	-	2,720	550	1,600	1,880	29,407
	5,800	28,700	26,160	3,850	300	3,800	-	13,100	1,800	83,510
	3,000	12,200	8,615	8,000	-	2,900	300	53,660	-	88,675
	45,776	60,180	13,640	2,040	2,400	-	-	3,600	100	127,736
	15,178	13,300	4,550	1,800	-	5,100	350	2,700	15,146	58,124
	45,600	6,690	12,000	49,200	-	5,820	-	84,390	600	204,300
	12,180	16,793	5,100	5,000	-	4,497	-	2,000	500	46,070
	182,299	166,123	105,824	84,958	3,700	45,255	5,910	203,520	35,296	832,885

: 1996 12 2 , ()

2-4.

(:)

						N F T			DFT	
		69,583	66,076	3,200	30,300	6,020	1,200	5,920	182,299	
		15,910	88,070	17,070	18,270	8,030	2,200	16,573	166,123	
		18,947	73,647	-	9,300	1,330	1,700	900	105,824	
		1,300	8,850	-	2,170	15,918	12,920	4,097	45,255	
		-	1,760	-	550	1,800	1,800	-	5,910	
		16,440	41,200	-	20,518	300	600	5,900	84,958	
		-	3,700	-	-	-	-	-	3,700	
		500	16,870	-	1,880	11,896	3,700	450	35,296	
		134,800	24,400	-	1,550	-	-	23,000	183,750	
		1,400	2,700	-	-	-	-	400	4,500	
		1,800	11,720	-	1,750	-	-	-	15,270	
		260,680	338,993	20,270	86,288	45,294	24,120	57,240	832,885	

: 1996 12 2 , ()

2-5.

(:)

						N F T		D F T	
		-	400	-	-	-	-	-	400
		-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-
		1,600	-	-	-	750	-	-	2,350
		-	5,250	1,200	2,900	-	-	1,250	10,600
		-	700	-	-	-	-	-	700
		-	24,975	-	-	300	-	-	25,275
		7,400	6,540	-	1,500	-	-	-	15,440
		-	-	-	-	-	-	-	-
		2,800	3,000	-	-	-	-	-	5,800
		3,000	-	-	-	-	-	-	3,000
		19,570	8,806	2,000	14,300	-	-	1,100	45,776
		3,573	6,505	-	5,100	-	-	-	15,178
		24,000	9,900	-	6,000	2,400	1,200	2,100	45,600
		61,943	66,076	3,200	29,800	3,450	1,200	4,450	170,119

: 1996 12 2 , ()

2-6.

(:)

					N F T D F T			
	-	-	-	-	-	-	-	-
	-	1,700	-	-	800	-	-	2,500
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	6,310	-	-	-	-	910	7,220
	-	-	-	-	-	-	-	-
	-	3,300	-	300	-	-	-	3,600
	1,400	2,400	-	-	-	-	-	3,800
	4,540	6,600	-	-	-	-	-	11,140
	-	28,700	-	-	-	-	-	28,700
	-	8,700	-	-	3,500	-	-	12,200
	6,370	18,870	17,070	14,970	100	-	2,800	60,180
	-	8,400	-	-	2,700	2,200	-	13,300
	3,600	3,090	-	-	-	-	-	6,690
	15,910	88,070	17,070	15,270	7,100	2,200	3,710	149,330

: 1996 12 2 , ()

2-7.

(:)

					N F T D F T			
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	30	-	-	30
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	3,100	-	-	-	3,100
	4,000	14,872	-	200	1,300	-	-	20,372
	3,440	900	-	-	-	-	-	4,340
	3,767	4,150	-	-	-	-	-	7,917
	-	26,160	-	-	-	-	-	26,160
	-	8,615	-	-	-	-	-	8,615
	4,140	8,000	-	1,500	-	-	-	13,640
	-	4,550	-	-	-	-	-	4,550
	600	5,700	-	4,500	-	1,200	-	12,000
	15,947	72,947	-	9,300	1,330	1,200	-	100,724

2-8.

(:)

					N F T D F T			
	-	-	-	-	-	-	-	-
	-	-	-	-	300	-	-	300
	-	-	-	18	-	-	-	18
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	600	-	-	-	-	-	600
	-	9,350	-	-	-	-	-	9,350
	-	1,200	-	-	-	-	-	1,200
	-	1,900	-	1,700	-	-	-	3,600
	-	3,850	-	-	-	-	-	3,850
	5,000	3,000	-	-	-	-	-	8,000
	940	300	-	800	-	-	-	2,040
	-	-	-	1,800	-	-	-	1,800
	10,500	21,000	-	16,200	-	600	900	49,200
	16,440	41,200	-	20,518	300	600	900	79,958

: 1996 12 2 , ()

2-9.

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					N F T D F T			
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	1,000	-	-	-	-	-	1,000
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	300	-	-	-	-	-	300
	-	-	-	-	-	-	-	-
	-	2,400	-	-	-	-	-	2,400
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	3,700	-	-	-	-	-	3,700

2-10.

(:)

					N F T	D F T		
	-	100	-	-	-	3,100	-	3,200
	-	-	-	-	900	-	-	900
	-	-	-	-	1,388	-	-	1,388
	-	-	-	-	850	-	-	850
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	1,500	1,500
	-	4,200	-	-	7,030	-	-	11,230
	-	750	-	300	300	-	-	1,350
	-	-	-	1,420	-	1,300	-	2,720
	-	3,800	-	-	-	-	-	3,800
	-	-	-	-	1,100	1,800	-	2,900
	-	-	-	-	-	-	-	-
	-	-	-	450	3,450	1,200	-	5,100
	300	-	-	-	-	5,520	-	5,820
	300	8,850	-	2,170	15,018	12,920	1,500	40,758

: 1996 12 2 , ()

2-6.

(:)

					N F T	D F T		
	-	-	-	-	-	1,800	-	1,800
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	1,760	-	-	1,150	-	-	2,910
	-	-	-	-	-	-	-	-
	-	-	-	550	-	-	-	550
	-	-	-	-	-	-	-	-
	-	-	-	-	300	-	-	300
	-	-	-	-	-	-	-	-
	-	-	-	-	350	-	-	350
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	1,760	-	550	1,800	1,800	-	5,910

2- 12.

(:)

					N F T D F T			
	-	-	-	-	-	1,200	-	1,200
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	600	-	-	-	-	450	1,050
	-	-	-	-	-	-	-	-
	-	11,870	-	-	1,150	-	-	13,020
	-	-	-	-	-	-	-	-
	-	600	-	1,280	-	-	-	1,880
	-	1,800	-	-	-	-	-	1,800
	-	-	-	-	-	-	-	-
	-	-	-	-	-	100	-	100
	-	1,400	-	600	10,746	2,400	-	15,146
	-	600	-	-	-	-	-	600
	-	-	-	-	-	-	-	-
	-	16,870	-	1,880	11,896	3,700	450	34,796

2- 13.

(:)

					N F T D F T			
	-	-	-	-	-	-	-	-
	6,500	-	-	-	-	-	-	6,500
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	1,800	-	-	-	-	-	1,800
	-	-	-	600	-	-	-	600
	21,700	8,350	-	-	-	-	-	30,050
	-	-	-	-	-	-	-	-
	700	900	-	-	-	-	-	1,600
	8,000	2,400	-	-	-	-	-	10,400
	44,860	-	-	-	-	-	-	44,860
	2,700	-	-	450	-	-	-	3,150
	2,700	-	-	-	-	-	-	2,700
	47,640	10,950	-	-	-	-	22,200	80,790
	-	-	-	500	-	-	800	1,300
	134,800	24,400	-	1,550	-	-	23,000	183,750

2-14.

(:)

					N F T D F T			
	-	-	-	-	-	-	-	-
	1,400	-	-	-	-	-	-	1,400
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	400	400
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	2,700	-	-	-	-	-	2,700
	-	-	-	-	-	-	-	-
	1,400	2,700	-	-	-	-	400	4,500

: 1996 12 2 , ()

2-15.

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					N F T D F T			
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	400	-	-	-	-	-	400
	-	-	-	-	-	-	-	-
	-	720	-	600	-	-	-	1,320
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	2,700	-	-	-	-	-	2,700
	1,800	7,000	-	-	-	-	-	8,800
	-	-	-	450	-	-	-	450
	-	-	-	-	-	-	-	-
	-	900	-	-	-	-	-	900
	-	-	-	700	-	-	-	700
	1,800	11,720	-	1,750	-	-	-	15,270

2-5

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2-6

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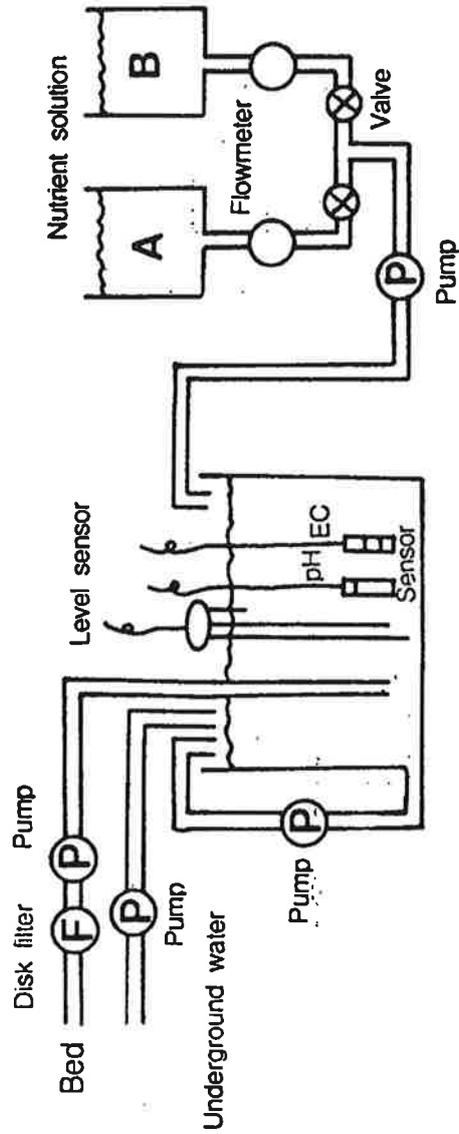


그림 2-1. 전남 무안군 봉탄면의 양액회석기(자가제작)

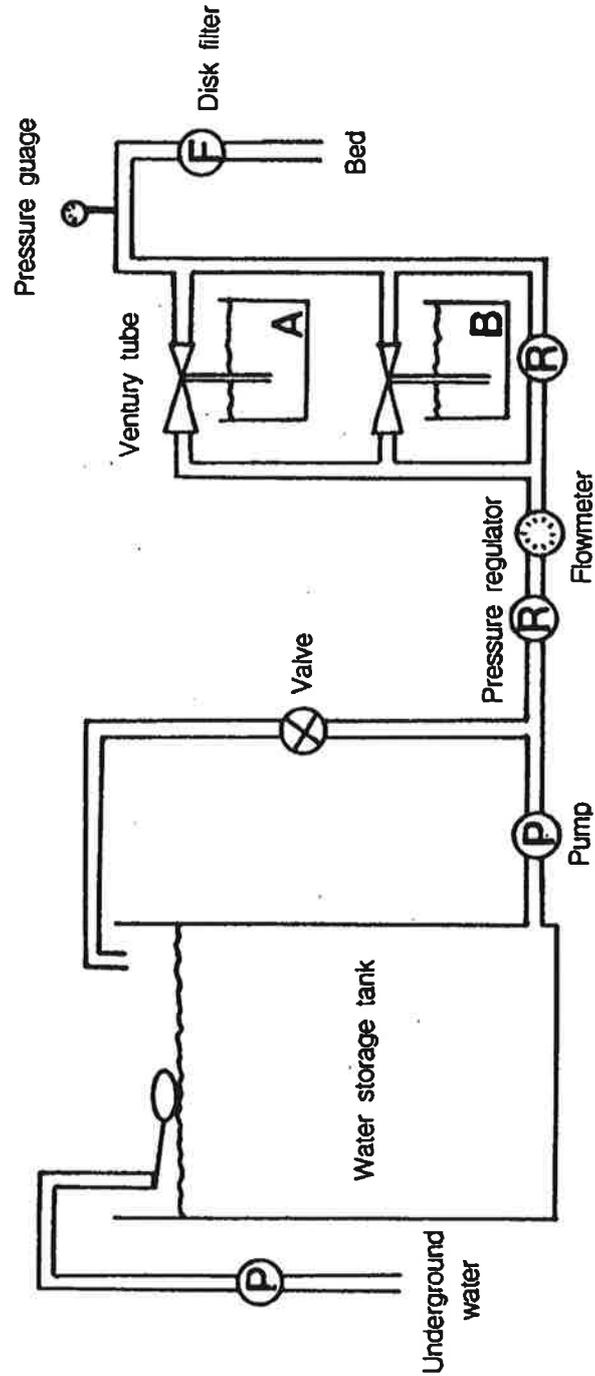


그림 2-2. 전남 구례군 구례읍 구례농고의 양액희석기(국산품)

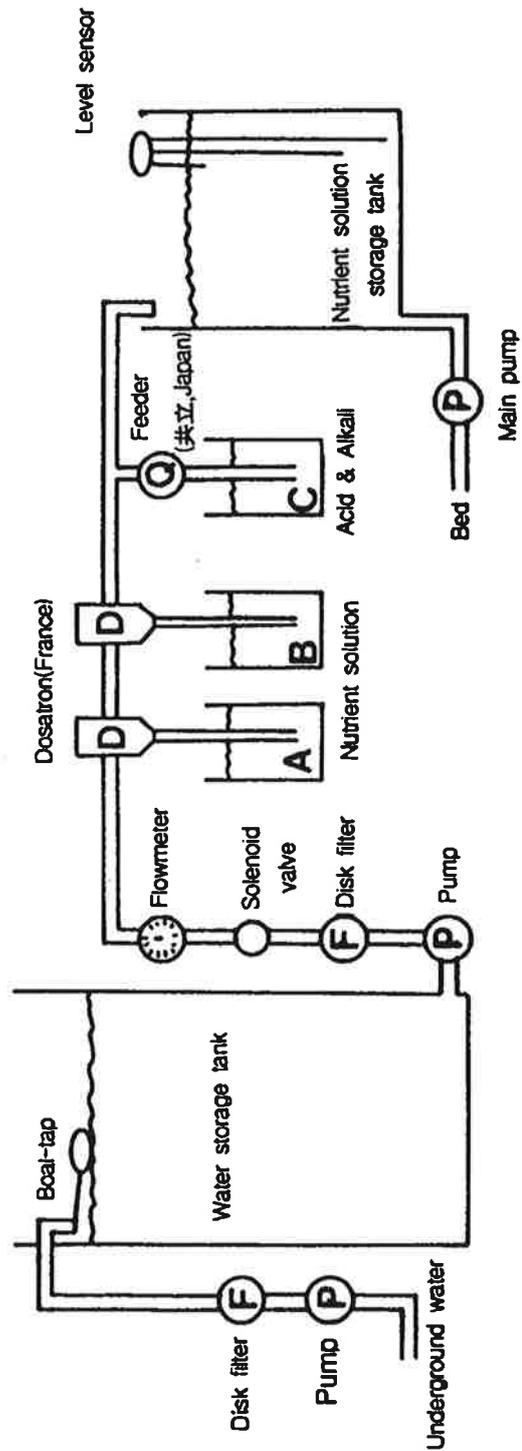


그림 2-3. 전남 장성군 장성읍 장성실고의 양액희석기(국산품)

2-2

가 . pH EC 가

. 가
, pH EC 가 .

B

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,
가 , A

가가

2-3

2-3

가 . pH

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2-4

1500

(, Topse)

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2-5

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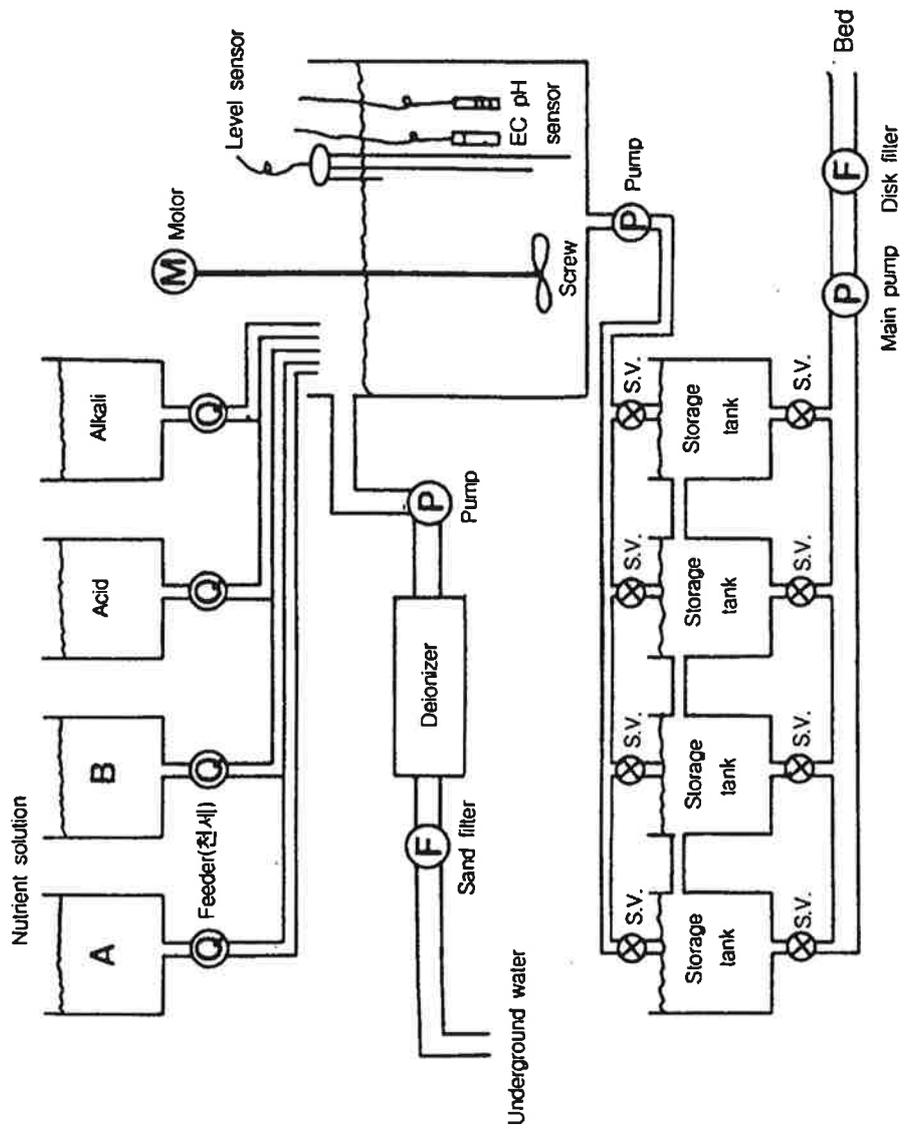


그림 2-4. 전남 영광군 영광읍 백수읍의 양액회석기

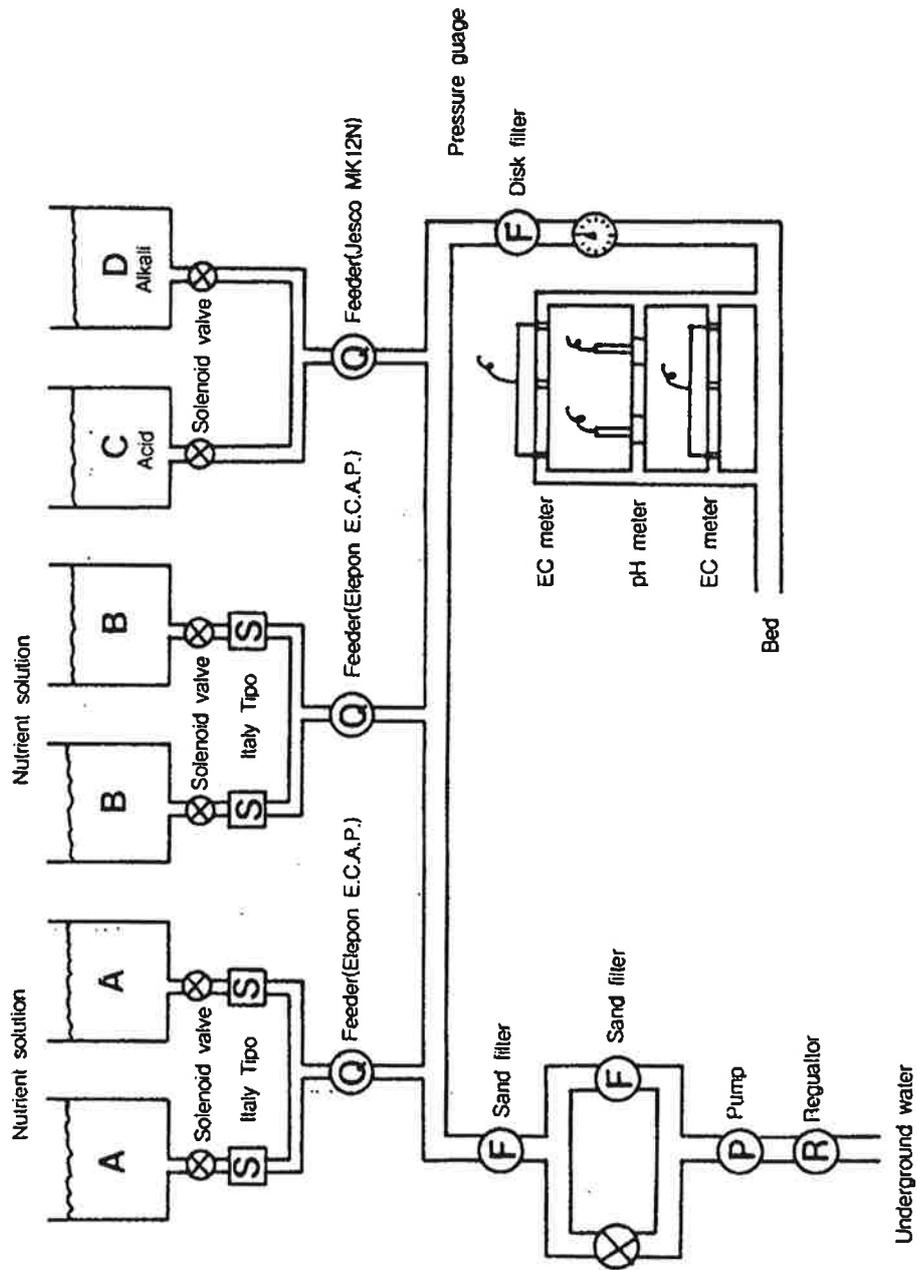


그림 2-5. 전남 광양시 금호동 농어촌진흥공사 광양은실의 양액회석기 개략도
(네델란드의 DACE사 제작)

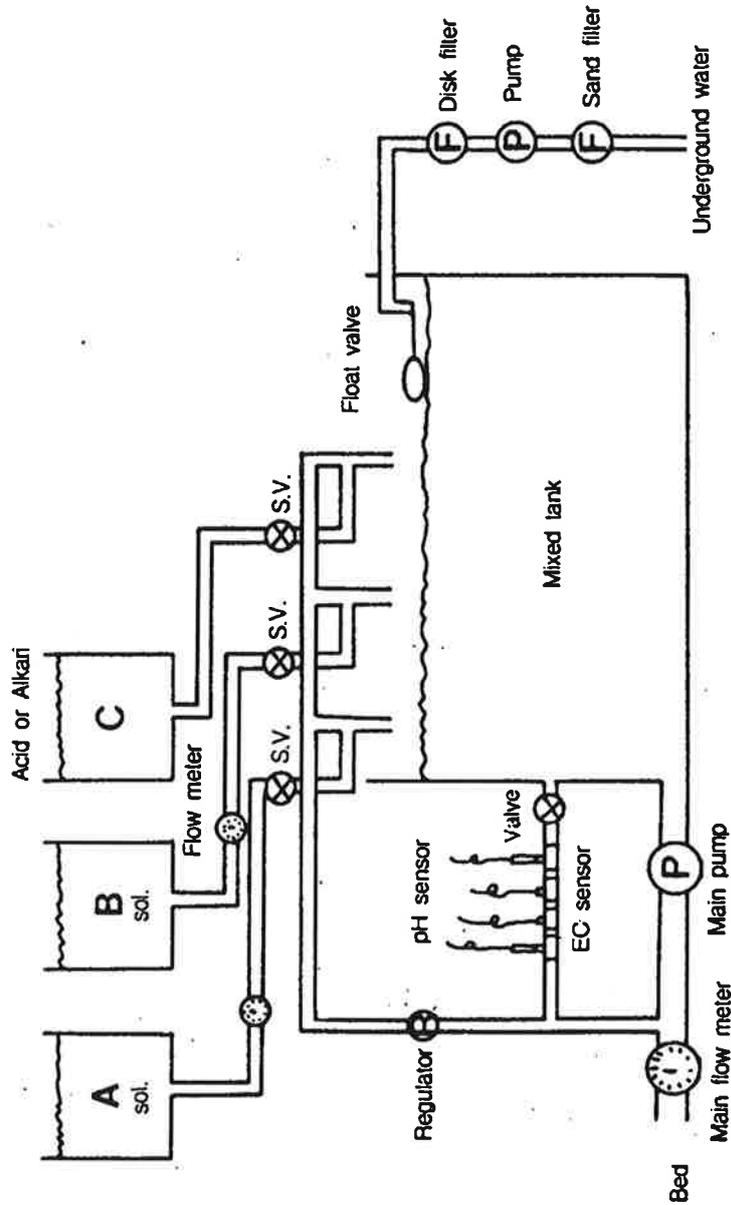


그림 2-6. 전남 광양시 진월면의 양액희석기
(네델란드의 P.v.d. Berg Techniek사 제작)

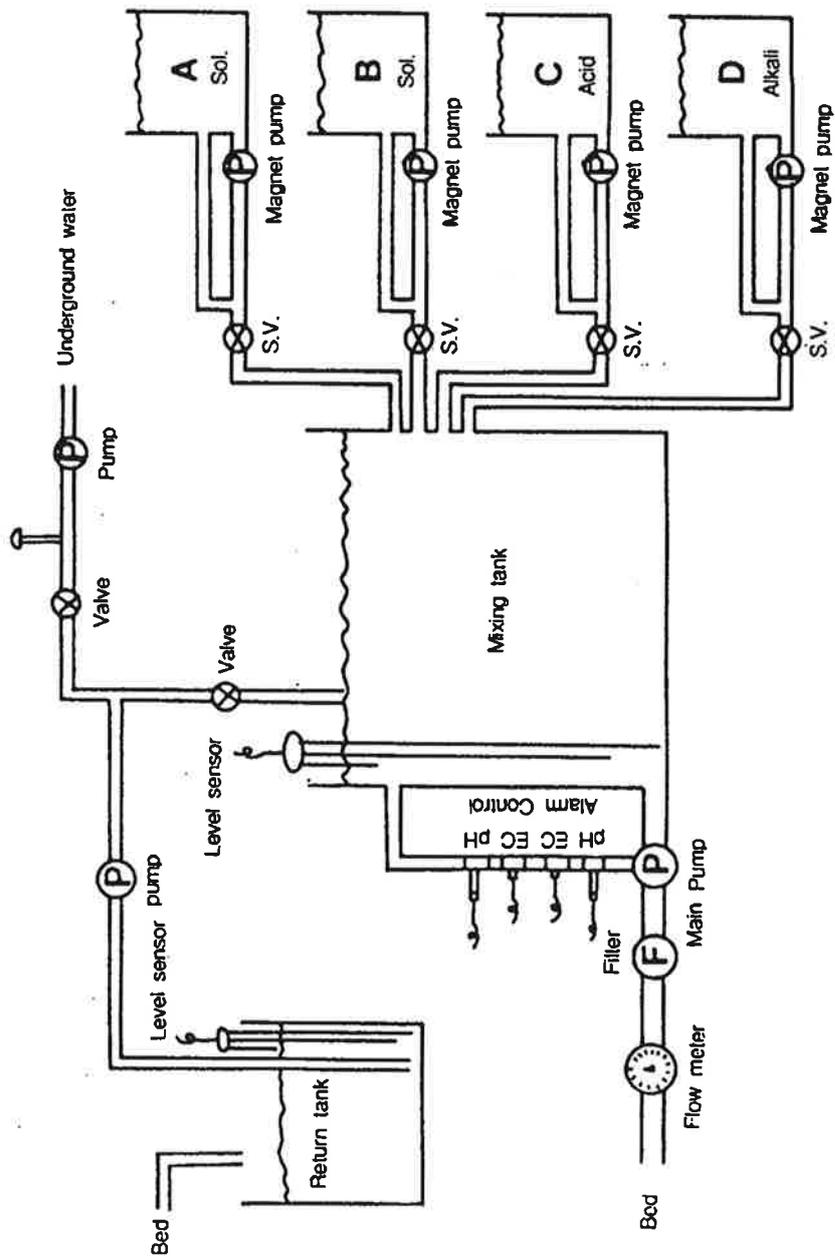


그림 2-7. 전남 나주시 산포면 산포농협육묘사업소의 양액회석기
(덴마크의 DGT-Volmatic사의 제작)

2-6

P.v.d. Berg Techniek가

2-5

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. pH EC

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Volmatic 가

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1. , , . 1993.
. 7 : 99- 112.
2. , . 1992. .
3. . 1988. (1). 1 : 88- 94.
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, EC, pH,

가
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, software

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2

1.

, pH,

가

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3

1

(detecting- transduction), 2

(signal conditioning), 3

(signal readout)

가

가

(transducer) , (detector) (sensor) .
1
1
가 . 1

2 가 1
가 가 .
(analog-to-digital conversion)

A/D 가 . 3
가

가

(least square method) (linear
regression equation)

, (), pH,

3-1

3-1.

	()		pH	
	()			
	0 50	0 20mS	pH 2 12	0 10ppm
	0.5- 1.0% F.S	0.5 2.0 mS/F.S	0.2 pH, 2% F.S	2% F.S 2% F.S
(90%)	30 -2			
			pH	
			, (: , :0.1N) pH	
	() 가			

EC, pH,

가.

가

가

가

가

thermostat()가

6

1

가

thermostat

15 25

4

pH(: $\text{pH} = \log 1[\text{H}^+]$)

(pH)

pH

pH

pH

5.5 6.5

pH가

KOH

NaOH ,

H₂SO₄

가

pH ()

pH가 2

pH

가

pH

pH

2% (), 5% (), 10% (

)
pH

가

pH 5.5 6.5

14

0.2 pH

2% FS,

10

pH 0

(electric conductivity : EC(mS/cm))

1cm²

1cm

. EC가

가

EC

가

(

)

가

가

가

가

가

가

가

0 20mS, () 0.5 2.0%FS, 10 가

2%/

가

가 가

2.

가.

EC

EC

가

:
가

EC가
EC sensor : EC sensor
monitoring

EC
EC
(100)
EC pH

EC sensor Ca⁺⁺, Mg⁺⁺
가 pH (6.0)
가

:

가 가

가
K⁺, NO₃⁻, Ca⁺⁺
K⁺, NO₃⁻, Ca⁺⁺
calibration 가 가
가 가

batch
가
가 가

가 가 , controller

:

- 가

ON-OFF : on-off
 . pH, EC - pH, EC,
 가 pH EC가
 pH EC Qd pH EC

$$Q = \begin{cases} Q_d \{1 - \exp(-t/T)\} & : t < L \\ 0 & : t < L \end{cases}$$

, L : , T :

ON/OFF

가 가 가
 ON/OFF (offset)
 가 가
 가 pH EC

a

$$a = Qd\{1 - \exp(-L/T)\}$$

PID : PID

offset

PID

e(t)

m(t)

$$m(t) = Kp\{e(t) + \frac{1}{TI} + \frac{1}{TI}\} e(t) + TD \frac{de(t)}{dt}$$

Kp : , TD : , TI :

, Kp : , Kp/TI : 가

PID

e(t)

$$m(k) = KP \{ e(k) + \frac{TS}{TI} \sum_{i=0}^k e(i) + \frac{TD}{TS} [e(k) - e(k-1)] \}$$

, m(k) e(k) t = kTS m(t) e(k)

$$m(k) - m(k-1)$$

$$m(k) = m(k-1) + e(k) + e(k-1) + e(k-2)$$

$$\begin{aligned} &= KP(1 + TS/TI + TD/TS) \\ &= -KP(1 + 2TD/TS) \\ &= KPTD/TS \end{aligned}$$

monitoring time

(adaptive) :

가

가

가

PID

가

가

가

가

offset

가

가 가

PID

3way valve

: ,

가

.

,

가
가

,

가

software

.

3

1.

가.

, , A/S ,

.

.

, , (),

.

2.

가. : (pH)

.

(combination

electrode)

가

.

Specication

.

- Display :

LCD

- Inputs :

pH electrode

RTD Pt 100 3 wires

- Output : 4/20 mA dc isolated
0.00/14.00 pH
- Temp. Compensation : manual or automatic
- Zero : adjustable +/- 15%
- Sensitivity(Span) : adjustable from 86% to 112%
- Input Current : < 2 pA
- Input Resistance : > 10 exp 12 Ohm
- Operating Temperature : 0/50
- Operating Humidity : 95% without condensation
- Power supply : 10/30 VDC
- Isolation : 500Volt Input to Output
- Terminal block : Detachable
- Net weight : 200g
- Mounting : DIN Rail mountable

pH sensor 2

. pH EC sensor
by-pass

. : (EC)

가

가

(EC)가

hA

가

sensor

- Display : LCD
- Input : 2- electrodes EC cell
4- electrodes EC cell
RTD Pt100 2 wire
- Output : 4/20 mA isolated
- Scales : 0/200.0 μ S - 0/2000 μ S 0/20 mS
- 10.0/120.0
- Temp. Compansation : manual or automatic
- Temp. Com. Coefficient : 0/4.0 %/ adjustable
- Temp. Com. Reference : 20
- Zero : adjustable +/- 15%
- Slope : adjustable 86/112 % narrow range
adjustable 0/160 % wide range
- Operating Temperature : 0/50
- Operating Humidity : 95% without condensation
- Power supply : 10/30VDC
- Isolation : 500 Volt Input to Output
- Terminal block : Detachable

2 sensor

EC

EC

EC

가

- : DC 24V
- : < 1.2VA
- I() : UA = DC 0 - 10V = 0 - 10klux, 1Amax 5mA
- II() : UA = DC 0 - 10V = 0 - 100klux, 1Amax 5mA
- : 100µsec (10-90%)

A, B,

가

가

(PM- 015NM)

3 way valve

3- 1

3- 2

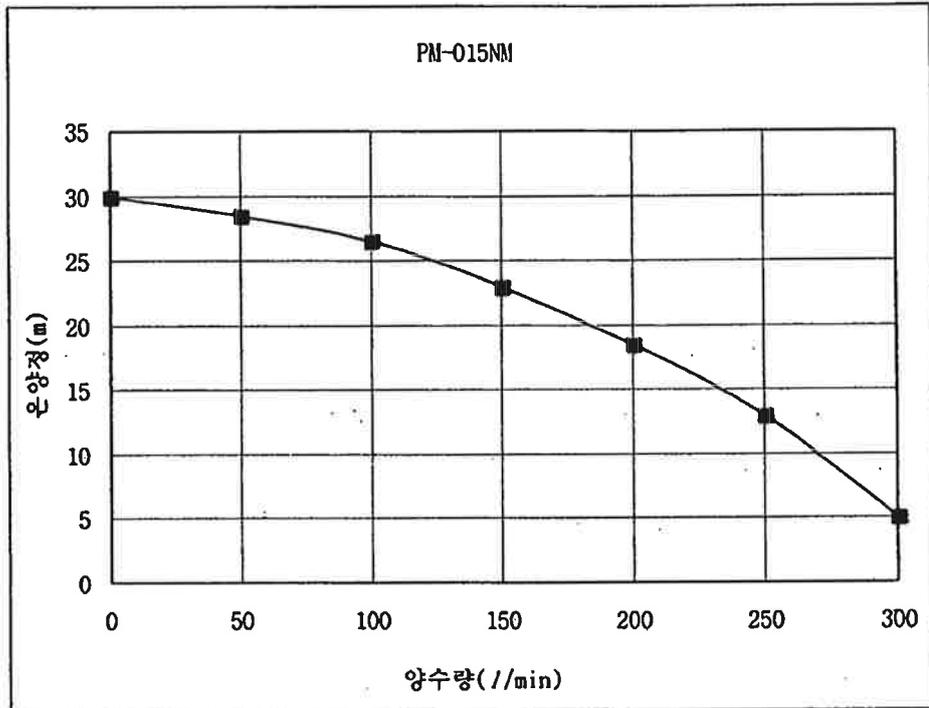


그림 3-1. 액비펌프의 온양정에 따른 양수량 측정

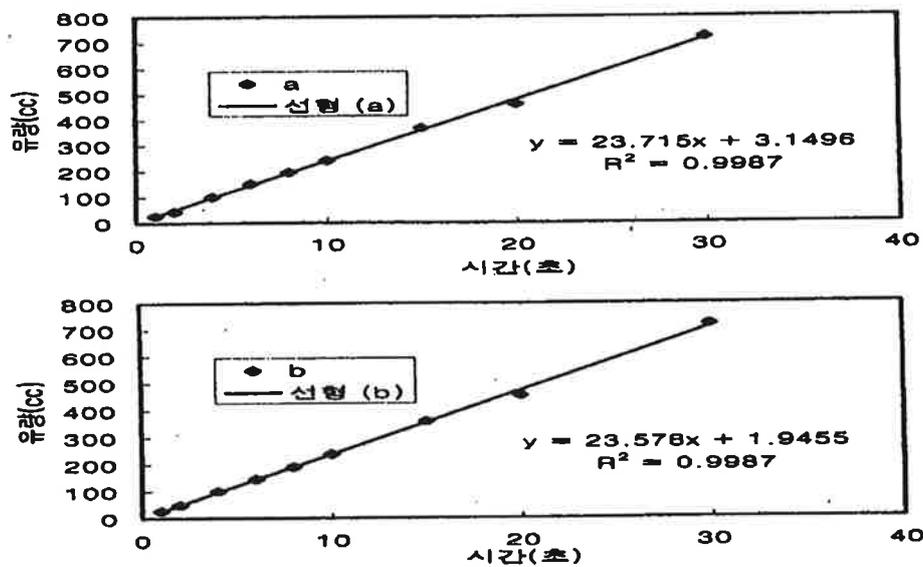
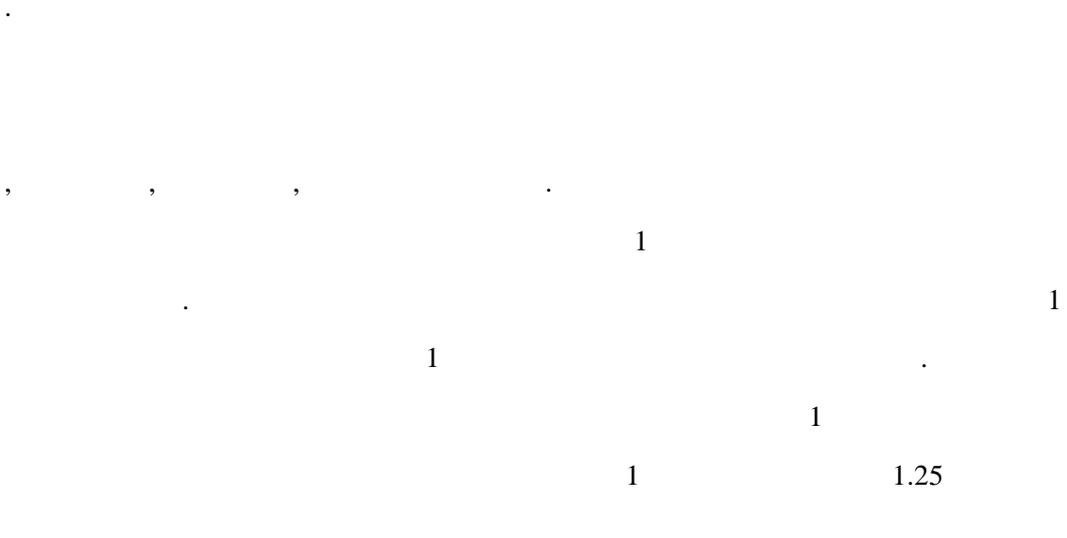


그림 3-2. 액비펌프(PM-015NM)와 3way valve를 결합시켰을 때 작동시간에 따른 유량

- 가
- ,
- 가
- ,
- : 0.5 10kg/cm2
- : ±2% ()
- : 10l, 100l, 1000l,
- : 24V AC(60Hz)
- : 0.4amp(inrush), 0.20amp(holding)
- block ()

- main
- ,
- ,
-
- controller
-
-
- : 0.7 - 10kg/cm2

- : 24V AC(60Hz)
- : 0.40amp(in- rush), 0.20amp(holding)



$$= \frac{\times \times}{(\quad) \quad 1} \times 1.25$$

가

. Main pump

1

1

220V

AC

5000l

가

pH EC

EC pH

가 , 2 3

가

data

3-3

3-3,

3-4

, pH EC

controller

one-board chip

controller

○

pH EC

○

(IC)

PC

(ROM)

(RAM)

- EC pH .
- main pump main valve(1), (2), (3), (3), 2 16
- , 32 가 가 .
- data
- PC , data 가 .
- .
- , , ,
- : 220V AC 60Hz
- 12V RAM
- : 8 , 3 , On/Off 5 , Analog (4 20mA) 4
- : , , , IBM PC,

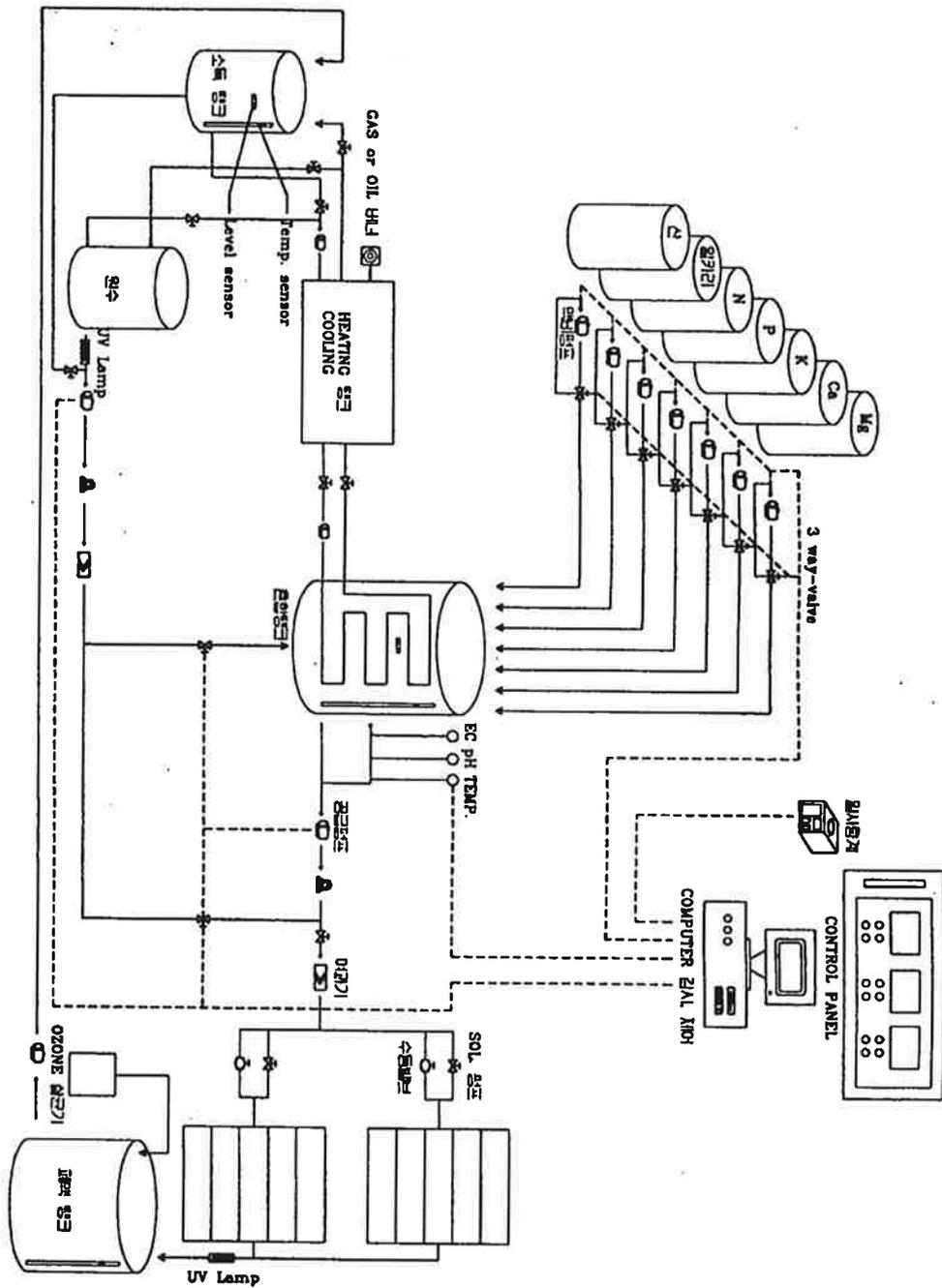


그림 3-3. 양액회석기의 모식도

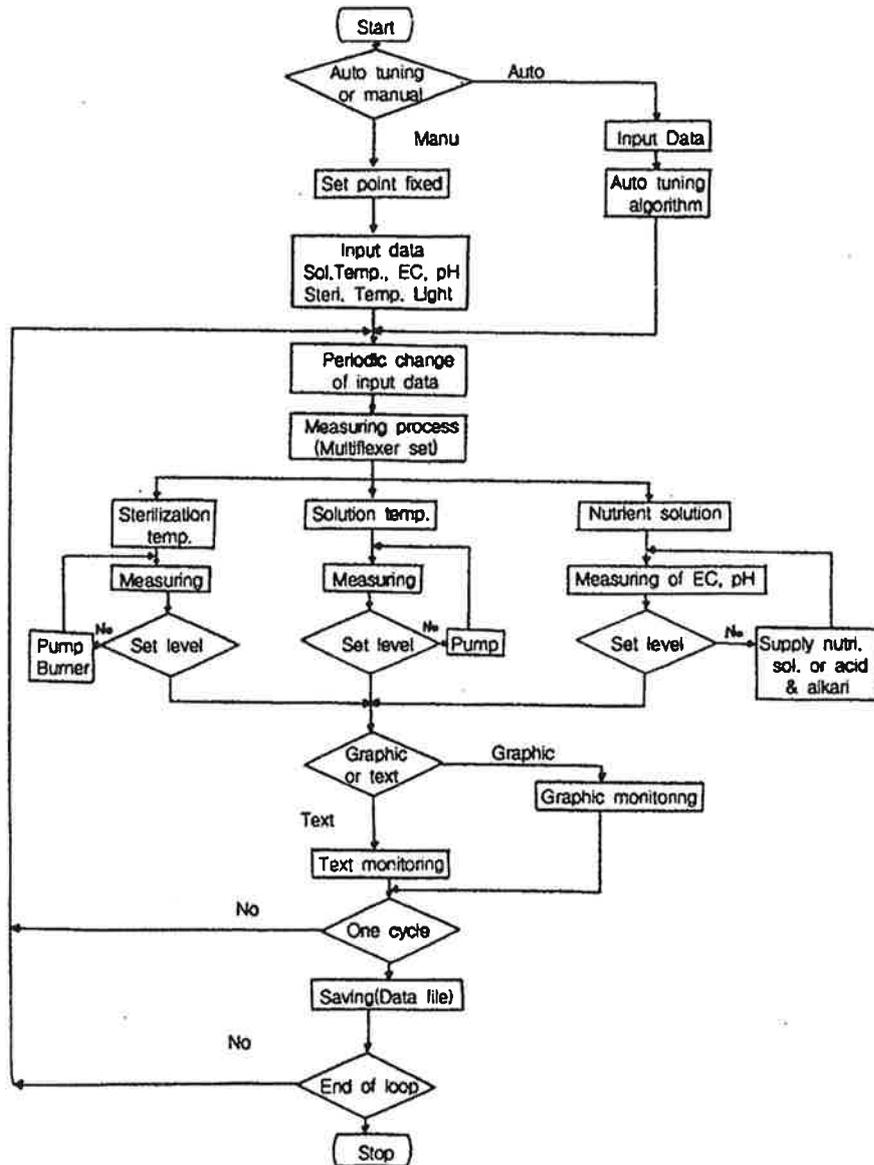


그림 3-4. 양액희석기, 양액살균기 및 양액온도조절기의 제어 흐름도

1. . 1992. (I).
1 : 93- 97.
2. . 1993. . 2 : 147- 149.
3. . 1995. - - .
4. . 1991. .
5. 伊東 正. 1988. 植物の工場的生産への實際的アプロ-チ. 農業および園藝 61 別策. 養液栽培新技術 : 94- 100.
6. 橋本 康 外. 1988. 植物工場システムとは. 農業および園藝 61 別策. 養液栽培新技術 : 89- 93.
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9. 日本施設園藝協會. 1991. 施設園藝における高度集約生産システムの課題と今後の方向- 野菜の工場的生産の可能性- .
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12. Cooper, A.J. 1979. The ABC of NFT. Grower Books.
13. Donald J. Pitts, A. James, et al. 1986. Trickle irrigation lateral line design by computer analysis, Transactions of the ASAE 29 : 1320-1324.
14. Hisao Anyoji and I-pai Wu. 1987. Statistical approach for drip lateral design. Transactions of the ASAE 30 : 187-192.
15. Hollis, P. and R.W. Hindmarch. 1980. A microcomputer controlled farm management system. Transactions of the ASAE 35 : 35-37.
16. Kenneth H. Solomon. 1985. Global uniformity of trickle irrigation systems. Transactions of the ASAE 28 : 1151-1158.
17. Numan, M., and E. Gordon. 1989. Emmitter discharge evaluation of subsurface trickle irrigation systems. Transactions of the ASAE 32 : 1223-1228.
18. Yasushi Hashimoto, Gerard P.A. Boot, W. Day, H.J. Tantau and Hiroshi Nonami. 1993. The computerized greenhouse. Academic Press, Inc.

4

1

가

29 32.7

16 22

가

가

가

藤井 (1968)

(1982)

16

2

8

가

가

Morgan (1978)

20/17

20/12.2

25.5

가

가

가 , Jones (1978)

가

가

30

30 가

. Gosselin (1983)

가

가

20

150 200 μ l O₂/g(fresh root)/hour가

QI(=2가

30

300

400 μ l O₂가

100g

20

10I

4.3

30

1.8

cytokinin

abscisic acid

25

가

가

가

1 2

12

3

가

가

24

22

가

가

22

가

24

2

22

가

가

가

가

15 , 18

NFT

가

가

가

NFT

가

가

가 18

, 19

21

가

3%

가 가

가

가

가

15

가

가

30

가

. NFT

가가

가

25

가

가

,

가

가

가

25

가

25

가

가

가

가

(南 等, 1992)

가

30

24

1.5

가

가

2

1. 가

가

가. 가

- : SUS 27 (304) 1.5 t
- : 2.32m²
- : 40W, 220V, 1/18HP(3600l/h)

-
- :
- .
- : PE(XL pipe) stainless
- : 6.28m²/100m
- .

- 가 : 80,000 kal/h
- : 90 95%
- : 10.3 l/h
- : 220V
- : 1 Kw/h
- :
- :

2.

가 .
 가 가 .
 compressor .

3

가 .
가 가 .

NFT

가

가 가 .
가 가

가 가
가 가

electric heating bar

가

가

가 가
on-off thermostat

가 가 , 가 가
가 가 가

XL pipe PE

. PE pipe(100m, 6.28m²)
65

146,952 kcal/m² · hr

8,980,400 kcal/m² · hr가

가 가

LPG

가 가

5

가 가 (가 6

0 95)

30

15 17

가

- 가 가

- 가

- 가

- 가 20 40 가

-

- 냉각시 지하수를 순환시켜 냉각하며 24~28℃범위로 유지할 수 있다.

개발된 양액온도조절기의 사진과 개략적 모식도는 다음과 같다.

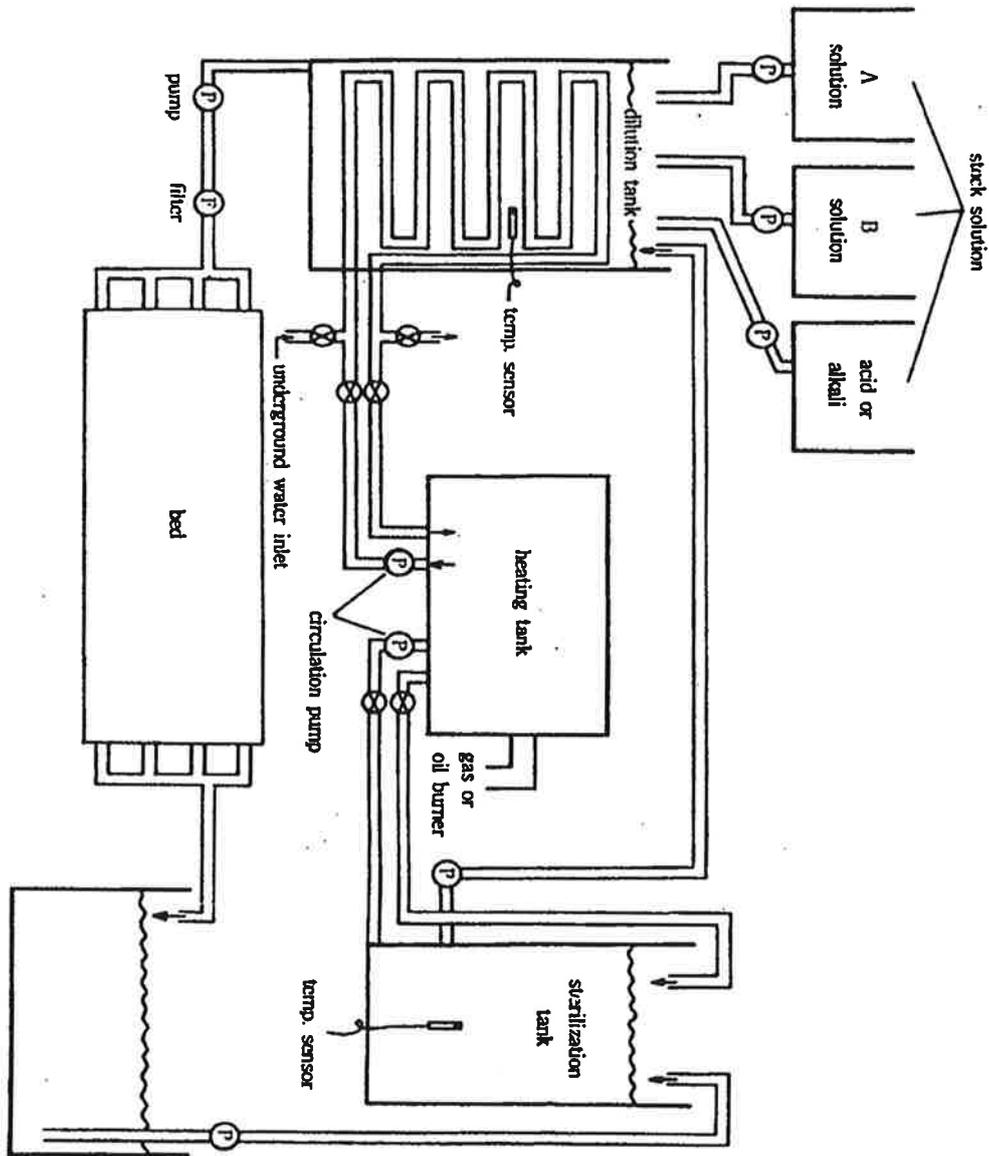


그림 4-1. 양액온도조절기와 가열살균기의 개략도

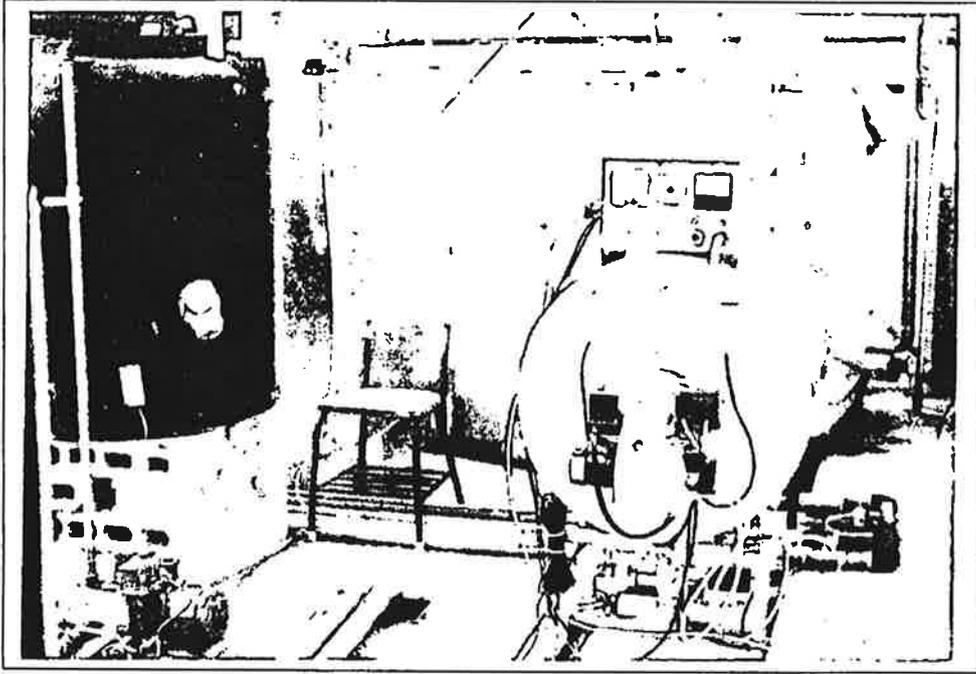


사진 4-1. 가열탱크 및 가열기의 모습

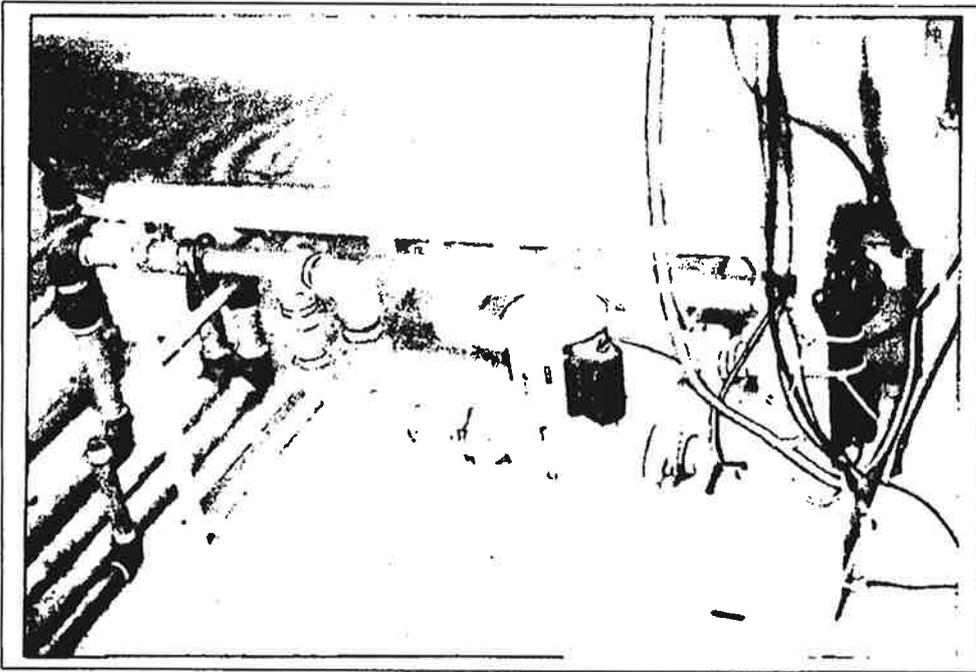


사진 4-2. 가열탱크 하부의 순환모터 설치모습

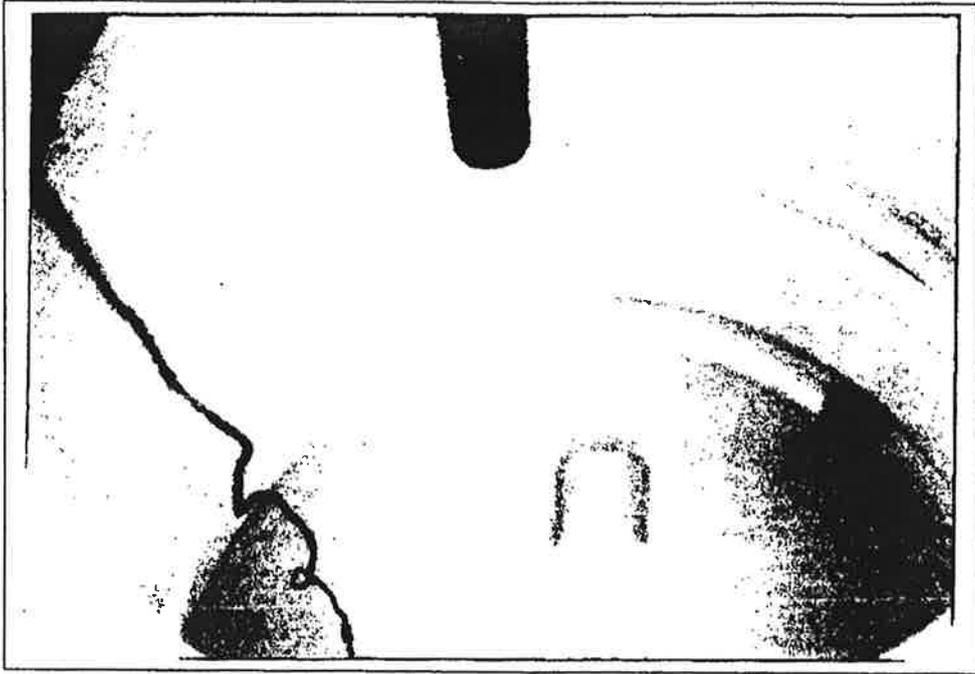


사진 4-3. 양액회석탱크내 열교환파이프의 모습

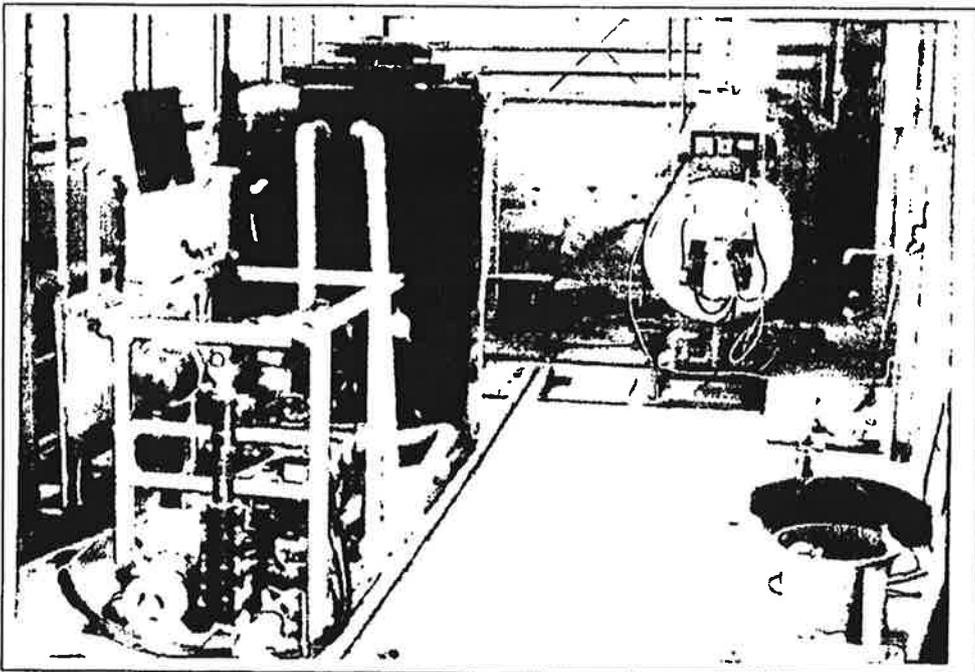


사진 4-4. 온도조절기의 전체적 모습

1. 橋本 康, 高汁正基. 1992. 植物の工場的生産への実践的アプローチ. 農業および園藝 17 : 97- 104.
2. 橋本 康, 高汁正基. 1993. 植物の工場的生産への実践的アプローチ. 農業および園藝 2 : 1- 8.
3. 橋本 康, 高汁正基, 藤井健雄, 伊東 正. 1995. 施設園藝の環境調節 新技術 - 基礎と展望 -. pp. 59- 117.
4. 橋 昌司. 1986. 養液栽培における環境要因と根の機能. 農業および園藝 61 : 223- 228.
5. 藤井健雄, 伊東 正. 1968. 千葉大園學報 10 : 59- 70.
6. 古在豊樹. 1985. 施設園藝の環境調節 新技術 - 基礎と展望 -. pp. 59- 117.
7. 橋本 康, 高汁正基. 植物の工場的生産への実践的アプローチ. 農業および園藝 62 : 86- 90.
8. 吉野 實. 1985. 野菜工場の栽培環境と作物生育. 農業および園藝 60 : 1213- 1216.
9. 高橋英紀. 1972. 農耕地における熱的現象の模型実験. 日本農業氣象. 28(1) : 19- 22.
10. Gosselin, A. and M.J.Trudal. 1986. Root- zone temperature effects on pepper. J. Amer. Soc. Hort. Sci. 111(27):220- 224.

11. Kitaya, Y. T. Imanaka, M. Kiyota, and I. Aiga. 1988. Advantageous arrangement of plants in a plant factory- cultivation of lettuce suspended upside down. *Acta Hort.* 230 : 271- 278.
12. Kuo, B.C. 1987. *Automatic control systems*, 5th ed., pp. 721. Prentice- Hall, Inc.
13. Mastalerz, J.W. 1978. *The greenhouse environment*. John Wiley and Sons.
14. McLendon, B.D., R.B.Dodd and J.M.Allison. 1981. Panel heating using polyvinyl chloride pipe(PVC). *Trans. of the ASAE* 24 : 1287- 1290.
15. Matsuoka, T. and H. Suhardiyanto. 1992. Thermal and flowering aspects of growing petty tomato in cooled NFT solution during summer. *Environ. Control in Biol.* 30:119- 125.
16. Morgan, J.V., A.T.Moustage, and A.Tan. 1980. Factors affecting the growing-on stage of lettuce and chrysanthemum in nutrient solution culture. *Acta Hort.* 98:253- 261.
17. Okada, M. 1990. The heating load of greenhouse. *J. Agri. Met.* 35 : 235- 242.
19. Rudd- Jones, D. and G.W.Winsor. 1978. Environmental control in the root zone : Nutrient film culture. *Acta Hort.* 87:185- 195.

1

가 , , .

가 (神納,1966) 가 , , , .

가 , .

가 , .

가

가 가 2000

(closed recycling system)

(PTG)

가

(green mottle mosaic virus ; CGMMV),

(tomato mosaic virus ; ToMV),
 virus ; TNV), big vein virus agent(LBVA)
 (Paludan, 1985).

(tobacco necrosis
 TNV LBVA가

Olpidium brassicae()

, NFT

LBVA 99- 100%
 Faithfull 1979).

(Tomlinson and

Phytophthora cryptogea

,

(Wohanka, 1990a).

Fusarium

oxysporum j. sp radicis- lycopersici
 1991).

(Rattink,

가

60 10

10

가 70

. 가

Runia(1988)

가 10

Verticillium 83 , TMV 97

95 30

가

virus> > >

가

pH 4 (However Farooq et al., 1977).

가 10g 1m2
 1 가 5-1 ,
 UV
 가

5-1. 20g (1)

()		
0	560	33,200
10	-	10,800
15	206	-
30	3	104
45	2	-
60	0	76

UV(ultra- violet) 100- 400nm . 200- 280nm
 UV 가 , 253.7nm
 가 가 (Gelzhauser , 1985). 2가
 UV 가 200- 280nm
 253.7nm (10% UV)
 (40% UV) . UV
 0.4- 0.8mm
 10mJ/cm2 UV 가

250mJ/cm2

(Runia

1994).

(membrane)

(microfiltration membrane)

가

(*Phytophthora*)

(*Fusarium*)

3-7m

90cm

Ceramic

4m

100%

가

가

(iodine)

가

0.7ppm

가

(hydrogen peroxide)

가

400ppm

99.97%

가

()

가

, 가 ,

2 가

1.

3가 . 가 ,
(*Phytophthora*), (*Pythium*), (*Fusarium*)
가 ,
Phytophthora, Pythium

, 가 ,

가

(長紅,1980).

(宮田 ,

1972a,b) ,

(*Pythium*)

(草刈・田中,1986).

가

가 .

가

가

2.

가. 가

가 . main pipe 가

가 main pipe 가 가 가 . 가

(500l)

가 .

가

160l .

가 가 가 . 가

가 95 97 가

. 가 1

. 가 ,

(XL- pipe, 16mm, 100m, 62.8m2) .
thermostat on- off 가

. 가

(1) 가

- : SUS 27 (304) 1.5 t
- : 2.32m²
- : 40W, 220V, 1/18HP(3600l/h)
-
- :

(2)

- : PE(XL pipe) stainless
- : 6.28m²/100m

(3)

- 가 : 80,000 kal/h
- : 90 95%
- : 10.3 l/h
- : 220V
- : 1 Kw/h
- :
- :

.

가

(*Pseudomonas*

solanacearum) glucose가 가

가 3x10⁴cfu/ml

50 80

. 300ml 3 10 50ml
5 120 .
7 , 25 .

(*Fusarium oxysporum* f. sp. *radicis lycopersici*) PDA

3
가 2cm 5ml
10 50 90
Fusarium 20 30
10 .

2 (30x30x7.5cm)

가
300ml 6 50ml 95 , 1 가
가 (IC- 500,
Dionex, USA) .

3.

가. 가

가 1 20 가
가 95, 85, 75, 65 55 5.7, 5.9, 6.1, 6.4

7.1(I/) .

80, 78, 76, 74 70%

, 2

45

.

5-2.

가

()	()				
	5	10	20	30	60
50	+	+	-	-	-
60	+	-	-	-	-
70	-	-	-	-	-
80	-	-	-	-	-

2×10^4 cfu/ml + - :

5-3.

가

()	()					
	3	5	10	20	30	60
50	10*	10	10	10	10	10
60	10	10	6	4	2	0
70	2	1	0	0	0	0
80	0	0	0	0	0	0
90	0	0	0	0	0	0

* 가 10

50

(5-2) 60 10

70 5

가

1

. 60 30

70

50

10

, 80 3 .(5-3)

. 가

5-4 . 가

NO₃-N, K, Ca 가 95 ,

1 가 , 가

5-4. 가

(:%, mS/cm, ppm)

	EC	NO ₃ -N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu
가	1.7	207	0	296	125	27	26	2.72	1.73	0.13	0.12
가	1.9	209	0	313	128	28	27	2.58	1.65	0.18	0.11
/ x100		(101)		(106)	(102)	(103)	(102)	(95)	(95)	(138)	(92)
가											
가	2.7	309	23	406	185	58	52	3.26	1.89	0.66	0.76
가	2.9	334	25	464	193	60	48	3.50	1.85	1.63	0.78
/ x100		(108)	(109)	(114)	(104)	(103)	(92)	(107)	(98)	(96)	(103)

95 1 가

1.

100 400nm 200
 400nm(short- wave) UV 253.7nm
 가 (Gelzhausen, 1985). UV- C
Giardia cysts
 150mJ/cm² 20 25mJ/cm²
 (Bernard, 1991). UV
 가 . 가 430mJ/cm²
Fusarium 가 100% ,
Verticillium 74%
 (Runia,1991).

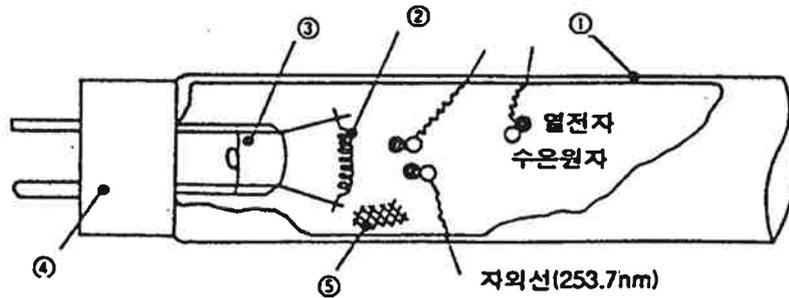
2.

가.

(1) UV

(253.7nm)
 , (emitter;
 Br, Sr, Ca 가)가 .
 가

가스와 다른 불활성가스와 혼합하여 만든다.



1. 자외선 투과 유리 2. 전극 3. Stem 4. 소켓연결구 5. 아르곤가스

그림 5-1. 살균램프의 구조

(2) 온도특성

살균램프에 봉입되어 있는 수은의 증기압이 주위온도, 램프전류 등에 의해 변화되어 램프에서의 자외선 방사강도가 변화된다. 일반적으로는 주위온도가 20~22℃, 램프관벽온도 40℃전후에서 자외선 방사강도가 최고로 된다.

(3) 자외선램프에서의 자외선 발생의 원리와 살균

양단의 전류를 보내어 전극을 예열시키고, 발열자로 부터 열전자를 방출시켜, 아르곤가스를 매개로 방전(점등)시키는 원리이다. 방전에 의해 관내에 흐르는 전자는 포화상태의 수은증기에 급격히 충돌하여 수은공명선으로 253.7nm의 파장을 발생한다. 살균램프는 253.7nm의 자외선을 사용함으로써 살균작용에 이용되며, 관내에 발생된 자외선을 자외선투과율이 높은 특수한 유리 또는 투명석

(4)

253.7nm
3.2W × 2) , 15W
2 (15W × 2;

38mm

가 가 가

AL pvc

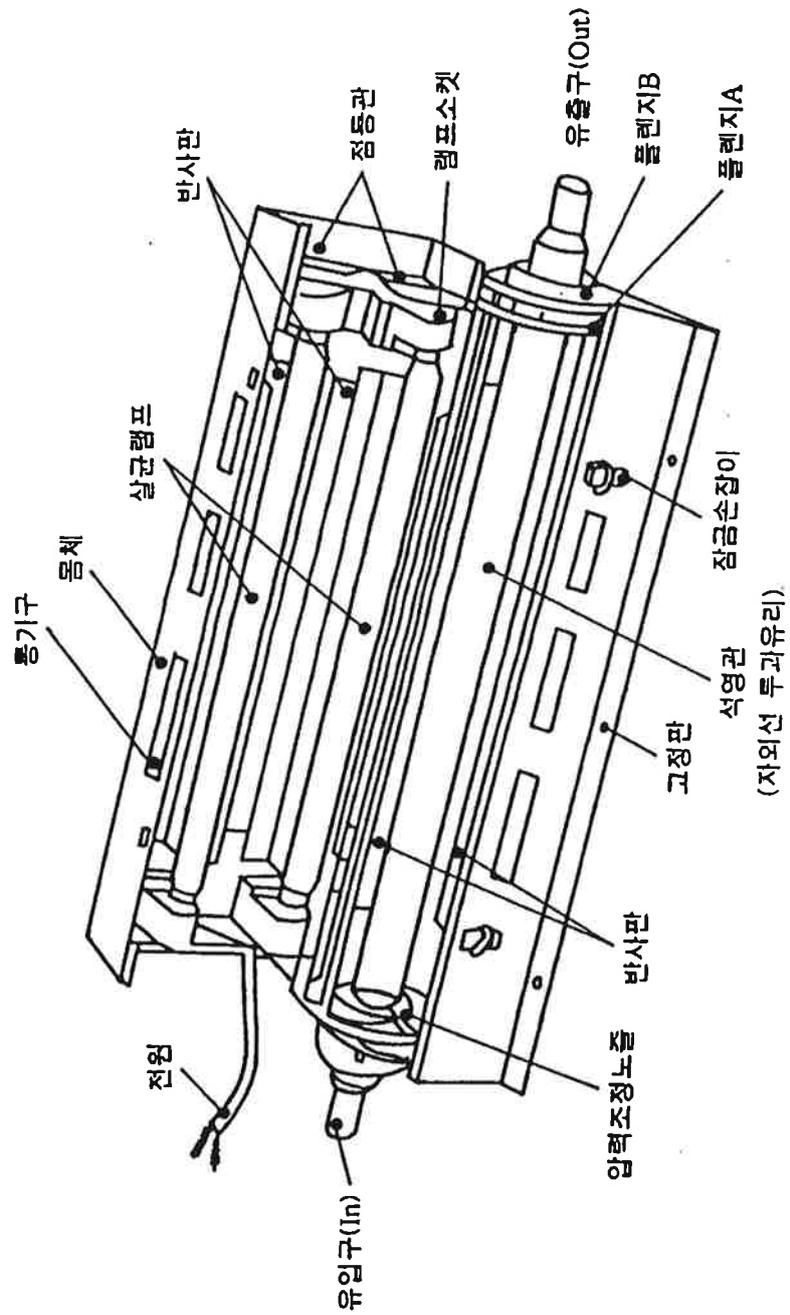


그림 5-2. 자외선 살균기의 구조도

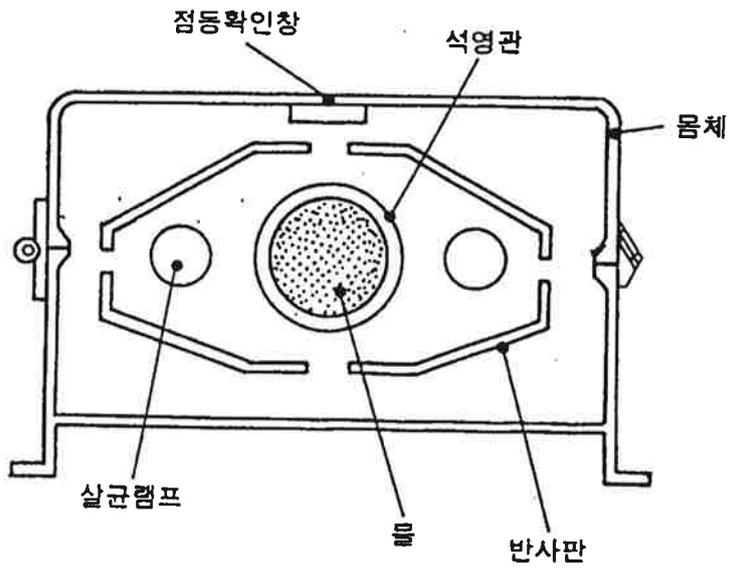


그림 5-3. 자외선 살균기의 단면도

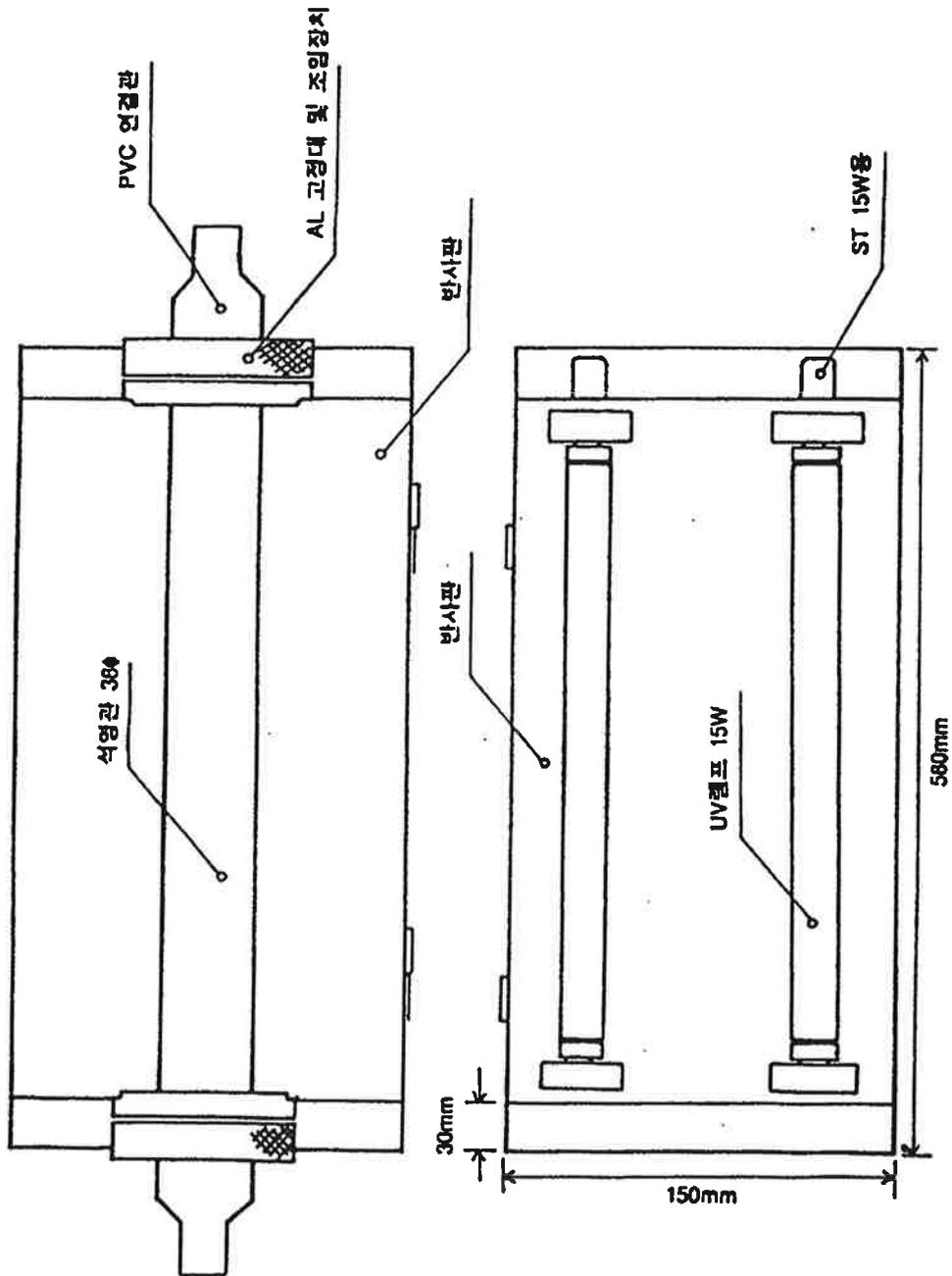


그림 5-4. 자외선 살균기의 평면도

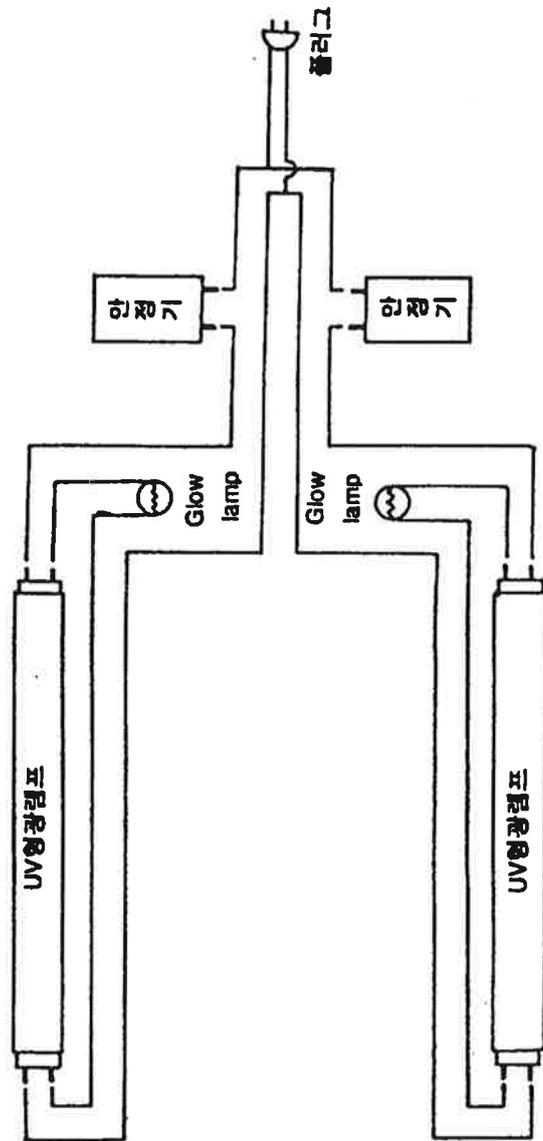


그림 5-5. 자외선 살균기의 배선도

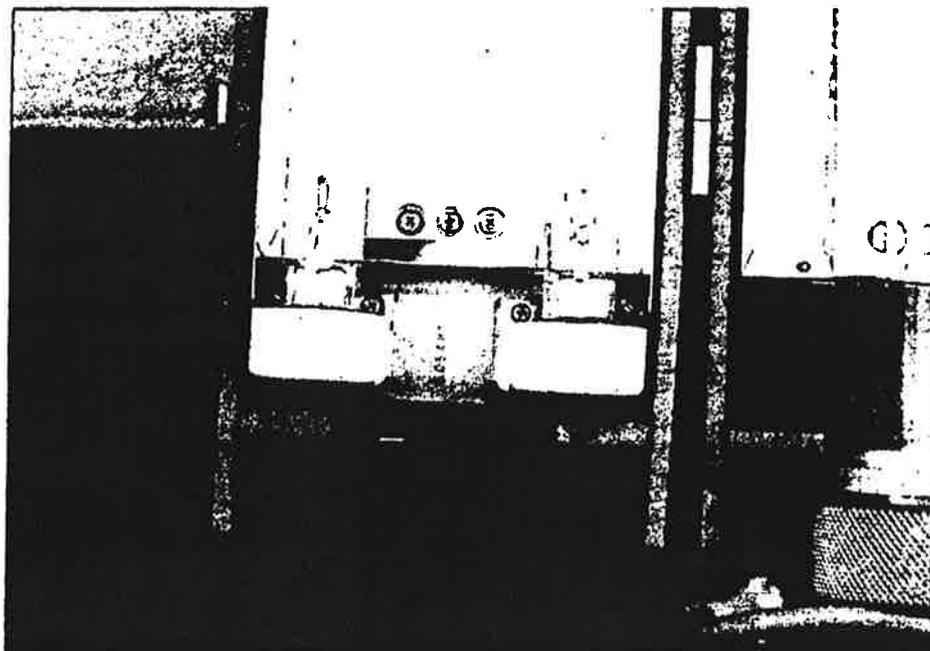


사진 5-1. 자외선 살균기의 시제품의 램프 소켓 배열

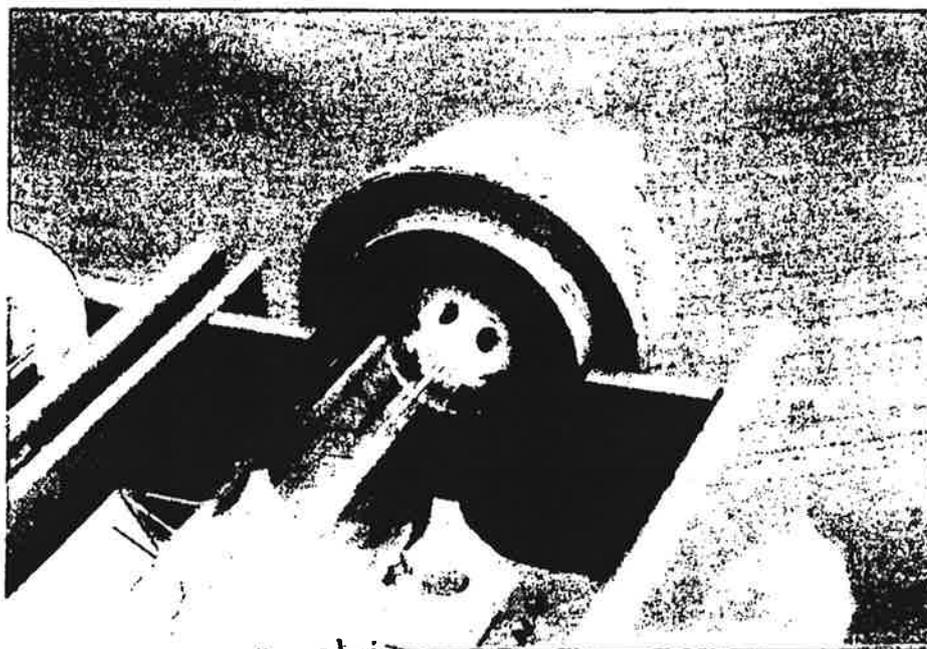


사진 5-2. 자외선 살균기의 시제품의 석영관 실링 장치

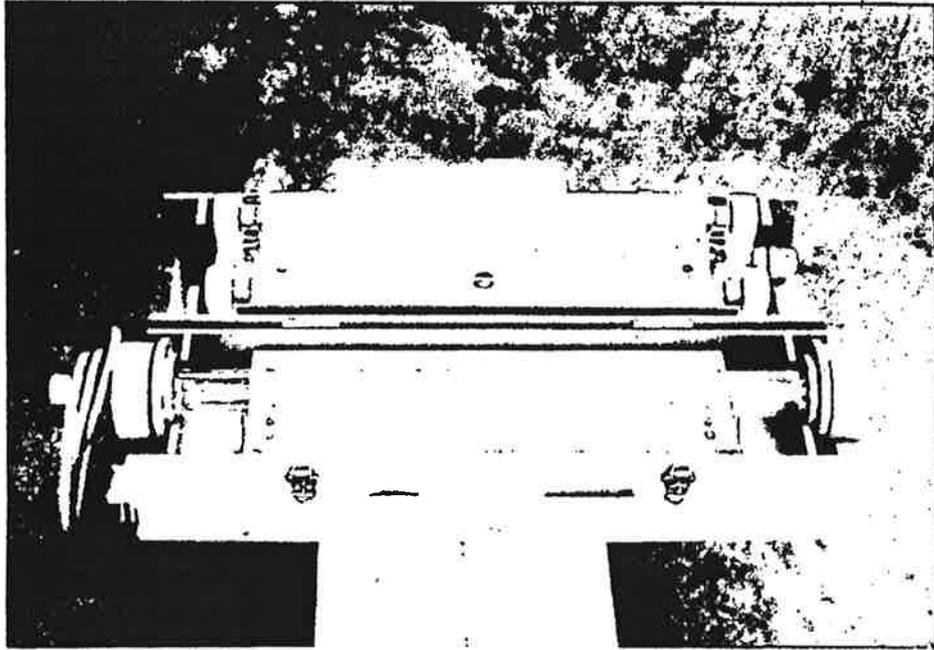


사진 5-3. 자외선 살균기의 시제품

3. 개발결과

가. 자외선 살균효과

자외선의 살균효과는 조사에너지에 비례한다. 미생물이 어느정도의 조사에너지에 사멸하는 가는 작물의 종류와 생육단계, 조사되는 기관에 대해 다르고, 일반적으로 세균에서는 낮고, 사상균에서는 높으며, 세균에서도 아포를 형성하는 종에서는 높은 조사 에너지가 필요로 한다. 미생물을 살균하는데 필요한 자외선 양은 자외선 램프를 일정 거리에 설치하고, 조도, 조사시간과 미생물의 생존을 조사하는 것으로 측정된다. 표 5-5는 미생물의 사멸에 필요한 자외선량으로

Bacillus, Pseudomonas

Penicillium, Aspergillus 20,000 40,000uw · s/cm²,
(山崎,1986).

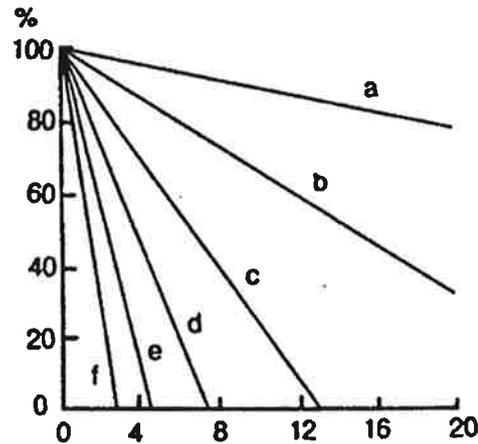
Saprolegnia, Achilia, Aphanomycets 200 × 10³hw ·
s/cm², 30 49 × 10³hw · s/cm² (木村, 1980).
120 × 10³hw · s/cm², 360 × 10³hw · s/cm²
(袁原, 1974).

5- 5.

	a(uw · s/cm ²)
<i>Bacillus subkilis</i>	11,000
<i>B. subtilis(spore)</i>	22,000
<i>Corynebacterium diphtheriae</i>	6,500
<i>Pseudomonas aeruginosa</i>	10,500
<i>P. fluorescens</i>	6,600
<i>Salmonella sp.</i>	10,000
<i>Saccharomyces cellipsoideus</i>	13,200
<i>Penicillium roqueforti</i>	26,400
<i>Aspergillus flavus</i>	99,000
<i>Asp. niger</i>	330,000
<i>Mucor racemosus</i>	35,200
<i>Oospore lactis</i>	11,000

(hw/cm²) ()

,
, () ,
.
가 (5- 6).



a : 중류수 d : 소독하지 않는 우물물
 b : 열수 e : 작물재배용 양액
 c : 일반수돗물 f : 양어장에서 재순환된 깨끗한 물

그림 5-6. 여러가지 액체에 대한 자외선 침투깊이

제작된 자외선 살균기의 성능 검사를 하기 위해 담액재배조(100l)를 스티로폼으로 제작하였고 자외선 조도계로 자외선 펌프벽에서의 거리와 배양액중의 자외선 조도를 조사한 것을 표로 작성하였다(표 5-6). 배양액의 농도는 EC=2.1mS/cm로 비교적 투명하였만 살균 액의 두께가 40mm일 경우 투과율은 14%, 20mm일 경우 65%로 투과율이 높게 나타났다.

개발된 자외선 살균소독기내의 자외선조사는 표면적은 596.6cm²으로 살균등은 2분을 설치하였으며 2분의 자외선 출력은 6.4w(3.2w×2분)이다. 살균장치내의 살균램프, 반사판과의 석영관의 중심까지의 평균거리는 25mm이고, 평균 투과율은 44.3%이므로 램프를 점등할 경우 장치내의 살균선 조사도는 이론적으로 4752.26 μw/cm² 로 계산된다.

5- 6.

(mm)	(uw/cm2)	(%)
0	2,490	-
20	885	65
30	237	22
40	116	14
50	50	7.7
60	19	3.1
70	5	1.0

5- 7.

30cm

()	(%)	(%)	(%)
0	0	0	0
0.5	99	72	66
1	100	100	83
2	100	100	98
3	100	100	100
5	100	100	100

5- 7

가 30cm

1

100%

Fusarium

()

가

2

가

5

10

가

(5- 8).

가

5- 8.

()	(%)	
0	0	0
5	6.3	0
7	21.8	0
10	59.4	3.1
14	65.6	15.6
20	75.0	53.1

(

)

overflow er

15, 13, 11, 9, 7, 5 l/min

(1/3HP, 15l/min)

1 , 2

표 5-11. 수생균에 대한 살균효과

공시병원균	자외선램프가 점등된후 석영관을 통과한 양액량(liter/min)					
	무조사	15	13	11	9	7
<i>Pythium aphanidermatum</i>	+	+	+	+	-	-
<i>Fusarium oxysporum</i>	+	+	+	+	±	-

자외선 램프(Tosiba;자외선출력3.2W×2분)를 사용하여 조사함.
 자외선 조사는, 집중된 배양액을 석영관 38mm, 길이 500mm로 양액을 조사함.
 +:생존, ±:약간에 생존이 인정됨, -: 살균.

나. 자외선조사시간과 Fe-EDTA 상호관계

오존이나 자외선을 배양액에 연속처리하면 배양액내의 철의 함량이 저하되고
 처리를 시작한 2주후 부터 철결핍증이 발생한다.(그림 5-7) 이러한 증상은 킬레
 이트철을 처리후 4~7일 정도에서 배양액에 일정한 비율로 첨가하여 재배작물
 의 철결핍을 막을 수 있을 것으로 사료된다.

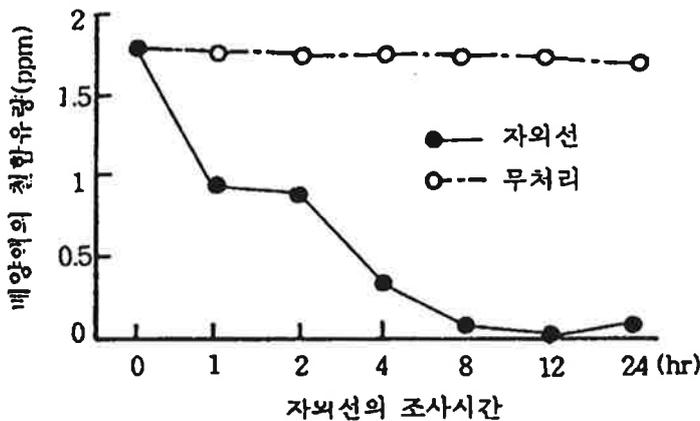


그림 5-7. 자외선 조사가 배양액의 철함량에 미치는 영향

1.

가 ,
high- tech

(李 等, 1994 ; Price Nolan, 1984 ; van Assche Vangheel, 1994 ; Davies, 1980 ; Jenkins Averre, 1983).

, NFT

가

(Price Nolan, 1984 ; Davies, 1980).

(Stanghellini , 1988).

가

(inoculum levels),

(Price

Nolan, 1984).

(van Assche Vangheel,

1994).

(Ewart Chrimes, 1980).

Pseudomonas sp.(van Peer Schippers, 1989 ; Eklund, 1970 ;

Howell Stipanovic, 1979), *Bacillus* sp.(Schippers, 1987) *Azospirillum* sp.(Okon, 1988) siderophores, 2, Fe (Eklund, 1970 ; Schippers, 1987 ; Scher Baker, 1980).

2.

'96 2 '97 1

가.

(*Fusarium oxysporum* f. sp. *cucumerium*)

(*Fusarium oxysporum* f. sp. *lycopersici*.) (*Pythium*

sp.), (*Rhizoctonia* sp.)

가 (土壤微生物研究會, 1975).

70% ethanol 5% sodium hypochlorite(NaOCl) 10
, HCl 가 pH 3 [potato dextrose
agar (PDA) medium] 25 incubator
(5- 8). (NASTI)
(5- 12).

Table 5- 12. Isolation of root-infected pathogenic fungi from hydroponically grown cucumber and tomato plants

Pathogens	Hosts	Korean name	Common name	Sources
<i>Fusarium oxysporum</i> f. sp. <i>cucumerium</i>	Cucumber		fusarium wilt	this study, NASTI*
<i>Fusarium oxysporum</i> f. sp. <i>lycopersici</i>	Tomato		fusarium wilt	this study, NASTI
<i>Pythium</i> sp.	Cucumber, tomato		damping off	this study, NASTI
<i>Rhizoctonia</i> sp.	Cucumber, tomato		damping off	this study, NASTI

NASTI* : National Agricultural Science and Technology Institute

Sampling the infected plant tissues

Washing and surface-sterilization (70% ethanol, 5% NaOCl)

Rinsed in saline solutions (0.85% NaCl solution)

Placed on fungi selection medium (PDA+HCl, pH 3.0)

Sporulation and pure culture

Fig. 5- 8. Selections of root-infected pathogenic fungi from plant tissues
(日本土壤微生物研究會, 1975)

가 5 20cm
 0.85% saline solution ,
 [nutrient agar(NA) medium] .
 35 incubator 24 48 782
 (colony) .

(pH 5.6) 25 24
 PDA .
 2cm

(inhibition zone) . PDA 7
 colony
 (5-8).

cell mass 4 5,000rpm 15 3
 0.22ml ,

Restreaking the antagonistic rhizobacteria on the NA media for activation

Culture of pathogenic fungi(*Pythium* sp., *Fusarium* sp. and *Rhizoctonia* sp.)
on the PDA media at 25 (24 48hrs, darkroom)

Spotting of root-infected pathogenic fungi on the center of the PDA media

Incubation at 25 for 24hrs(darkroom)

Spotting of selected and purified rhizobacterial isolates on the side
(2cm apart from the center) of the PDA media

Incubation for 3 7 days at 25 (darkroom)

Selection of antagonistic rhizobacteria showing strong inhibition zone

Genetic marking adding kanamycin and rifampicin 200ppm into the NA
media

Incubation(35 incubator) for 24hrs and single colony picking up

Single colony culture in nutrient broth(to O.D.(cm^{-1})=1.2)

Preservation of strains(adding glycerol 10%) in microcentrifuge tube at -68

Fig. 5-8. Selections of antagonistic rhizobacteria against root-infected
pathogenic fungi of hydroponically grown cucumber and tomato
plants(日本土壤微生物研究會, 1975)

Bergey's manual, Microbiological method, The Procaryotes

Biolog system

(土壤微生物研究會, 1975

; Krieg Holt, 1984).

Bacillus subtilis ATCC 6633 ,

Azospirillum brasilense ATCC 29145 , *Pseudomonas jluorescens* ATCC

31125 , *P. putida* ATCC 11250 American Type Culture

Collection(ATCC) (Rockville, Maryland, USA)

3.

(Schippers , 1987),

(Eklund, 1970),

(Schippers , 1987)

(*Fusarium* sp.),

(*Pythium* sp.)

(*Rhizoctonia*

sp.)

5- 9 5- 12

5- 13

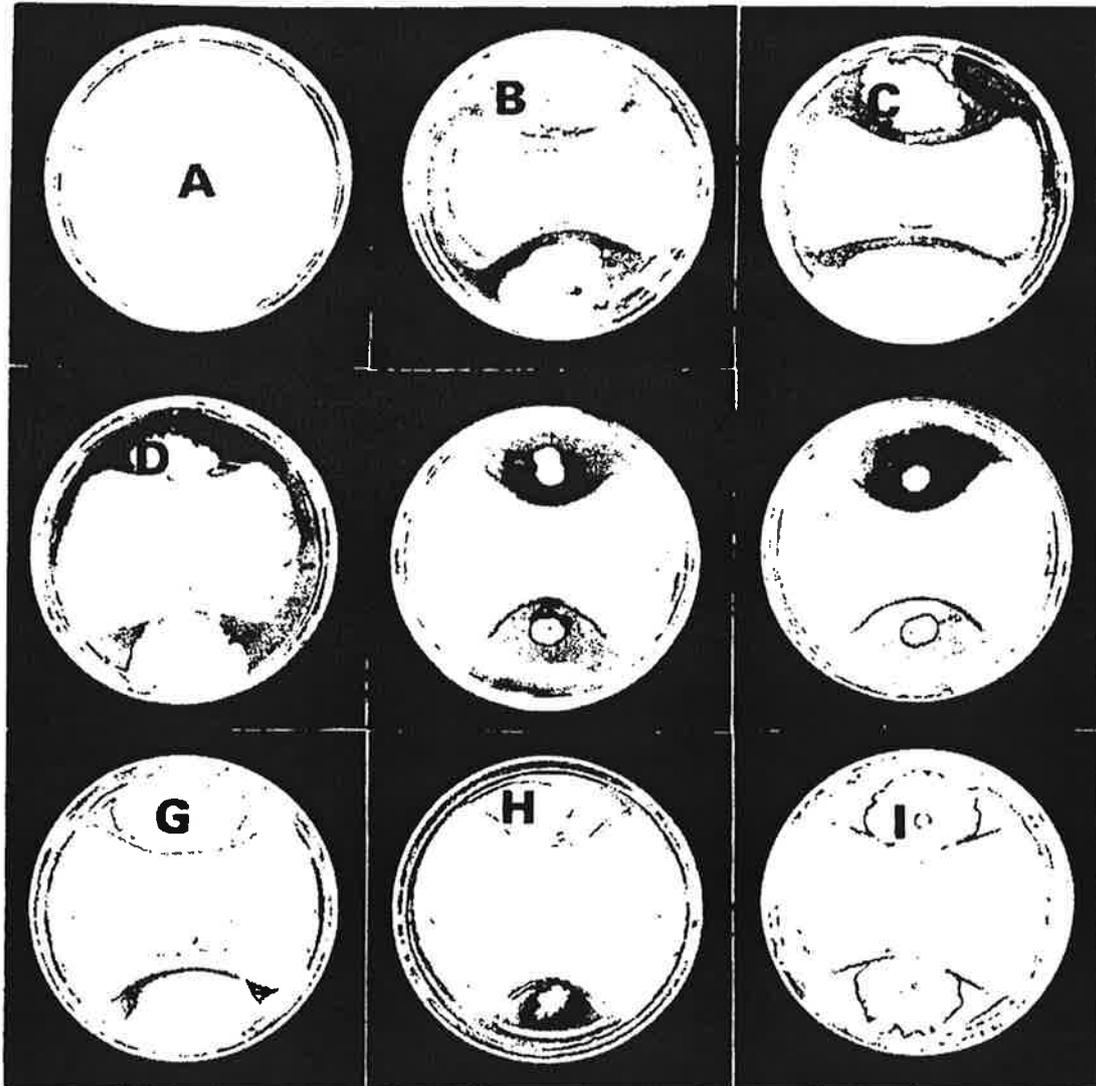


Fig. 5-9. Inhibition effect of antifungal bacteria against *Fusarium* sp. of hydroponically grown tomato. Plates were incubated at 25°C for 7days. A, B, C, D, E, F, G, H and I represent *Fusarium* sp., antifungal rhizobacteria JY20A, JY233, JY20B, JY20C, JY231, JY220, JY211 and JY218, respectively.

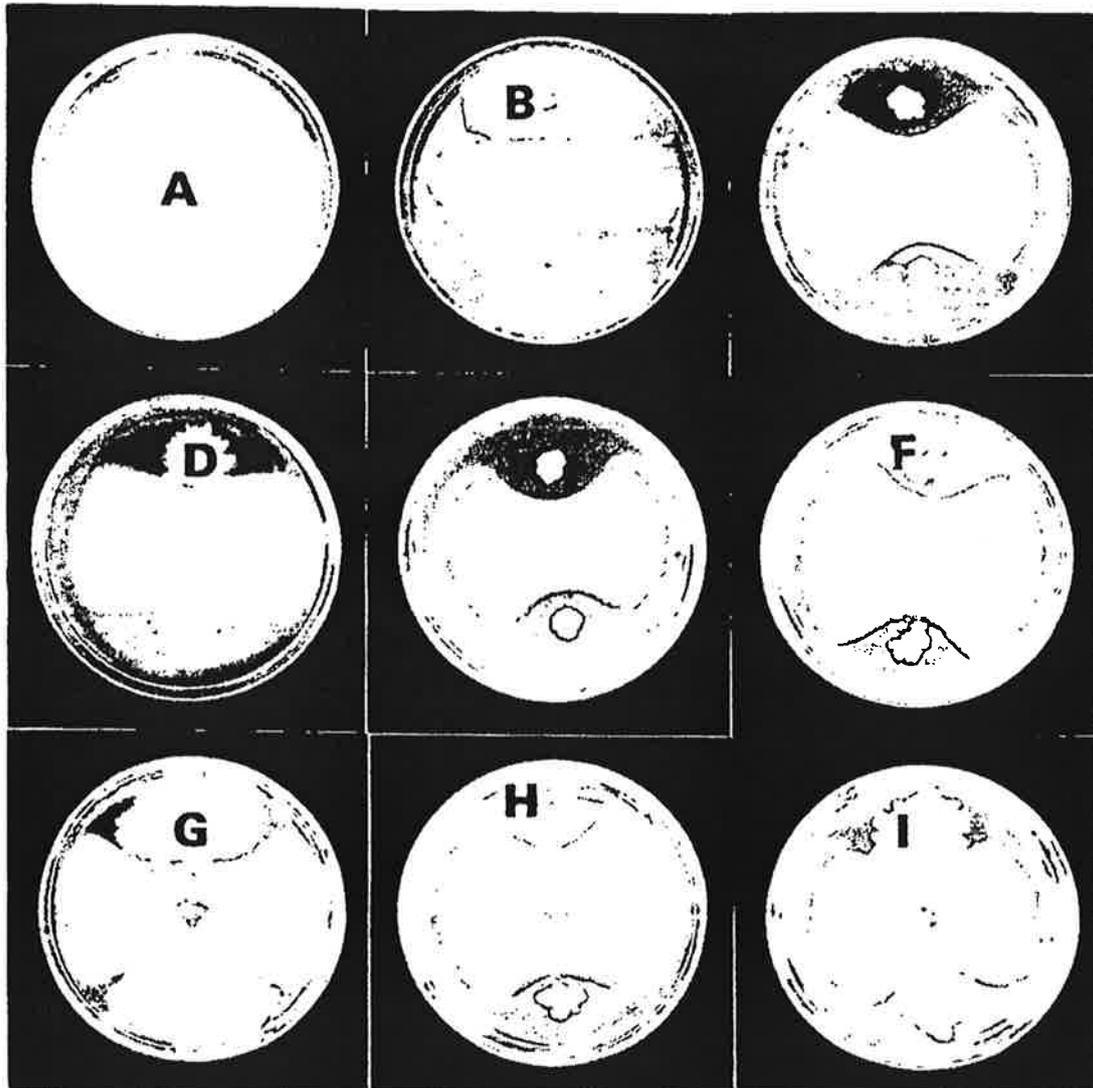


Fig. 5-10. Inhibition effect of antifungal bacteria against *Fusarium* sp. of hydroponically grown cucumber. Plates were incubated at 25°C for 7days. A, B, C, D, E, F, G, H and I represent *Fusarium* sp., antifungal rhizobacteria JY20A, JY233, JY20B, JY20C, JY231, JY220, JY211 and JY218, respectively.

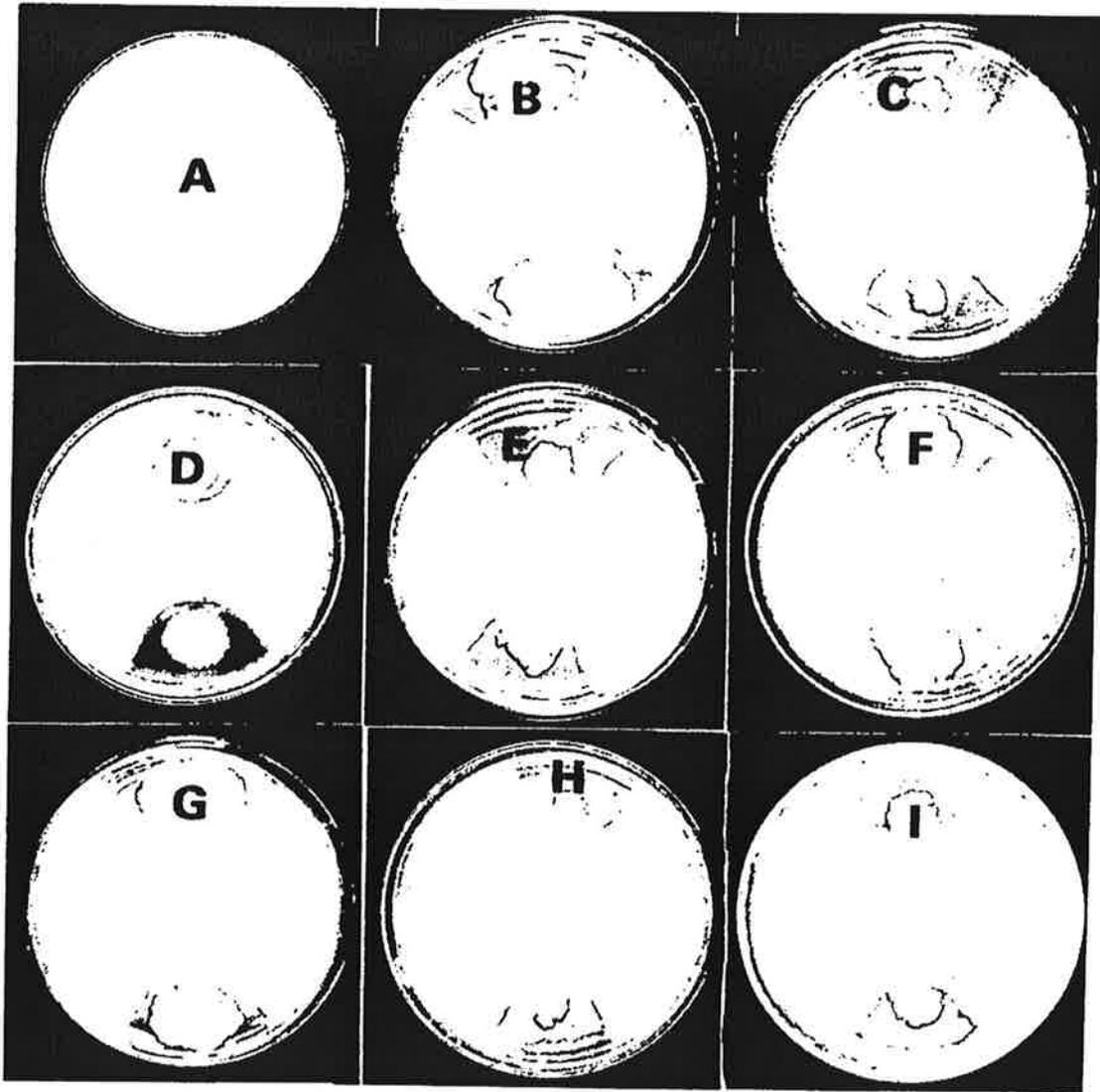


Fig. 5-11. Inhibition effect of antifungal bacteria against *Pythium* sp, of hydroponically grown tomato and cucumber. Plates were incubated at 25°C for 7days. A, B, C, D, E, F, G, H and I represent *Pythium* sp., antifungal rhizobacteria JY20A, JY233, JY20B, JY20C, JY231, JY220, JY211 and JY218, respectively.

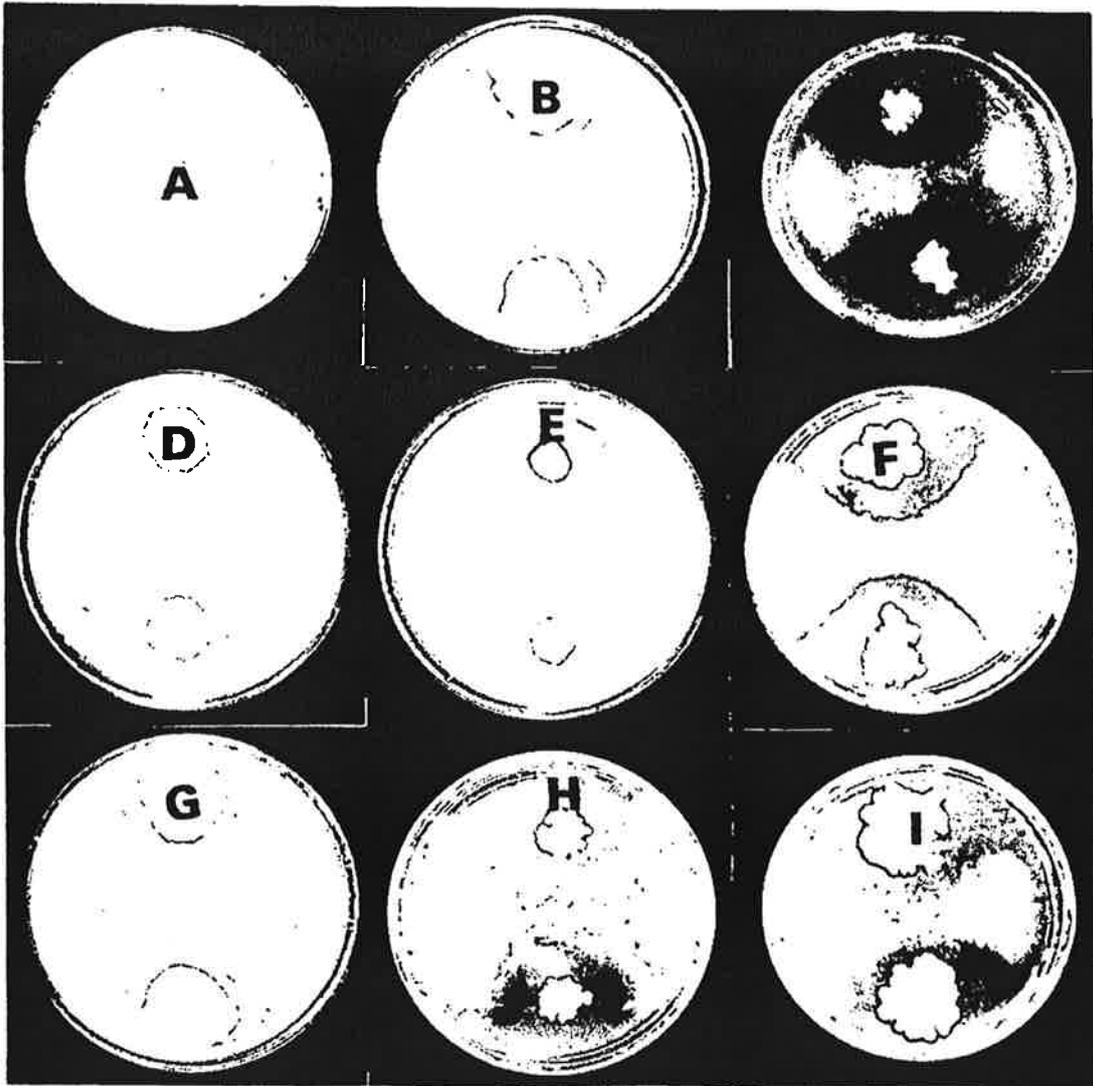


Fig. 5-12. Inhibition effect of antifungal bacteria against *Rhizoctonia* sp. of hydroponically grown tomato and cucumber. Plates were incubated at 25°C for 7days. A, B, C, D, E, F, G, H and I represent *Rhizoctonia* sp., antifungal rhizobacteria JY20A, JY233, JY20B, JY20C, JY231, JY220, JY211 and JY218, respectively.

Table 5- 13. Suppressiveness of antagonistic rhizobacteria against root-infected *Fusarium* sp., *Pythium* sp., *Rhizoctonia* sp. of hydroponically grown cucumber and tomato. Antifungal activities were measured at 7 days after incubation(25 , darkroom).

Antagonistic rhizobacteria	<i>F. o. lycopersici</i>		<i>F. o. cucumerium</i>	
	Inhibition zone(cm)	Antifungal activities(%)	Inhibition zone(cm)	Antifungal activities(%)
JY20A	5.85	65.0z)	6.00	66.7
JY233	5.77	64.1	5.40	60.0
JY20B	4.50	50.0	5.61	62.3
JY20C	5.82	64.7	5.85	65.0
JY231	6.11	67.9	4.78	53.1
JY220	5.16	57.3	5.61	62.3
JY211	4.72	52.4	4.72	52.4
JY218	5.29	58.8	4.97	55.2

Antagonistic rhizobacteria	<i>Pythium</i> sp.		<i>Rhizoctonia</i> sp.	
	Inhibition zone(cm)	Antifungal activities(%)	Inhibition zone(cm)	Antifungal activities(%)
JY20A	5.76	64.0	5.81	64.6
JY233	5.62	62.4	7.29	81.0
JY20B	5.90	65.6	5.62	62.4
JY20C	5.62	62.4	5.38	59.8
JY231	5.62	62.4	7.33	81.4
JY220	5.21	57.9	5.72	63.6
JY211	4.93	54.8	6.99	77.7
JY218	5.33	59.2	6.86	76.2

$$z) \text{ Antifungal activities(\%)} = \frac{\text{Colony diameter of antagonistic rhizobacteria}}{\text{Pathogen colony diameter of no treatment}} \times 100$$

가 8 ,
 50 67.9%
 (2). 가 JY231
 67.9% , 50%

JY20A가 가

66.7%

JY20B JY231

65.6% 81.4%

3

2 35

20 25

(Krieg Holt, 1984 ; Stanghellini , 1988 ; Price Nolan, 1984),

25

가

(Gullino Garibaldi, 1994 ;

Orlikowski, 1987).

(van Peer Schippers, 1989).

5- 14

8

4 5.2×10^7 c.f.u. 3.6×10^4 cells

yeast extract

0.01% 가 山崎處方(山崎, 1979)

200ml

1% (2ml)

53.1 84.6%

가 가 가

根細胞 破片(root cell debris)

가 ,

가 (Jenkins

Averre, 1983 ; Schippers , 1987).

가

가

(Eklund, 1970 ; Schippers , 1987).

Table 5- 14. Antifungal effects of antagonistic rhizobacteria against root- infected pathogens of hydroponically grown cucumber and tomato as affected by antagonistic cell intacts. 2ml cultures of antagonistic bacterial cells(5.2×10^7 c.f.u) and pathogenic fungi(3.6×10^4 cells) were added into 200ml cultural broth and incubated at 25 for 2days. Colonies on selective agar media were incubated and counted after homogenization and dilution of antagonistic and pathogenic cultures.

Rhizobacteria Pathogens	Rhizobacteria							
	JY20A	JY233	JY20B	JY20C	JY231	JY220	JY211	JY218
<i>F. o. cucumerium</i>	76.0z)	62.4	60.8	81.2	76.3	67.8	62.1	63.4
<i>F. o. lycopersici.</i>	82.3	71.9	60.5	75.3	63.4	65.7	64.2	65.8
<i>Pythium, sp.</i>	74.0	63.4	53.1	83.4	81.7	64.3	64.6	73.8
<i>Rhizoctonia sp.</i>	84.6	73.9	83.7	60.7	79.3	60.1	67.7	80.1

z) ratios of antagonistic bacterial cells to root-infected pathogens on selective media

5- 15

cell mass

Table 5- 15. Antimicrobial activities of antagonistic rhizobacteria as affected

by filtered secondary metabolites against root-infected fungi of hydroponically grown cucumber and tomato.

Secondary metabolites Pathogens	Antimicrobial activities of secondary metabolites(%)							
	JY20A	JY233	JY20B	JY20C	JY231	JY220	JY211	JY218
<i>F. o. cucumerium</i>	67.4	64.1	60.8	61.3	51.7	60.9	51.0	53.7
<i>F. o. lycopersici.</i>	62.0	61.8	52.7	62.8	60.7	51.9	54.8	60.4
<i>Pythium sp.</i>	65.0	61.9	60.8	58.7	68.4	54.2	56.1	61.4
<i>Rhizoctonia sp.</i>	62.7	70.9	60.7	54.1	76.9	60.8	72.9	72.1

50%
가
JY20A 67.4%
JY20C가 62.8%,
JY231 68.4% 76.9% 가
2
(Schippers ,
1987).

Table 5- 16. Morphological characteristics of antagonistic rhizobacteria

Characteristics	Strains							
	JY20A	JY233	JY20B	JY20C	JY231	JY220	JY211	JY218
Cell diameter	2.0µm	2.2µm	1.6µm	1.8µm	1.5µm	2.0µm	2.3µm	1.9µm
Endospore	+	-	-	-	-	-	-	+
Gram stain	+	-	-	-	-	-	-	+
Form	rod	rod	rod	rod	rod	rod	rod	rod
Motility	+	+	+	+	+	+	+	+

Symbols : -, 90% or more of are negative ; +, 90% or more are positive ; d, 11 89% are positive

가 , 1.5 2.3µm
 m . JY20A JY218
 , *Bacillus* sp.
 (Krieg Holt, 1984). JY20A JY218
 negative . rod
 , 가 ,
 .
 Biolog system Bergey's manual
 JY20B JY231 *Pseudomonas fluorescens* , JY220
 JYJY20C *P. putida* , JY211 JY233 *Azospirillum* sp. , JY20A
 JY218 *Bacillus* sp. (Krieg Holt, 1984
 ; 土壤微生物研究會, 1975).

JY20A, JY233, JY20B JY20C
 chitinase, pectinase cellulase
 5- 17 .

Table 5- 17. Production of chitinase, pectinase and cellulase by antifungal

782 , JY20A, JY233,
 JY20B, JY20C, JY231, JY220, JY211 JY218 8
 . JY20A가 66.7%,
 JY231가 67.9%, JY20B
 JY231 65.6% 81.4% 가 .
 2 .
Pseudomonas sp., *Azospirillum* sp. *Bacillus* sp.
 , 1.5 2.3µm . chitinase
 chitin

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PE, PVC, FRP,

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. Chun and Takakura(1994)

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가 0.003mM

가 (Veen, 1988). Neuman and Smit(1991)

가

. Yoshida (1996)

가

(Nobel, 1991). Yoshida(1996)

가 6.9g/m³

가

. Everard and Drew(1987,

1989)

가

가

가

長野 石田(1984) 長野

(1993)

80%

가

가

가

. Katou and Taura(1989)

proton pump

가

가

가

가

가

2

1.

1)

2)

3)

4)

5)

2.

1.

1-1 :

1997 2 5

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1997 1 20 1 22 가 2 13 1

2 26 2

(6-1) ½ 가 4 13

1

6-1.

		JBS (ppm=mg/l)
	Ca(NO ₃) ₂ · 4H ₂ O	944
	KNO ₃	808
	NH ₄ H ₂ PO ₄	15
	KH ₂ PO ₄	-
	MgSO ₄ · 7H ₂ O	492
	Fe- EDTA	20
	H ₃ BO ₃	2.860
	MnSO ₄ · 4H ₂ O	1.567
	ZnSO ₄ · 7H ₂ O	0.220
	CuSO ₄ · 5H ₂ O	0.080
	(NH ₄) ₂ MoO ₄	0.025

30(cm) × 2(m)

20(cm) × 25(cm)

26

가

1m 20-25

B-1, B-2, B-3

B-1

B-2

가

B-3

6-1

6-2

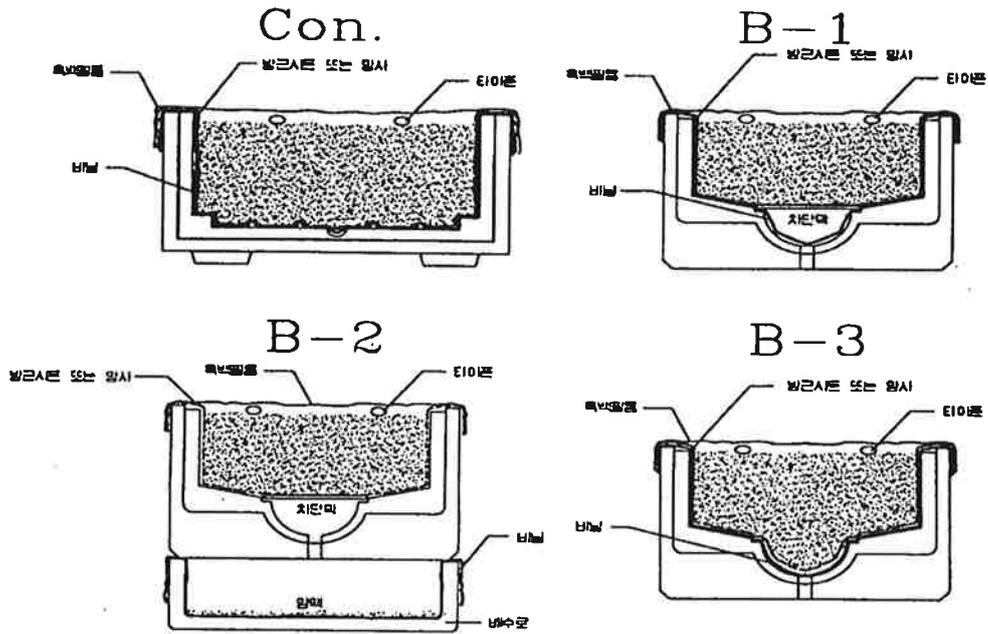


그림 6-1. 실험에 사용된 베드 구조

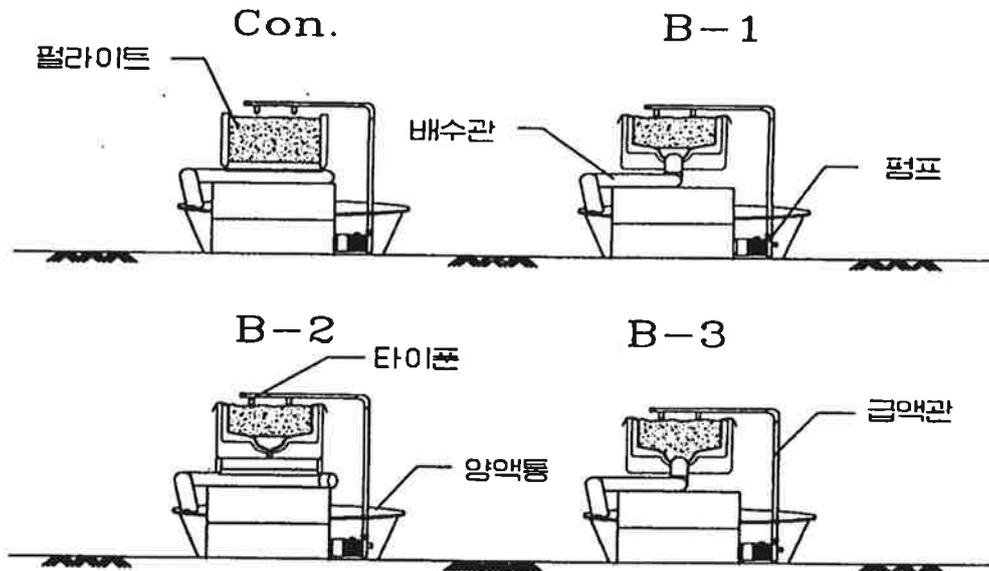


그림 6-2. 시험을 위해 제작한 시스템 구성도

6-2 . 50

6 6 1 3 .
10 14 7 3

, , , , , ,

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20cm 5cm .

6-2.

		B- 1	B- 2	B- 3
()	74.5	43.1	43.1	51.0

40%

가

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5cm

pH EC

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50l

3 6 , 8

, 10 4 3 , 5 , 7 5 1 , 3 , 5

.

3

0.5l

1 .

가 가

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2 - 2.

1

6-3

6-3.

	1	2	3	4	5	6
(V) : (V)	100 : 0	80 : 20	60 : 40	40 : 60	20 : 80	0 : 100

2

6-3

10

14

6

20cm

5cm

40%

가

pH EC

1 390ml

20 7,800ml

로 하루 20회 7,800ml를 공급하였다. 또한 배출된 배양액을 일정간격으로 수집하여 Ion Chromatography (DX-500, Dionex, USA)로 양이온과 음이온량을 분석하였다.

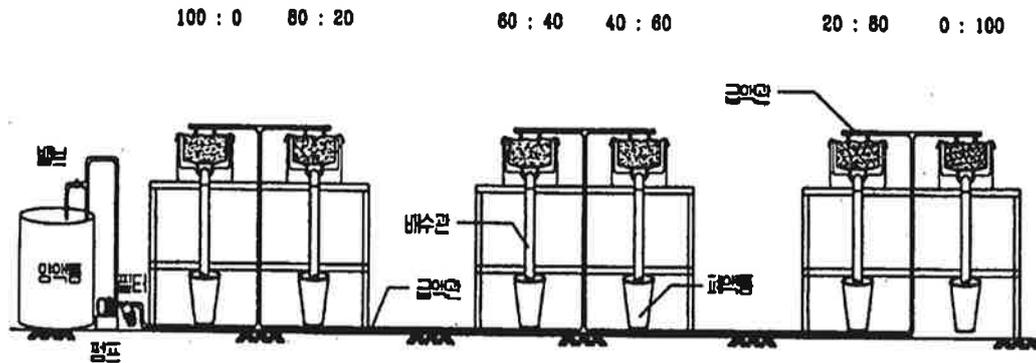


그림 6-3. 배지 혼합비를 실험을 위해 설치한 시스템 구성도

실험 2. 바이오베드를 이용한 오이의 양액재배

본 실험은 겨우살이 청장오이(홍농종묘)를 공시품종으로하여 4월 25일 양액 재배 베드에 정식하였다. 사용된 재배베드는 새롭게 개발된 바이오베드를 이용하여 통기구조를 달리한 3처리와 기존의 베드를 사용한 3처리로 베드구조 및 배지량에 따른 차이를 비교하였다.

베드의 구조 처리는 다음과 같다.

- ① **기존베드** : 기존 농가에서 사용하고 베드로서 내부용적 40리터로 단순 직육면체이다.
- ② **대형베드** : 기존 농가에서 분무경용으로 사용되는 단순구조의 베드로서 내부용적이 60리터이다.
- ③ **바이오베드** : 초기 설계된 바이오베드로서 별도의 배수구가 없이 베드의 저면에 통기구멍을 설치한 것으로 내부용적 25리터이다.

25 .

II-2 :

가 가

II-3 :

3 30 6 10 1 5 , 10
 5 , 3 6 1
 10 , , ,
 pH EC . 15

3.

“ ” 1997 6 4 7 8
 4 . 240*120*990(mm)
 240*110*1000(mm)() .
 , EC 2.0 2.4mS/cm .
 (TRIME- FM) .
 2000ppm

15 4 . 9 10

3

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가 1980

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가

가

10 가

가

가

가

가

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가

가

가

가

50 60

가

가

가

가

PE, PVC, FRP,

가

가

(Bio-bed)

5

97%

가

가

가가

가

가

(1)

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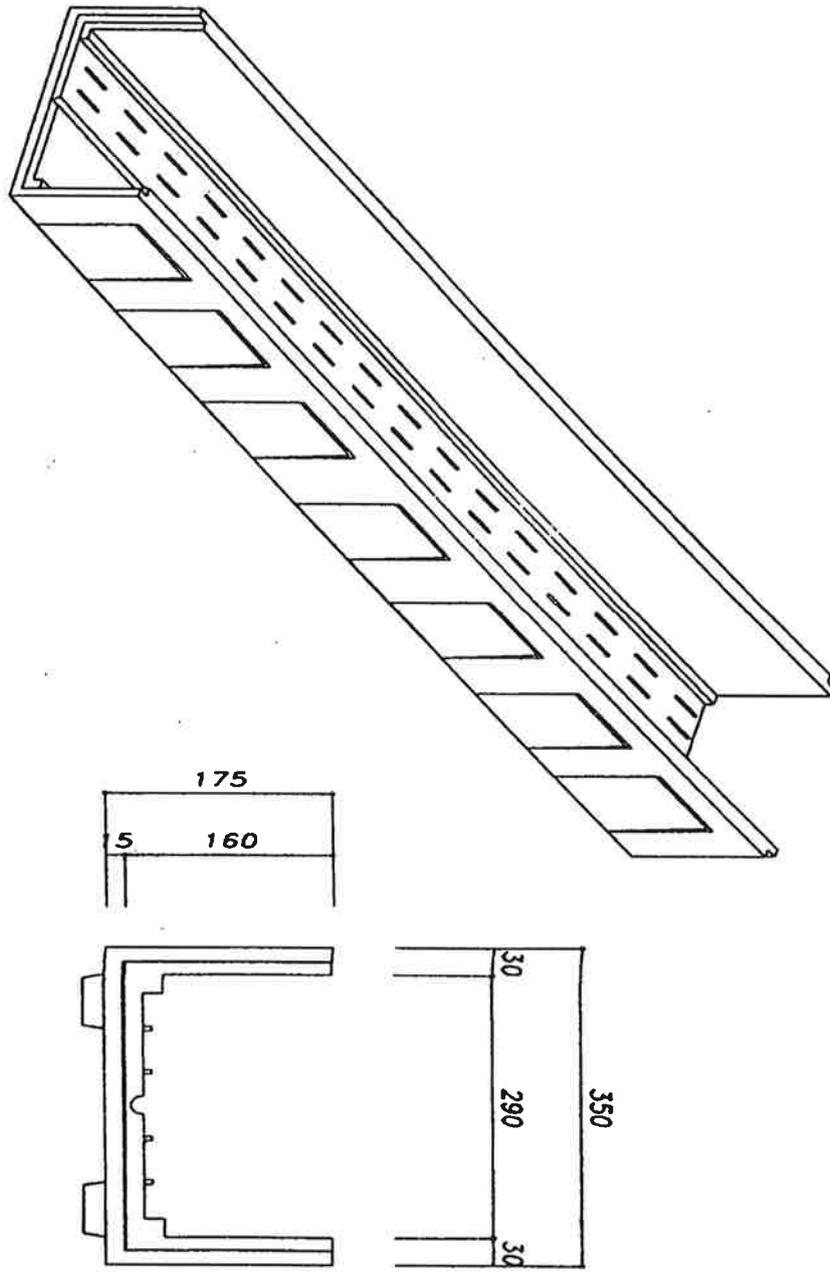


그림 6-4. 기존의 단순한 베드구조

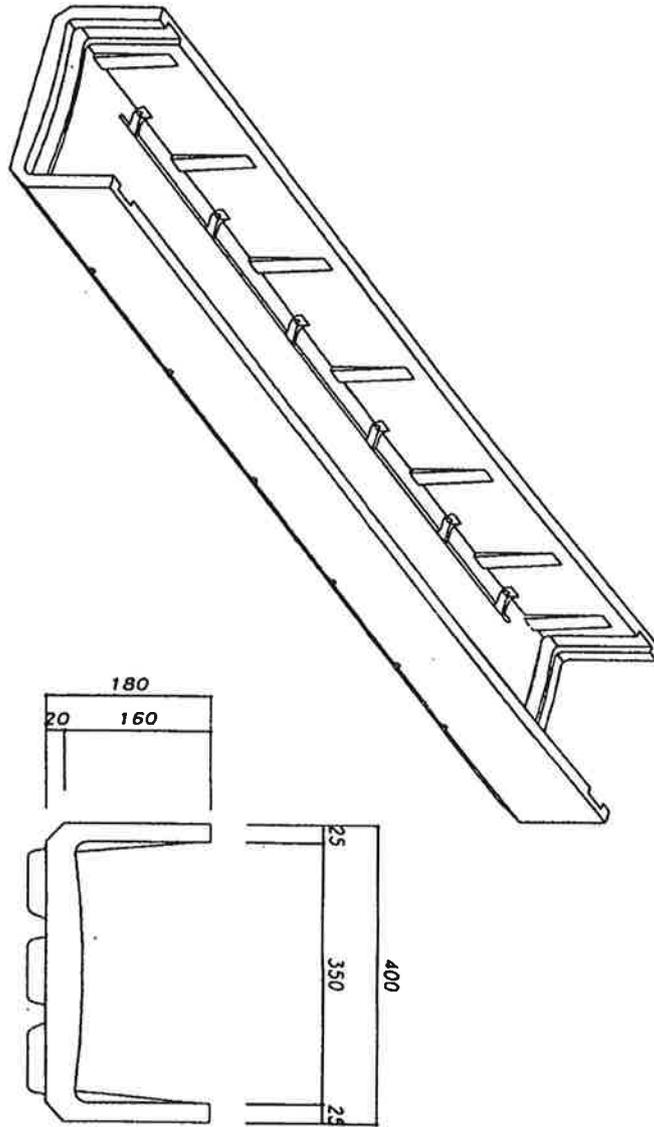


그림 6-5. 기존의 베드구조(측면에 배수구멍이 있음)

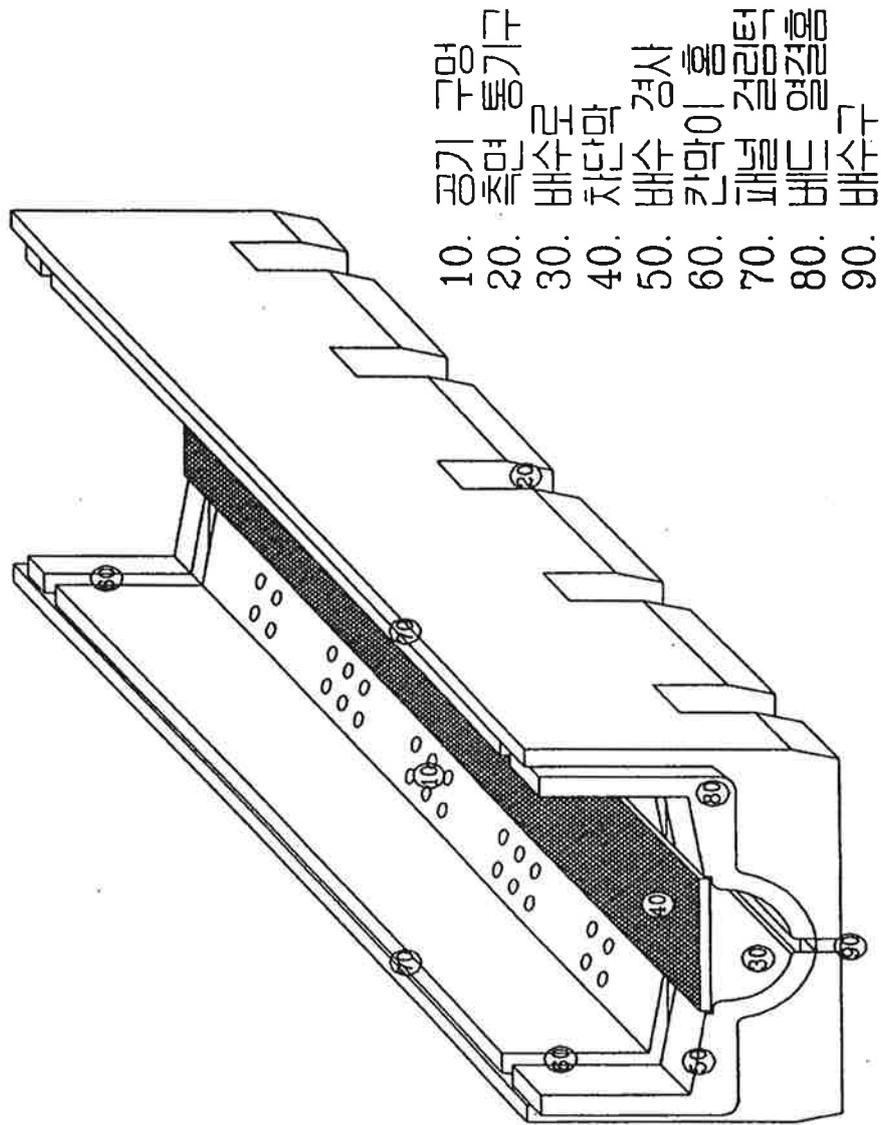


그림 6-6. 개발된 바이오베드의 구조

6-4 6-5
6-4 가

가 가

6-5

가

가

20cm

가

가
1.5cm (10) 52

가

(20)

가

(30)

가

(40)

(50).

(60)

(70)

⑦ 본 바이오베드를 길이방향으로 연결하여 사용할 수 있도록 베드의 앞뒤로 베드연결홈(80)을 만들었다.

⑧ 패널걸림턱(70)에 정식패널을 설치하면 바이오베드를 고품배지를 사용하지 않고 재배하는 담액수경, 분무경, 박막순환양액재배 등의 재배조로 이용된다.

⑨ 기존의 재배베드가 1m를 기준으로 고품배지의 충진량이 약 50리터 이상이나 본 바이오베드는 내부체적을 줄여 25-30리터로 고품배지에 소요되는 비용을 획기적으로 줄일 수 있다.

이상의 모형을 가진 바이오베드는 통기구멍(10) 및 측면통기구(20)로 베드내부의 공기유동을 원활히 하고, 저면의 배수로(30)를 설치하여 별도의 배수를 위한 파이프배관이 필요없으며, 배수로의 깊이가 5cm정도로 10m정도 연결했을때는 특별히 구배를 설정하지 않아도 자연배수가 가능하다. 또한 배수로(30)와 배지를 구분하는 차단망이 원활한 배수와 통기를 조장한다. 앞뒤의 연결턱을 이용하여 길이방향으로 계속 연결할 수 있으며, 칸막이 홈에 판을 끼워 마감작업이 용이하도록 하였다. 또한 획기적인 배지의 감량으로 배지에 소요되는 비용을 줄일 수 있다. 본 고안의 가장 큰 요점은 베드내의 원활한 공기유동과 배지의 감량에 중점을 두었다.

Biobed의 정면도
SCALE = 1/5

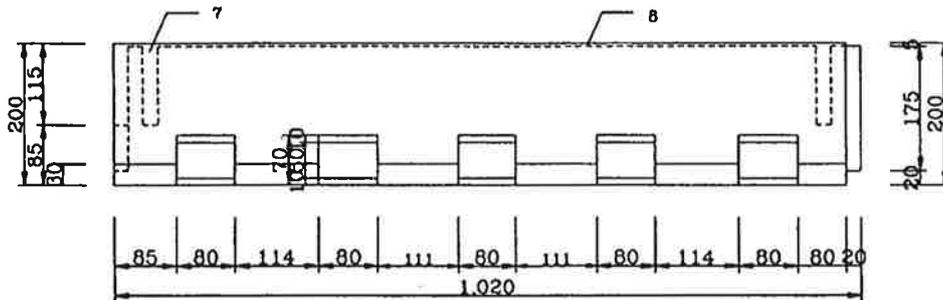


그림 6-7. 개발된 바이오베드의 측면 상세도

2. 바이오베드의 실용화 시험

실험 1. 바이오베드를 이용한 국화의 양액재배

실험 1-1 : 베드의 통기구조에 따른 국화의 생육특성

그림 6-10은 베드구조에 따른 실험기간동안의 근권온도변화를 나타낸 것이다. 전반적으로 대조구보다 B-1과 B-2 처리구가 약 1℃정도 높게 나타났으며 4월초까지는 14~16℃ 사이였으나 4월이후 근권온도가 상승하여 5월초에는 약 22℃정도를 나타냈다.

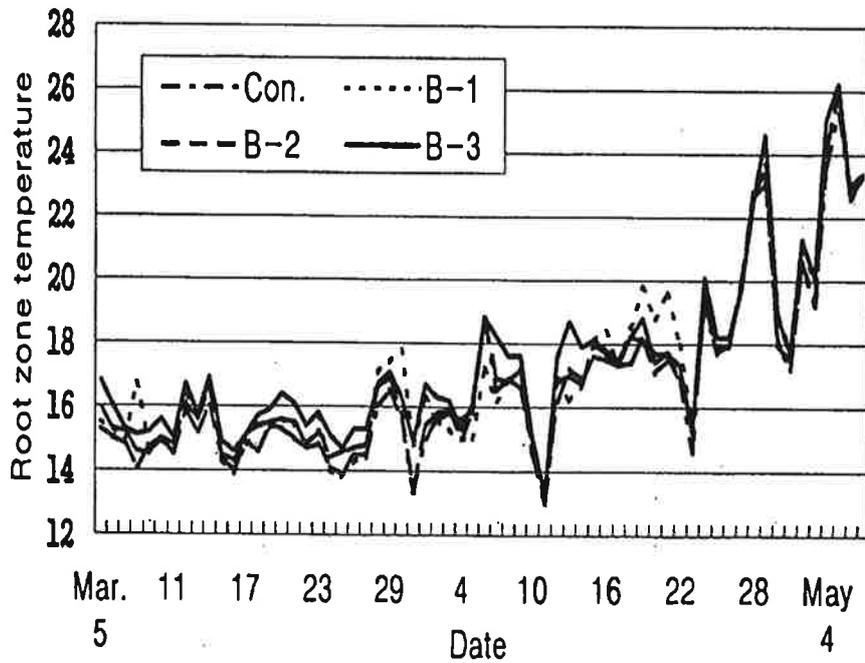


그림 6-10. 베드구조에 따른 근권의 온도변화

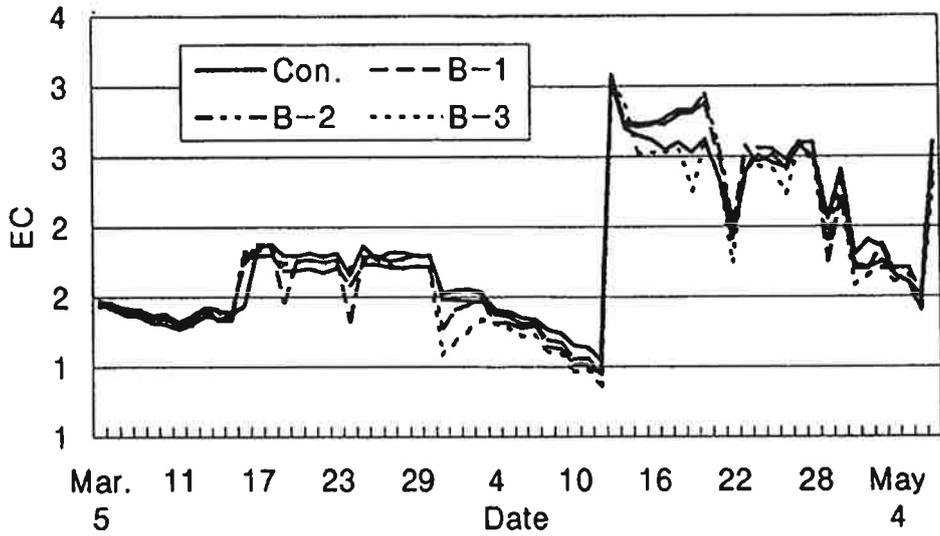


그림 6-11. 실험기간동안의 양액 EC변화

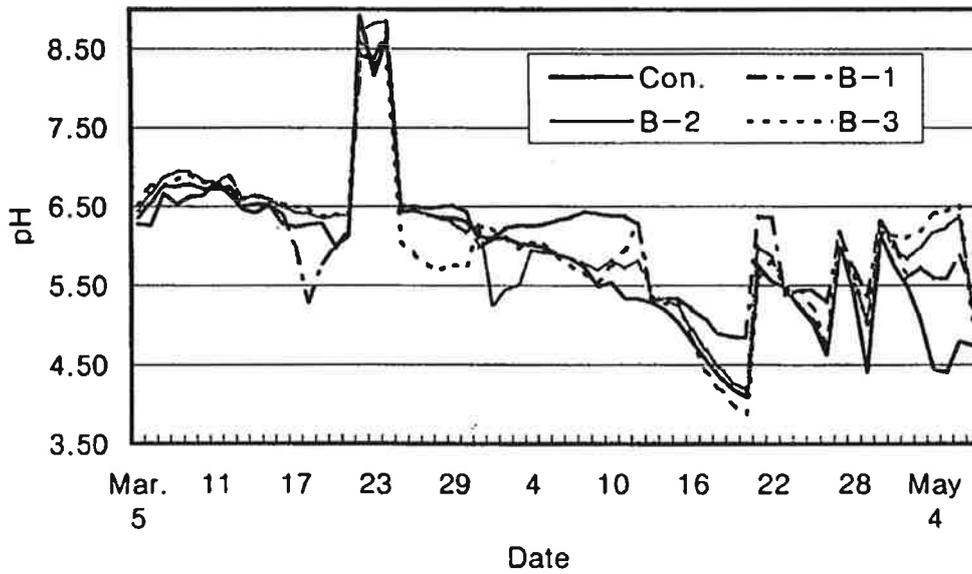


그림 6-12. 실험기간동안의 각 처리별 양액의 pH변화

6-11 EC EC
 4 14
 EC가 3.0 가 가 EC B-1
 B-2가 0.4 0.6mS/cm
 6-12 pH
 3 20 pH가 8.5
 4 10 pH
 pH 6.5 pH가

6-4. 85

	(cm)	(mm)	(cm)	(ea)	(cm)	(ea)					
							(cm)	(mm)			
Control	63.5cz	7.2c	30.9	63.0b	1842.3c	201.7	1.9a	4.8b			
B-1	70.7ab	7.8b	32.1	74.0a	2109.7b	220.3	1.2c	5.0b			
B-2	71.8a	8.4a	31.1	74.3a	3189.3a	194.3	1.7b	5.4a			
B-3	67.4bc	7.2c	32.5	63.7b	2076.7b	172.7	1.7b	5.0b			
	(cm)	(g/plant)					(g/plant)				
Control	12.8c	72.3c	41.3b	76.6	31.1c	217.9	14.4c	19.6b	11.7	3.6	49.3b
B-1	15.9b	76.4c	46.2b	106.7	42.7ab	271.9	16.1bc	20.5b	16.0	5.6	59.2b
B-2	17.0a	139.9a	71.6a	85.8	44.1a	217.9	26.0a	32.2a	16.2	5.3	80.3a
B-3	16.0b	90.0b	40.8b	73.6	35.6bc	250.0	18.3b	18.5b	14.4	4.4	57.6b

z Mean separation within columns by Duncan's multiple range test at 5% level.

6-4

장과 경경은 비닐에 의해 막혀있는 대조구와 B-3처리구에서 낮게 나타났으며 통기구조가 양호한 B-1 및 B-2처리구에서 높게 나타났다. 엽수에 있어서는 그 차이가 현격하게 나타났으며 엽면적은 통기성이 가장 양호한 B-2처리구에서 3189.3cm²로 근권의 통기성이 엽면적 증대에 깊게 영향을 알 수 있었다. 개화된 절화의 화수를 세어본 결과 표준편차의 범위가 크게 나타나 처리간의 유의성은 인정되지 않았다. 만개된 절화의 크기를 나타내는 화경의 경우도 B-2처리구에서 가장 높게 나타났으며 생체중과 건물중에 있어서는 그 차이가 현격하였다. 특히 잎과 줄기의 생체중 및 건물중에서 차이가 많았으며 근의 경우 배지경의 특성상 근의 정확한 채취가 힘들다는 점에서 처리간의 유의차를 인정하지 않았다. 이러한 결과로 볼 때 근권의 통기구조가 초장과 엽면적 및 건물생산에 확연한 영향을 미친다는 것을 알 수 있었다.

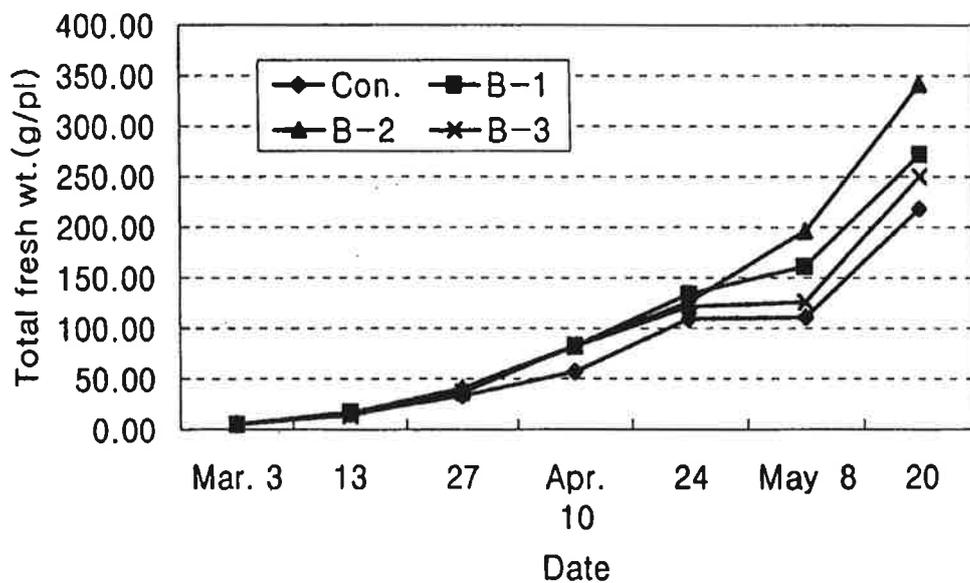


그림 6-13. 베드구조에 따른 양액재배 국화의 총생체중 변화

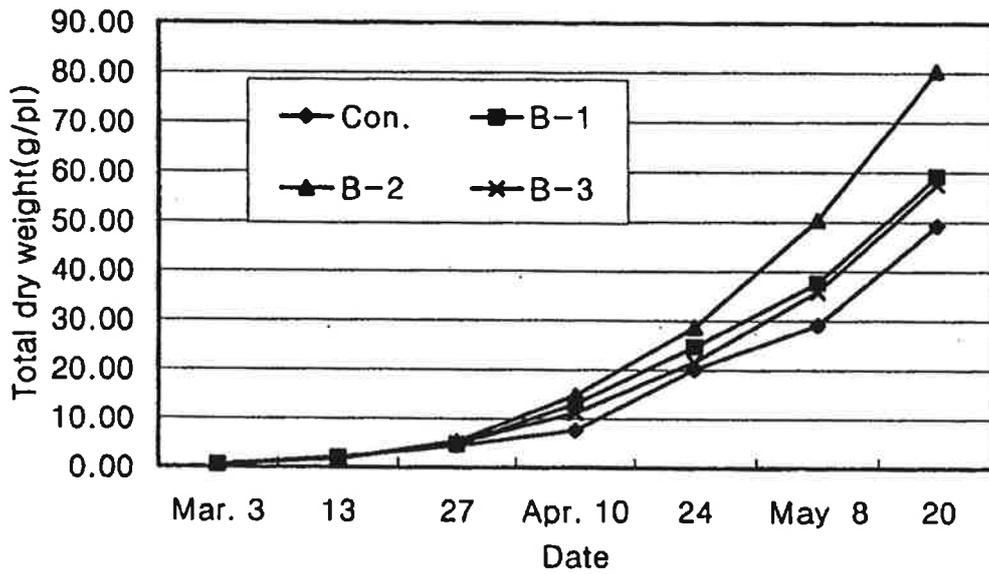


그림 6-14. 베드구조에 따른 양액재배 국화의 총건물중 변화

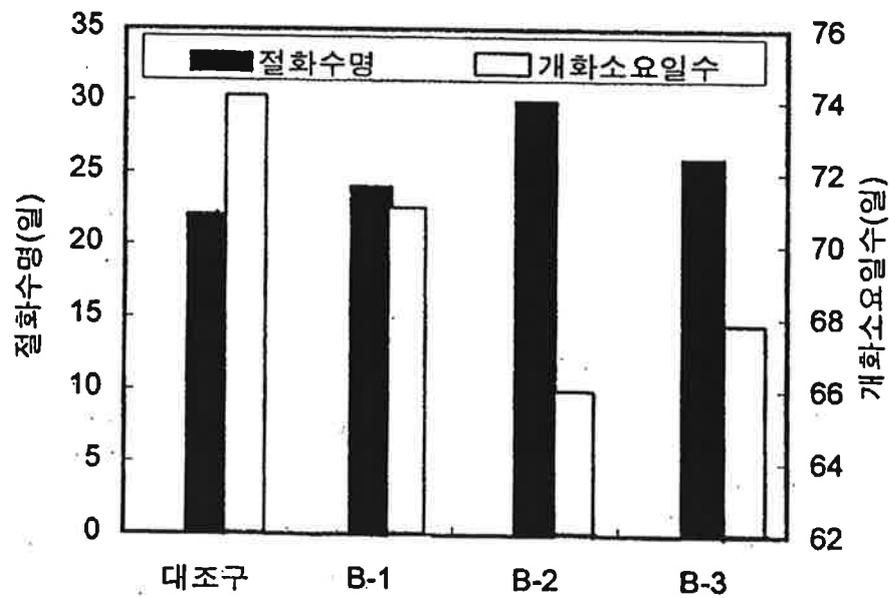


그림 6-15. 베드구조에 따른 양액재배 국화의 정화수명과 개화소요일수의 비교

6-13 6-14

5 4 24

4 10 가

B-2

B-1 B-2

50g/plant

가

6-15 30%가

가 74 Bio-bed

68 , bio-bed

66 ,

bio-bed

71 가

B-2가 가 가

B-3 가 가 3

가

가

22 B-2 29

가

B-2 10 1

, 2

가

많은 곳에서 자란 국화를 삼목을 하면 빨리 발근이 될것으로 유추되며, 삼목에서 정식까지의 시간을 줄일수 있을 것이라 생각된다. 이런 현상을 연구한다면 농가에서의 생산소요일을 줄이는데 중요한 여건으로 작용하지 않을까 한다.

실험 2 - 2. 배지의 혼합비율에 따른 국화의 생육특성

본 실험은 실험 1에서 가능성을 검토한 베드구조에 알맞은 배지의 혼합비율을 결정하고자 수행하였다. 배지로서는 최근 널리 사용되고 있는 펄라이트와 최근 도입되어 사용자가 늘어가고 있는 코코피트를 사용하여 비율별로 생장을 비교하였다. 정식일자 및 배양액 등 재배 일반관리가 실험 1과 동일하게 실시되었으나 배양액의 공급은 표준농도로 조제된 배양액탱크에서 재배베드로 점적 관수된 후 다시 회수하지 않는 개방형 방식(open system)을 택하였다.

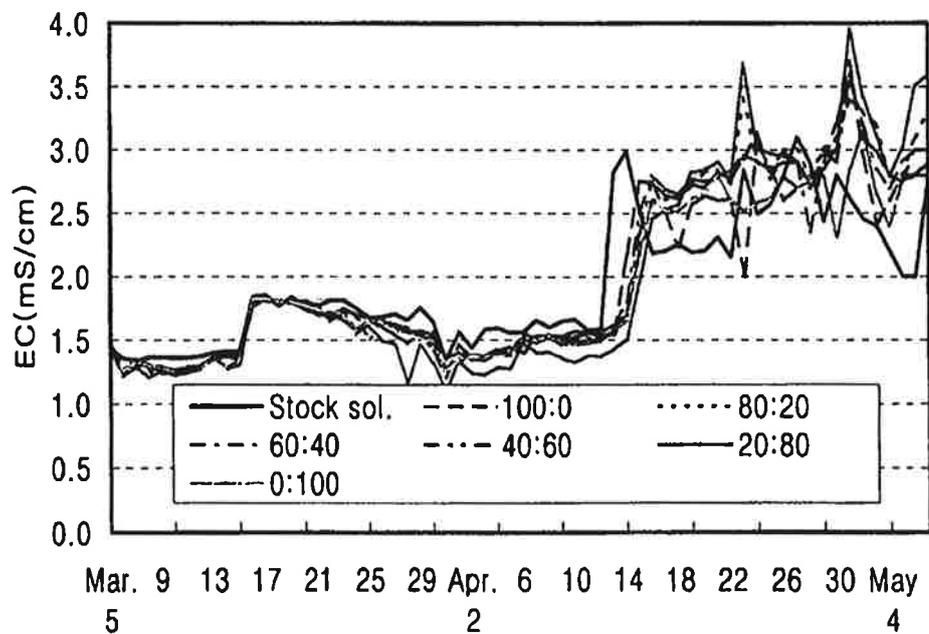


그림 6-16. 실험기간동안의 배양액의 EC 변화

그림 6-16은 재배기간동안의 배양액 EC를 나타낸 것이다. 측정위치는 배양액 탱크와 각 처리구의 배액통에서 측정하였다. 초기 배양액은 표준농도의 1/2 농도로 1.5mS/cm였으며 초기에는 약 1주일정도 큰 변화를 보이지 않았으나 그 후 갑자기 EC가 증가하였으며 이는 정식이후 활착된 뿌리가 활력을 되찾아 양수분의 흡수를 시작한 때문으로 생각되었다. 한편 4월 13일 양액을 표준농도로 변환시켜준 생육중기에는 EC의 변화폭이 심해지고 특히 20:80(퍼라이트:코코피트)처리구에서 높은 EC를 나타냈다.

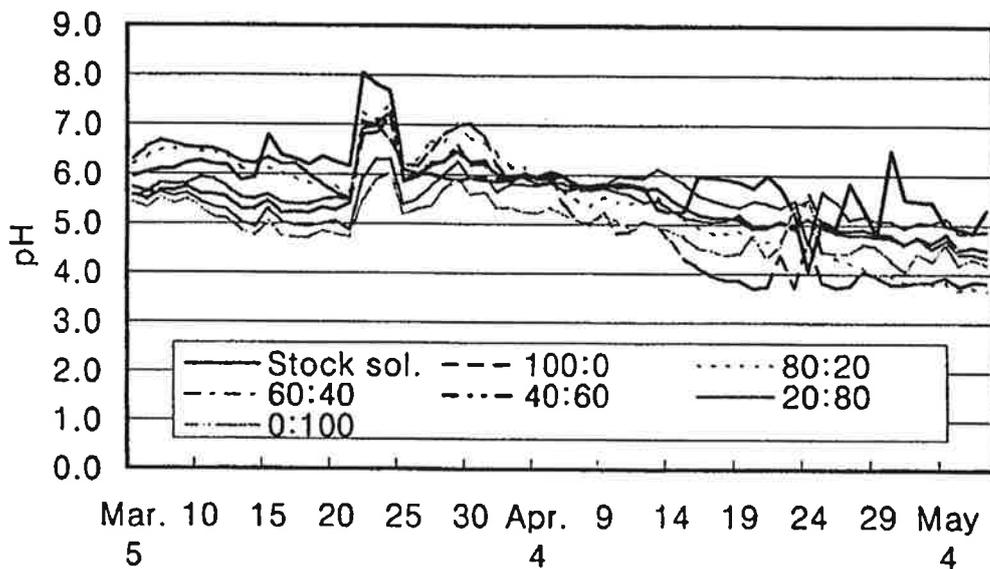


그림 6-17. 실험기간동안의 배양액의 pH 변화

재배기간동안의 배양액과 배출액의 pH를 나타낸 것이 그림 6-17이다. pH는 EC에 비하여 변동의 폭이 심하지 않았으며 생육이 진전됨에 따라 pH가 점차 저하하는 경향을 나타냈다. 코코피트가 100%인 처리구가 pH가 가장 낮았으며 퍼라이트가 많은 처리구보다 코코피트가 많은 처리구에서 pH가 낮았으며 생육 후기에는 퍼라이트가 많은 처리구가 더 저하하였다.

14

3

6-5

가

가

가

40:60

20:80

가

20:80

0:100

20:80

2317cm² 가

가

가

가

15cm

가

12

13cm

가

가

가

6-5.

71

	(cm)	(mm)	(cm)	(ea)	(cm)	(ea)					
							(cm)	(mm)			
P:C=100 : 0y	56.4cz	7.3	25.8a	50.3d	1563.7d	158.2c	1.7a	5.2			
80 : 20	59.4b	7.9	24.5a	57.0bc	1935.0bc	153.7cd	1.3b	4.9			
60 : 40	59.1b	7.6	24.1ab	54.6c	1817.3cd	147.3d	0.8c	5.4			
40 : 60	68.4a	8.0	20.2b	62.3a	1842.3c	170.0bc	1.3b	5.5			
20 : 80	69.1a	7.8	15.9c	63.0a	2317.7a	179.7ab	1.8a	5.2			
0 : 100	67.7a	8.0	18.2bc	58.6b	2269.0ab	197.5a	1.6a	5.0			
	(cm)	(g/plant)					(g/plant)				
P:C=100 : 0y	16.4a	61.5c	47.2d	87.7a	41.0a	237.4b	11.8c	15.1c	16.1a	4.4a	47.4c
80 : 20	15.7ab	83.4b	62.1c	63.5b	36.6bc	245.6b	15.6ab	20.7b	11.8a	4.2a	52.3b
60 : 40	16.0a	77.6bc	53.2d	55.2b	37.6ab	223.5b	12.6bc	16.7c	10.9a	4.2a	44.3c
40 : 60	15.4b	90.5ab	70.5a	80.1a	33.1c	274.9a	16.2a	22.0b	15.6b	3.3b	57.1a
20 : 80	12.3d	104.6a	68.9b	31.7c	16.1e	221.3bc	18.5a	26.1a	10.3c	2.0c	56.9a
0 : 100	13.8c	91.6a	66.3b	31.0c	22.2dc	214.0c	16.3a	23.4ab	10.0c	2.4c	52.1b

z Mean separation within columns by Duncan's multiple range test at 5% level.

y P:C represents mixing ratios(v/v) of perlite and cocopeat

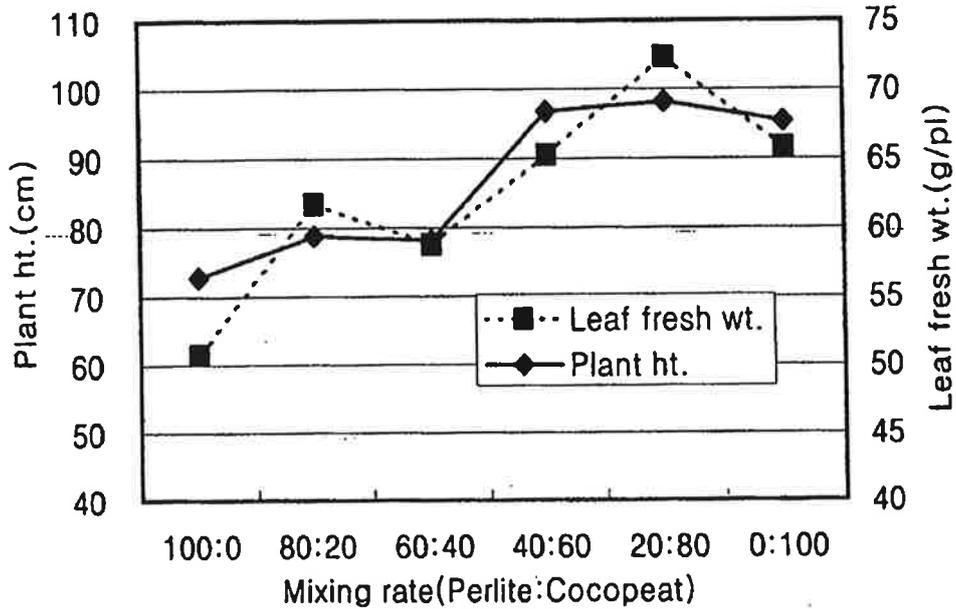


그림 6-18. 배지의 혼합비율에 따른 양액재배 국화의 초장과 엽생체중의 비교

그림 6-18은 배지의 혼합비율별 엽생체중과 초장을 비교한 것이다. 엽생체중과 초장은 거의 유사한 경향을 나타냈으며 퍼라이트가 많을수록 수치가 낮았으며 코코피트가 많을수록 양호한 성장을 나타냈으며 퍼라이트와 코코피트가 20:80으로 혼합한 경우가 초장생장과 엽생체중 확보에 있어 유리한 것으로 생각되었다. 그러나 절화에 있어 중요한 꽃의 경우 퍼라이트가 많은 처리구에서 우수한 것으로 나타나 이들을 조합시킬 수 있는 방법은 배지로서는 불가능하므로 배지의 혼합비율을 20:30으로 처리한 후 양액농도나 양액의 성분농도 증감에 의한 화경증대방안을 모색하여야 할 것으로 생각되었다. 그외 지상부 온도 환경이나 근권의 온도조절에 의한 화경의 증대방법도 고려해볼 수 있을 것이다.

그림 6-19는 재배기간동안의 수분소비량을 나타낸 것이다. 수분소비량은 배양액의 관수량에서 배액량을 뺀 것으로 나타났으며 이 자료는 각 처리구 전체

량을 표시한 것이다. 수분소비량이 가장 적은 것은 퍼라이트 100% 처리구였으며 가장 많은 것은 생육초기에 20:80처리구, 생육후기에는 코코피트 100%처리구로 나타났다. 수분소비량은 4월 9일 이후 급격히 증가하는 경향을 나타냈으며 4월 19일부터 27일까지 정점을 이루다 점차 소비량이 줄어드는 경향이였다.

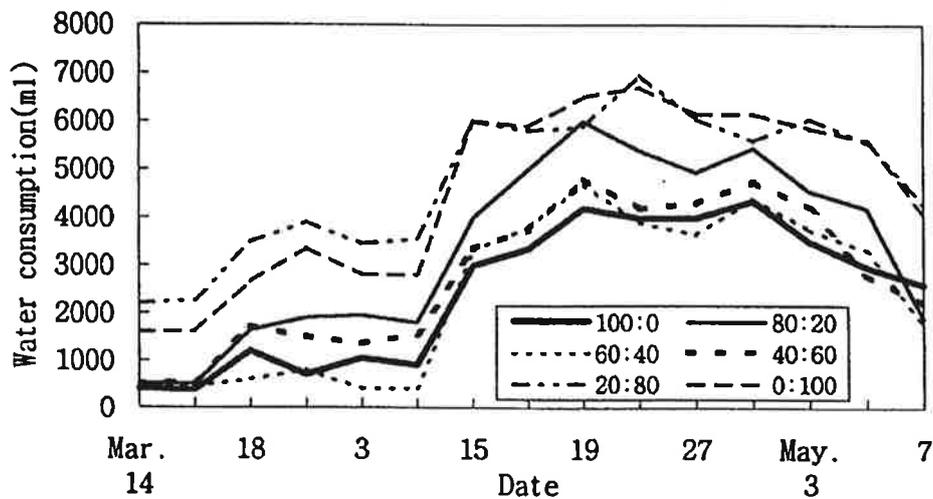


그림 6-19. 배지의 혼합비율에 따른 양액재배 국화의 수분흡수량 변화

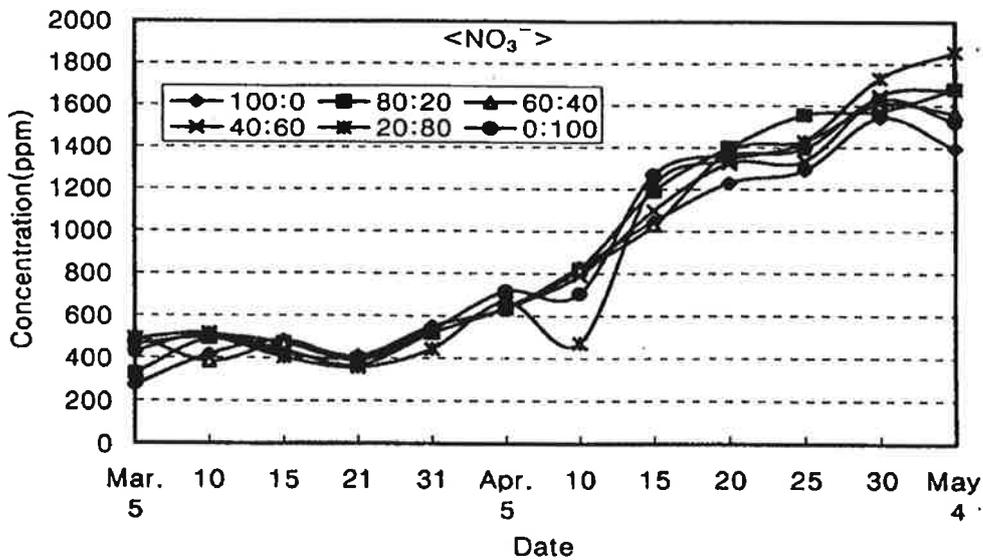


그림 6-20. 실험기간중 배액의 NO_3^- 의 농도변화

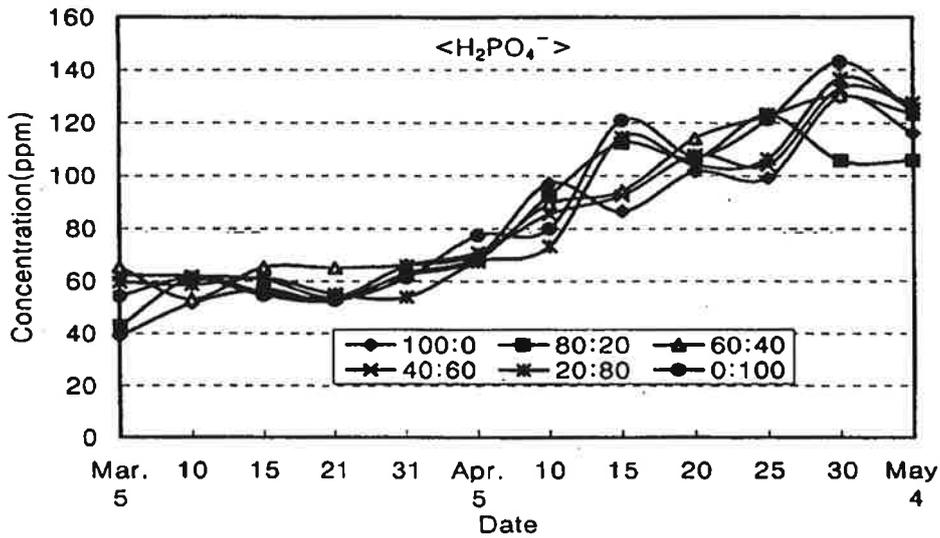


그림 6-21. 실험기간중 배액의 H_2PO_4^- 의 농도변화

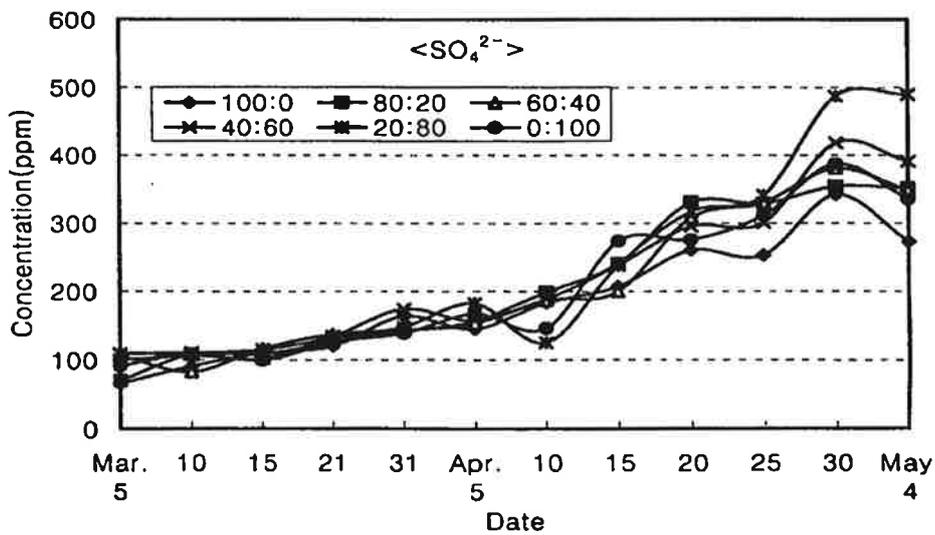


그림 6-22. 실험기간중 배액의 SO_4^{2-} 농도의 변화

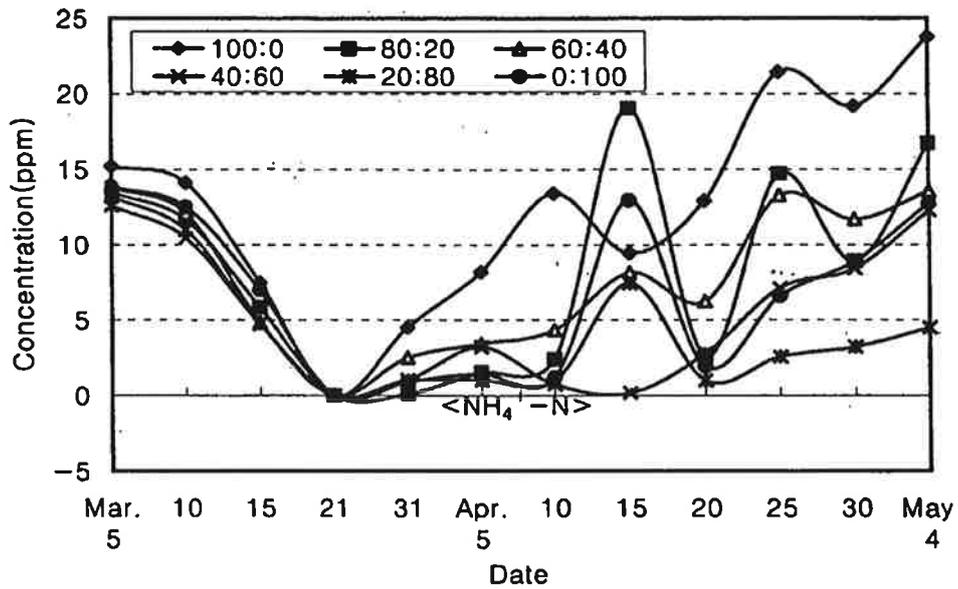


그림 6-23. 실험기간중 배액의 NH₄⁺ 농도의 변화

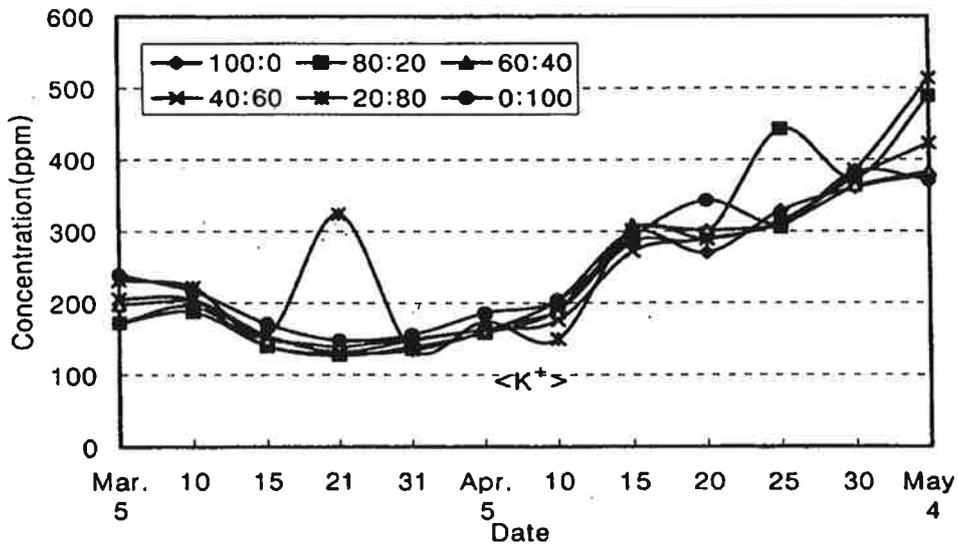


그림 6-24. 실험기간중 배액의 K⁺ 농도 변화

가 가

가

. NO₃⁻

3

가

가 4

가

5

1600ppm

가

.

6- 21

6- 22

H₂PO₄⁻

SO₄²⁻

.

40 60ppm

120ppm

50 100ppm

300 500ppm

40:60

20:80

가

.

6- 23

NH₄⁺

.

3 21

가 4 10

.

.

3 21

가

가

가

가

3 21

가

가

가

가

.

6- 24

K⁺

.

200ppm

3

21

가

가

400 500ppm

2.

, II-2 가 .
 가 II-3
 430g 가 가
 II-1 가 가 ,
 가 .
 가 I II-1 10
 228 237 가 II-3
 가 216 . 40 60 가
 . I
 10 39kg 가 가
 40 가 가
 32kg/10 가 .
 가 .
 가 가
 가 II-2 가 II-3
 가 .
 6-7 6-8 25 54
 .
 (NH₄-N) 25
 0 8% 54

20 50%

25 가 , , 100%
 , ,
 가
 400% 가

6-7.

(5 21 , 26) (: , %)

	Na+	NH ₄ -N	K+	Ca ²⁺	Mg ²⁺	Cl-	NO ₃ ⁻ -N	P	S
(40)	464	5	52	98	169	210	64	36	201
(60)	451	0	37	72	102	173	46	11	212
Biobed I () (25)	245	0	55	78	126	157	50	14	171
Biobed II-1 () (25)	313	5	69	113	217	168	81	86	275
Biobed II-2 () (25)	296	8	79	120	189	167	84	77	205
Biobed II-3 () (25)	337	8	51	85	124	173	40	12	200

54

25 100%
 가
 가 가

6-8.

(6 19 , 54) (: , %)

	Na+	NH ₄ -N	K+	Ca ²⁺	Mg ²⁺	Cl-	NO ₃ ⁻ -N	P	S
(40)	291	16	61	112	229	81	69	44	305
(60)	210	55	82	104	162	90	84	100	185
Biobed I ()	163	45	89	110	168	95	84	84	173
Biobed II-1 () (25)	200	57	100	114	164	114	75	89	197
Biobed II-2 ()	284	20	93	140	243	108	89	72	296
Biobed II-3 ()	293	18	84	131	236	115	84	58	297

3.

가

1884g

가

162 16.5

6.97g

4.42g

가

6-9.

				(Brix)	(g/plant)	
	(g)	(mm)	(mm)			
	1820.3 ± 100.3	147.2 ± 0.9	152.3 ± 2.3	16.2 ± 2.3	136.0 ± 19.1	4.42 ± 0.98
	1884.0 ± 81.7	147.2 ± 0.8	151.8 ± 1.2	16.5 ± 1.1	130.7 ± 21.1	6.07 ± 0.85

가

가

가

가

가

가

4

1.

1/3

가 가 .

가

가

(,)

6- 10.

(300)

	(가)		가	
(40)	2,000 *4,000 = 8,000,000	800 *8,000 = 6,400,000	1000	,
(25)	2,000 *2,500 = 5,000,000	500 *8,000 = 4,000,000	10% 1,000,000	10 15 1,000,000
	3,000,000	2,400,000	1,000,000	1,000,000
	7,400,000 (300)			

10.

(300)

	(가)		가	
(40)	1,000 *4,000 = 4,000,000	400 *8,000 = 3,200,000	1000	1000
(25)	1,000 *2,500 = 2,500,000	250 *8,000 = 2,000,000	5% 500,000	15% 1,500,000
	1,500,000	1,200,000	500,000	1,500,000
	4,700,000 (300)			

9 10 가

가 4000 가
 가 2500 가
 100 1 가 가 8000 300
 1000
 1 2
 3 1

2.

- (1) () 가
- (2)
- (3) 가

- (4) 가 (: ,)
- (5) ,
- (6)

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(n/w, n me

, w ,

l)

山崎 (1976)

高野 (1980)

가

, 山崎

80

가

가

90

가

EC

pH

가

가

가

가

가

가

가

가

1.

가

1 10a 5 6m³ pH가 , 가 ,

가

BOD() COD()
BOD가 가 , (CH₄),
(NH₄), (H₂S), (Fe), (Mn)
COD가 BOD가
가 (Cu)

1.0ppm 가
가
pH가

가

가
Ca, Mg, Fe, Mn, Cu, Sn,

HCO₃⁻, Cd, Pb

가

가

가 .

(

)

가

가

pH가 4.5 5.2

가

가

(EC), (pH)

:

(NO₃⁻- N),

(NH₄⁺ N),

(K⁺),

(Ca⁺⁺),

(H₂PO₄⁻ P),

(Mg⁺⁺),

(SO₄²⁻ S)

:

(Fe²⁺),

(Mn²⁺),

(Cu²⁺),

(Zn²⁺),

(Mo²⁺),

(B²⁺)

:

(Na⁺),

(Cl⁻),

(HCO₃⁻)

7-1

7-2

全農

PTG가

7-1

7-1. 全農

EC	0.3mS/cm
pH	5 8
N(NO ₃ ⁻ N, NH ₃ - N)	
Ca	40ppm
Mg	20ppm
Cl	60ppm

7-2. PTG

	1	2
Cl	< 50 ppm	50 100 ppm
Na	< 30 ppm	30 60 ppm
HCO	< 40 ppm	< 40 ppm
Fe	< 1.0 ppm	< 1.0 ppm
Mn	< 0.5 ppm	< 1.0 ppm
B	< 0.3 ppm	< 0.7 ppm
Zn	< 0.5 ppm	< 1.0 ppm
EC	< 1.5 ppm	

7-3. (, 95)

	A	B	A	B	C
pH	5.5 7.5	5.0 8.0	6.0 7.5	5.0 8.0	5.0 8.0
EC(mS/cm)	<0.3	<0.5	<0.2	<0.5	<0.5
Ca(ppm)	<20	<60	<20	<40	<80
Mg	<10	<20	<5	<15	<30
Na	<20	<30	<10	<30	<60
Cl	<15	<30	<15	<30	<50
SO4	<20	<40	<20	<40	<60
HCO3	<50	<100	<50	<100	<200
Fe	<0.5	<1.0	<0.03	<0.5	<1.0
Mn	<0.2	<0.6	<0.2	<0.6	<1.0
Zn	<0.2	<0.5	<0.15	<0.5	<1.0
B	<0.05	<0.1	<0.05	<0.1	<0.7

A :

B :

C :

가

가

EC

가 0.3mS/cm

가

1.5mS/cm

가 .

Na

Cl

,

가

Ca,

Mg, K

가

EC

.

가

EC

Ca, Mg

Na

Cl

.

,

,

,

,

가

가

7-3

Na Cl

.

가

.

3

0 40ppm

Na

Cl

가

가

75ppm

100ppm

Ca Mg

가 .

NaCl

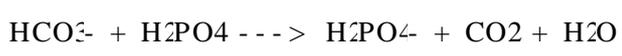
가

가

NaCl

가

Fe가 Fe(HCO₃)₂ , Fe(OH)₃
 Fe(OH)₃ 가
 HCO₃⁻ (A) pH
 가 (B)
 (4%) (40%) pH
 HCO₃⁻가



, , 가 가 가
 가 가 가
 1 가

7-4. (1997. 3 - 12)

		Ca	K	N	S	Cl-	HCO ₃ ⁻	
		6.7	0.5	1.7	22.3	10.1	198.0	1
		52.9	2.1	-	-	-	192.8	2
		7.0	0.8	0.7	2.1	11.3	173.0	3
		24.7	0.5	-	1.3	10.4	140.3	4
		4.5	10.1	3.2	0.8	27.0	140.0	5
		7.9	0.3	0.4	39.7	8.3	140.0	6
		41.9	1.4	2.0	3.1	16.3	140.0	7
		17.3	1.1	0.6	-	-	128.7	8
		14.3	0.5	3.0	3.8	15.1	125.6	9
		22.7	1.0	1.6	1.9	6.0	119.0	10
		9.1	1.4	0.6	19.0	11.0	90.0	11
		9.4	1.3	-	-	-	72.6	12
		9.5	1.2	0.4	-	-	69.5	13
		12.2	1.3	0.5	-	-	68.3	14
		4.2	3.4	2.5	9.8	14.0	65.0	15
		21.6	-	0.8	5.5	0.4	54.0	16
		16.3	1.1	-	-	-	52.5	17
		29.1	1.2	5.5	6.3	0.4	43.0	18
		21.0	5.6	8.2	8.5	5.3	30.6	19
		1.9	3.0	5.1	36.0	68.0	-	20

7-4

1997. 3

12

가

2.

가.

(EC)

가

가

EC

가

가

가

가

가

(, atm)

(mM)

$$= 0.0224 \times \times$$

가 . Jones(1983)

가

$$= 0.218 - 0.36 \times EC$$

가

가

가

가

가

가

가

pH

pH 5.5 6.5 가 , 5.0 7.0

pH 가

$\text{NO}_3^- \cdot \text{NH}_4^+$

가

NO_3^- 가

pH

, NH_4^+ 가

pH

pH

NO₃⁻ NH₄⁺
가

pH가

pH

pH가

가

pH가 가

3 Fuzzy

1. Fuzzy

1965 L. A. Zadeh “
(fuzzy set theory) 1974 E. H. Mandani
(FLC; Fuzzy Logic Controller)가
, 가 ,
가 가
가 가 .
가 ,
(neuron) . , system
.
.
(Membership function) (discrete)
가 . random 가
.
가
,
.
project

rule

2.

가.

가
(High Level) 가

()

가

가

- : 가
- :

- : ()
- :

(tuning)

- : (low level) ()
.)

- : (high level) ()
)

- : ()

- :
가 .

- : (classification)
(associative memory)
(function approximation)

- : (classification)
(associative memory)
(function approximation)
()

(anology)

(sigmoid)

가 ($\sum X_i W_i$)

($MAX\ MIN\ {\kappa_A(A'), \kappa_B(B')}$) .

가

() .

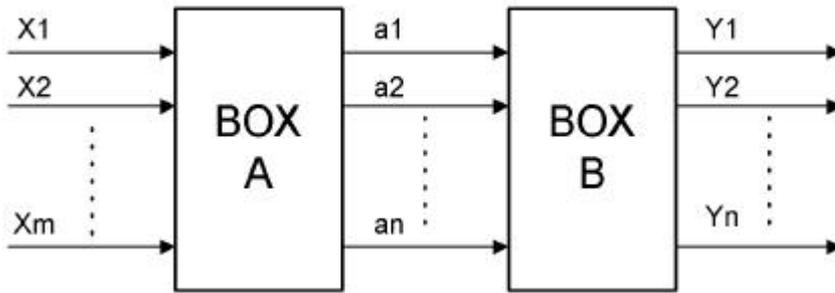
1)

()

2)

:
: 가 .()

3) block diagram.



7-1. block diagram.

BOX A:

BOX B:

◎ 퍼지추론 규칙

R_1 : if X_1 is A_1^1 and $\dots\dots\dots X_m$ is A_m^1
 then Y_1 is C_1^1 and $\dots\dots\dots Y_n$ is C_n^1

R_2 : if X_1 is A_1^2 and $\dots\dots\dots X_m$ is A_m^2
 then Y_1 is C_1^2 and $\dots\dots\dots Y_n$ is C_n^2

R_k : if X_1 is A_1^k and $\dots\dots\dots X_m$ is A_m^k
 then Y_1 is C_1^k and $\dots\dots\dots Y_n$ is C_n^k

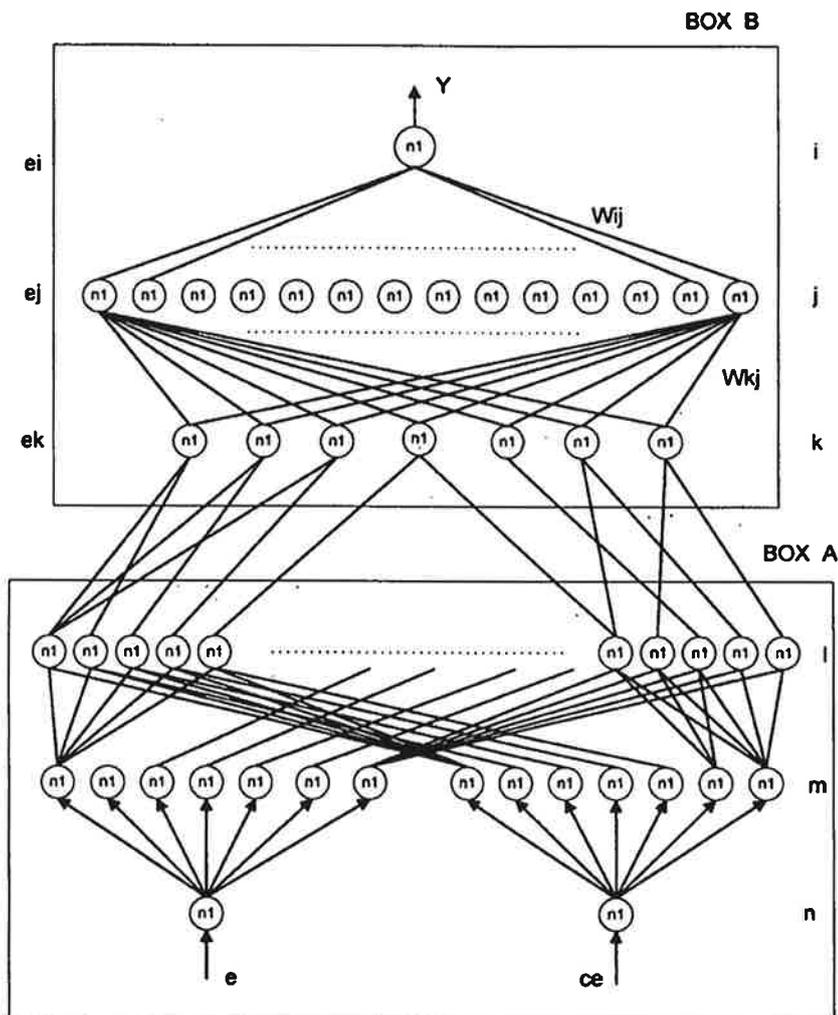


그림 7-2. 퍼지 신경망의 구성

BOX B : $\alpha_1^i, \alpha_2^i, \dots, \alpha_i^i, \lambda_i$
 - λ_i : $(\alpha_1^i, \alpha_2^i, \dots, \alpha_i^i,)$

가 ()

$$E = -\frac{1}{2} \sum (\vartheta_i - o_i)^2$$

가

1) i 가 j 가 Wji

$$\begin{aligned} \nabla W_{ji} &= - \lambda \frac{\partial E}{\partial W_{ji}} = - \lambda \frac{\partial E}{\partial o_i} \frac{\partial o_i}{\partial net_i} \frac{\partial net_i}{\partial W_{ji}} \\ &= \lambda (\vartheta_i - o_i) f'_i (net_i) o_j \end{aligned}$$

$$\frac{\partial E}{\partial o_i} = - (\vartheta_i - o_i) \quad \frac{\partial o_i}{\partial net_i} = f'(net_i) = f(1-f)$$

$$\frac{\partial net_i}{\partial W_{ji}} = \frac{\partial}{\partial W_{ji}} \sum W_{ji} o_j = o_j$$

$$net_i = \sum W_{ji} o_j$$

$$o_i = f(net_i)$$

$$\epsilon_i = - \frac{\partial E}{\partial net_i} = - \frac{\partial E}{\partial o_i} \frac{\partial o_i}{\partial net_i} = (\vartheta_i) f'(net_i)$$

:

f : ()

2) j 가 i 가 Wkj

$$\begin{aligned} \nabla W_{kj} &= - \lambda \frac{\partial E}{\partial W_{kj}} = - \lambda \frac{\partial E}{\partial o_j} \frac{\partial o_j}{\partial W_{kj}} = - \lambda \frac{\partial E}{\partial o_j} \frac{\partial o_j}{\partial net_j} o_k \\ &= \lambda \left(- \frac{\partial E}{\partial o_j} \right) f'(net_j) o_k = \lambda \sum_i \epsilon_i W_j f'(net_j) o_k = \lambda \epsilon_i o_k \end{aligned}$$

$$\frac{\partial E}{\partial o_j} = \sum_i \frac{\partial E}{\partial net_i} \frac{\partial net_i}{\partial o_j} = \sum_i \epsilon_i W_{ij} f'(net_j)$$

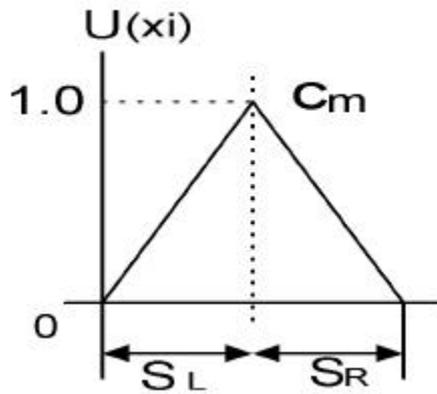
$$\epsilon_j = - \frac{\partial E}{\partial net_j} = - \frac{\partial E}{\partial o_j} \frac{\partial o_j}{\partial net_j} = \sum_i \epsilon_i W_{ij} f'(net_j)$$

3) (momentum rate) 가

$$\nabla W_{ji}^{(t)} = \eta \frac{\partial E}{\partial W_{ji}} + \alpha \nabla W_{ji}^{(t-1)}$$

$$\nabla W_{kj}^{(t)} = \eta \frac{\partial E}{\partial W_{kj}} + \alpha \nabla W_{kj}^{(t-1)}$$

BOX A : (x_1, x_2, \dots, x_m)
 (y_1, y_2, \dots, y_m)



7-3.

$$C_m, S_L, S_R(X) = \begin{cases} 1 - \frac{x - c_m}{S_R} & x \in [c_m, c_m + S_R] \\ 1 - \frac{x - c_m}{S_R} & x \in [c_m - S_L, c_m] \\ 0 & \text{otherwise} \end{cases}$$

$$C_m : \quad .$$

$$S_L, S_R : \quad (\quad)$$

- i :

$$\epsilon_i = - \frac{\partial E}{\partial net_i} = (\partial_i - o_i) f'(net_i)$$

- j :

$$\epsilon_j = - \frac{\partial E}{\partial net_j} = \sum_i \epsilon_i W_{ij} f'(net_j)$$

- k :

$$\epsilon_k = - \frac{\partial E}{\partial net_k} = \sum_j \epsilon_j W_{kj}$$

-

$$E' = -\frac{1}{2} \sum_k (t_k - o_k)^2$$

BOX A : t_k , : o_k

BOX A : $-\frac{\partial E}{\partial o_k} = (t_k - o_k)$ BOX B

k : k .

BOX A m .

(, MAX-MIN)

$$\begin{aligned} \nabla c^m &= - \frac{\partial E'}{\partial c^m} = - \frac{\partial \sum_k \frac{\partial E'}{\partial o_k} \frac{\partial o_k}{\partial c^m}}{\partial c^m} \\ &= - \frac{\partial \sum_k \frac{\partial E'}{\partial o_k} \sum_l \frac{\partial o_k}{\partial o_l} \frac{\partial o_l}{\partial c^m}}{\partial c^m} \\ &= - \frac{\partial \sum_k \epsilon_k \sum_l \frac{\partial o_k}{\partial o_l} \frac{\partial o_l}{\partial c^m}}{\partial c^m} \end{aligned}$$

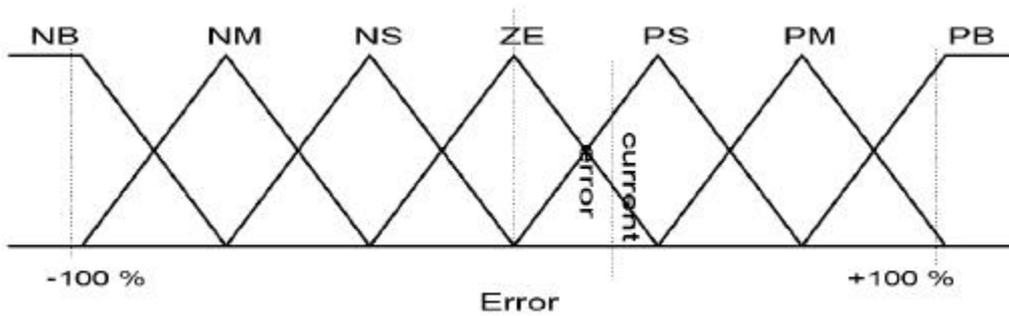
$$\frac{\partial o_k}{\partial o_l} = \begin{cases} 1 & \text{if } o_k = o_l \text{ and } W_{lk} = 1 \\ 0 & \text{otherwise} \end{cases}$$

$$\frac{\partial o_l}{\partial o_m} = \begin{cases} 1 & \text{if } o_l = o_m \text{ and } W_{ml} = 1 \\ 0 & \text{otherwise} \end{cases}$$

$$\nabla S_L = - \frac{\partial E'}{\partial S_L} = - \frac{\partial \sum_k \epsilon_k \sum_l \frac{\partial o_k}{\partial o_l} \frac{\partial o_l}{\partial S_R}}{\partial S_L}$$

$$\nabla S_R = - \frac{\partial E'}{\partial S_R} = - \frac{\partial \sum_k \epsilon_k \sum_l \frac{\partial o_k}{\partial o_l} \frac{\partial o_l}{\partial S_R}}{\partial S_R}$$

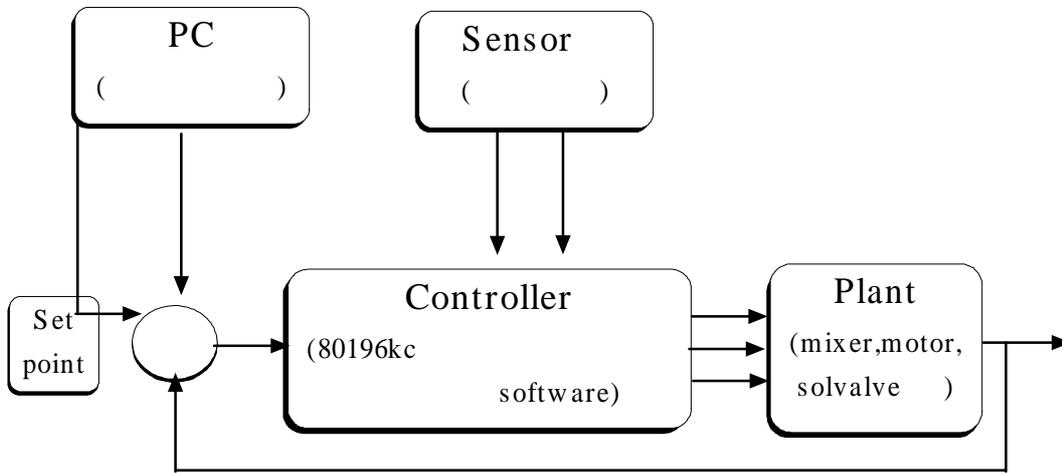
$$\frac{\partial o_m}{\partial c^m}, \frac{\partial o_m}{\partial S_R}, \frac{\partial o_m}{\partial S_R} :$$



7-4.

3.

7-5 block diagram



7-5. block diagram

, Plant

가. (Controller)

	Hardware,	Software	Relay
Solanoid Valve	Actuator		
	Hardware , 4	Main, Sub, Input- Output()	
DIO	. Main	가	가
	Intel 80C196KC		
Memory	ROM(27256) RAM(62256)		PC

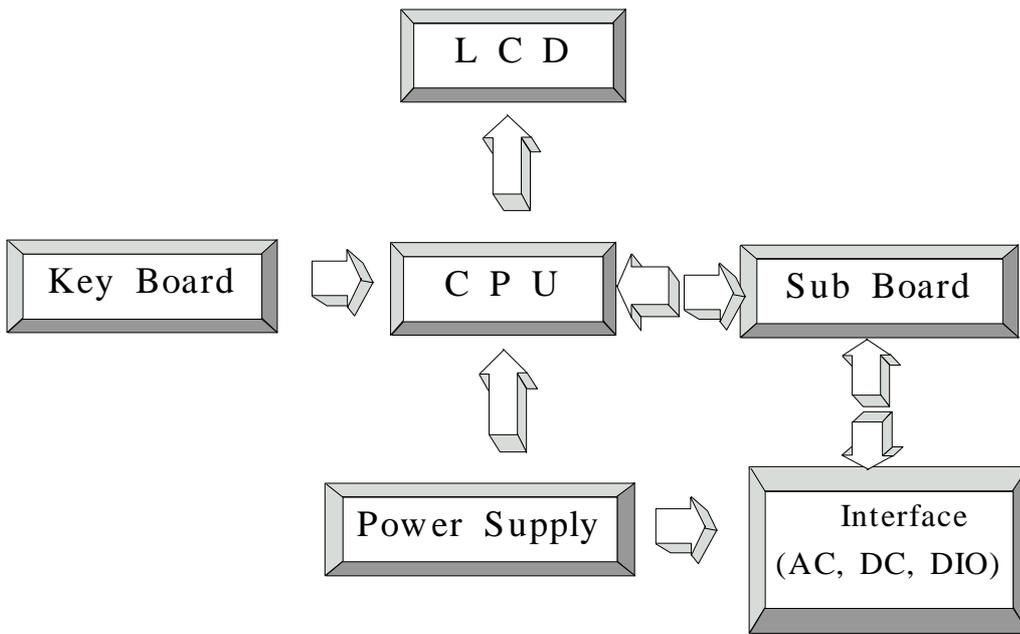
RS-232C . Intel 80C196KC
 64K 가
 가
 , 0x0000 0x01FF
 0x1FFF 0x207F .
 , (memory-mapped IO)
 7-5 Intel 80C196KC
 가 .

7-5. 80c196kc Memory Map

FFFF	6000	
5FFF	2080	/ (ROM)
205E	207F	[] []
2040	205D	PTS
2030	203F	8
2020	202F	ROM
2019	201F	[] []
	2018	
2014	2017	[] []
2000	2013	8
1FFE	1FFF	3, 4
1FFD	200	
100	1FF	(가 RAM, 196KC)
0	FF	()

Sub DIO main CPU interface
 . A/D converter actuator

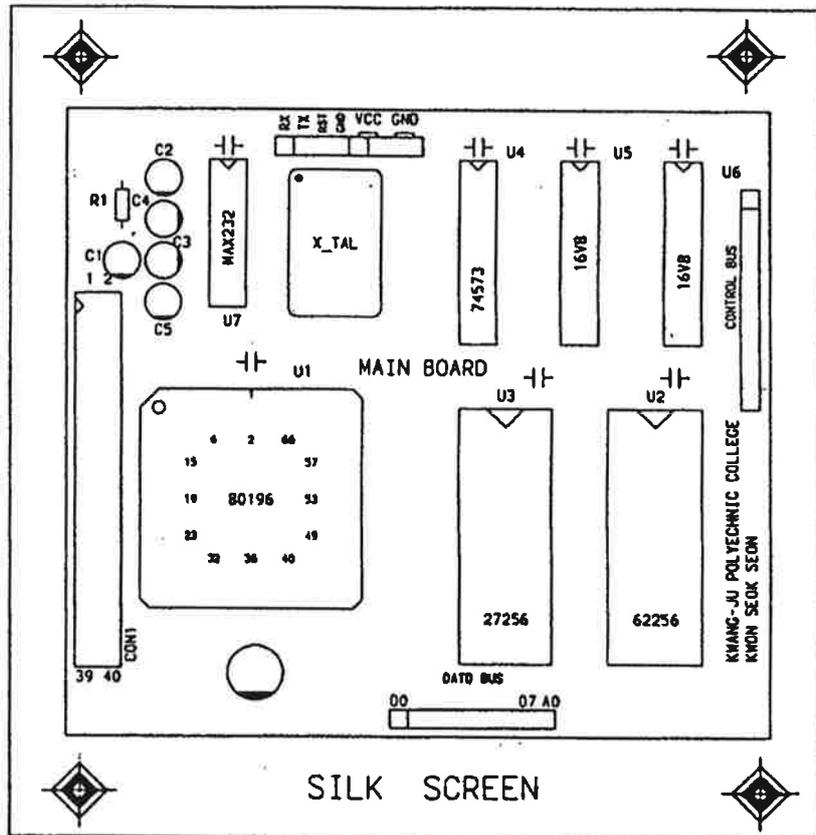
CPU digital input-ouput
 . A/D converter 8 channel , DIO Triac
 AC Sol- Valve .
 가 AC 32 channel DC 16 channel .
 DIO 가 .
 Input- output() user가 가
 , .
 key- board 가 , LCD
 .
 , software Fuzzy-
 . Turbo C++ .
 Map , 80C196KC .
 controller .
 compile link ROM writer 27C256 ROM
 .
 , relay solenoid valve actuator . Actuator
 , .
 relay , .
 . motor
 . 7-6 block diagram . PCB



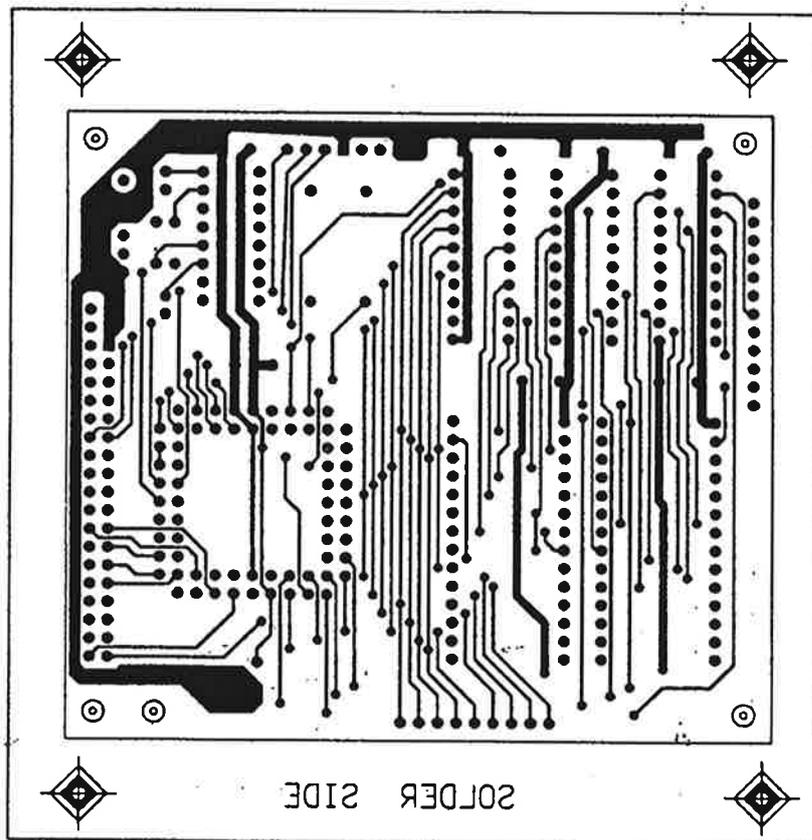
7-6. block diagram

7-7 7-14

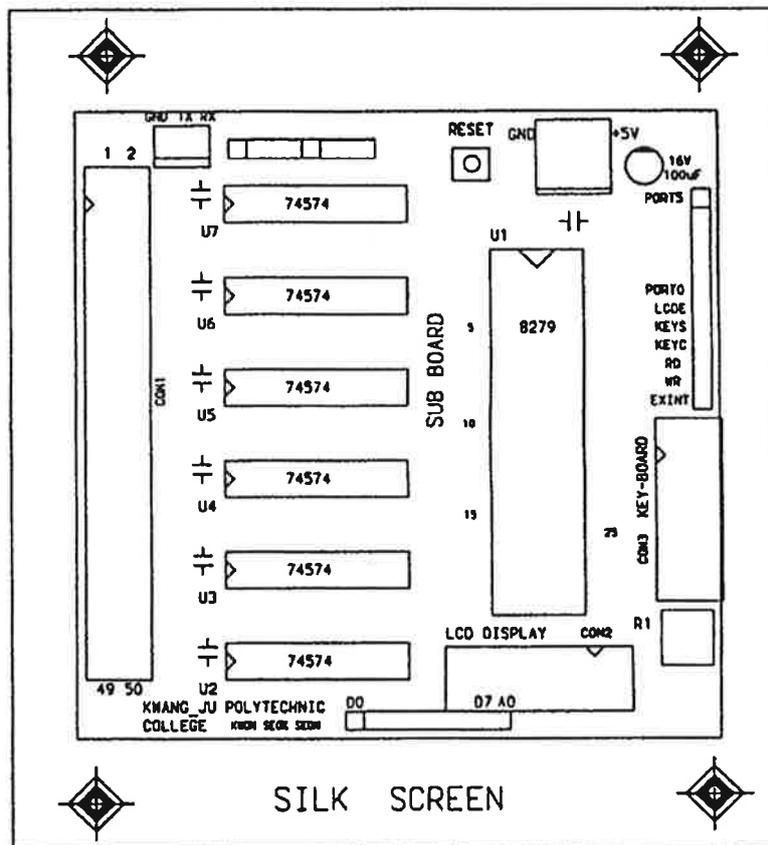
PCB



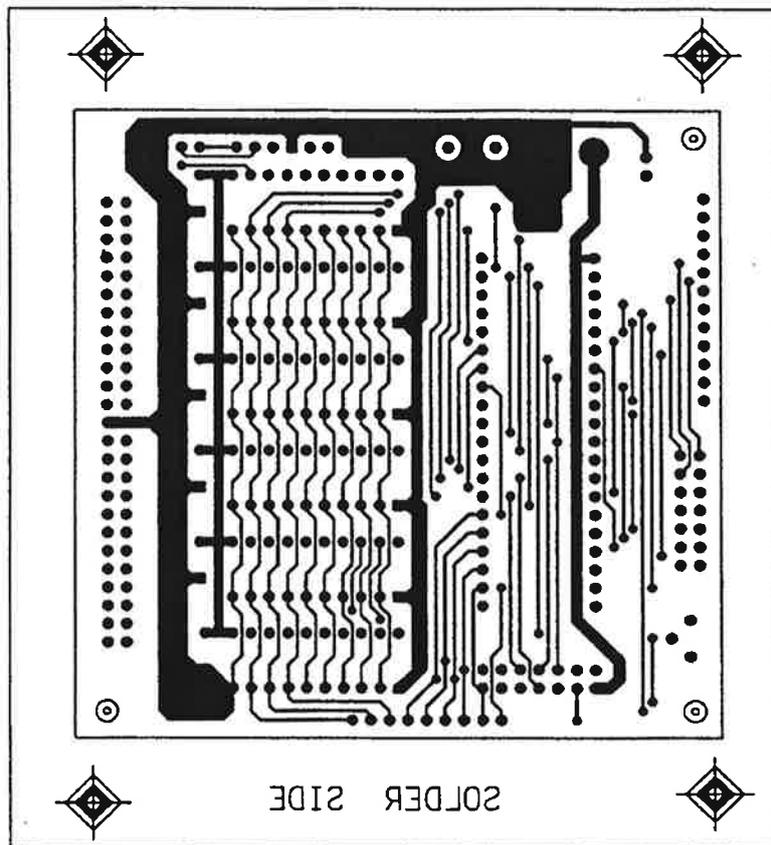
7-7. Main board의 silk screen



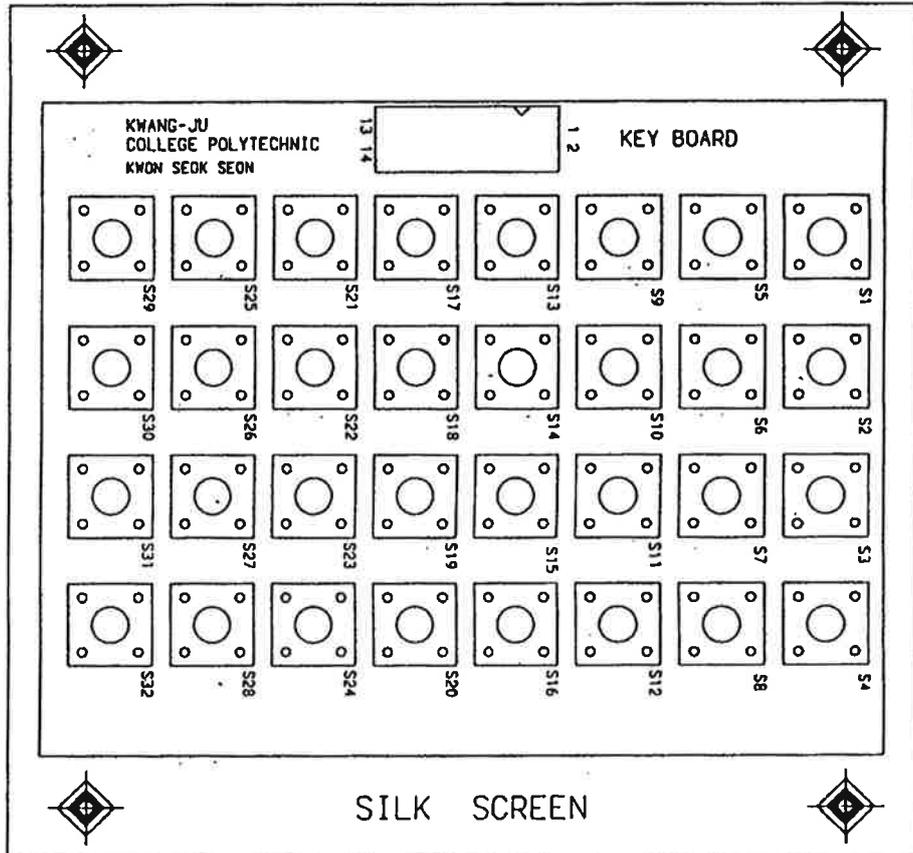
7-8. Main board의 solder mask



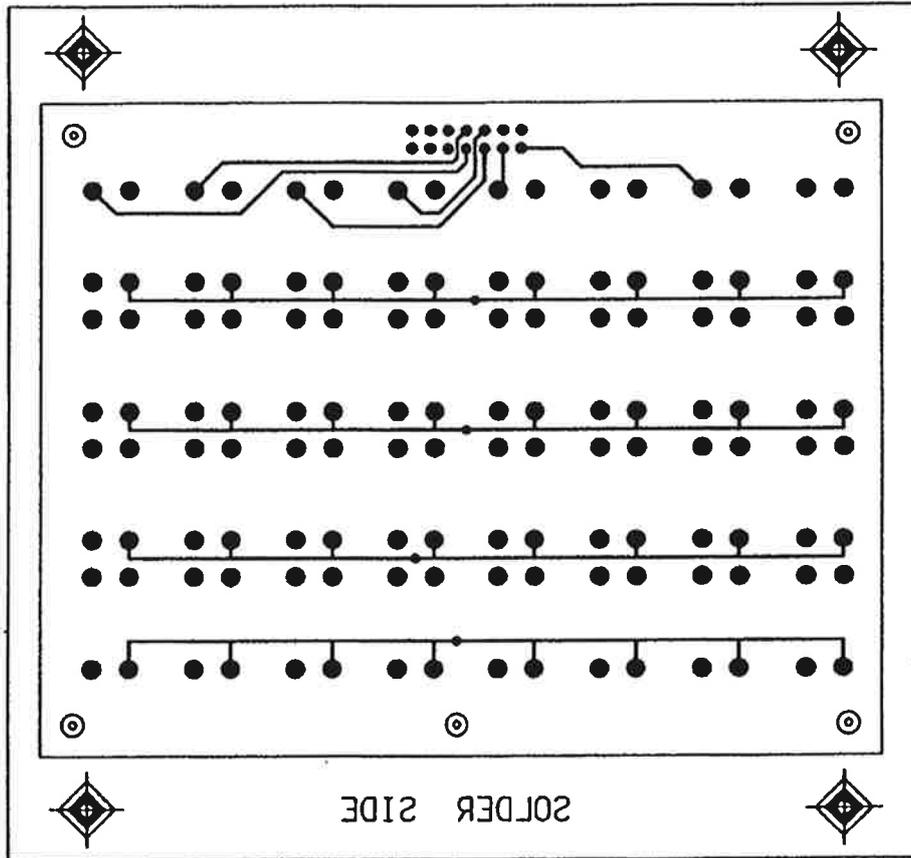
7-9. Sub board의 silk screen



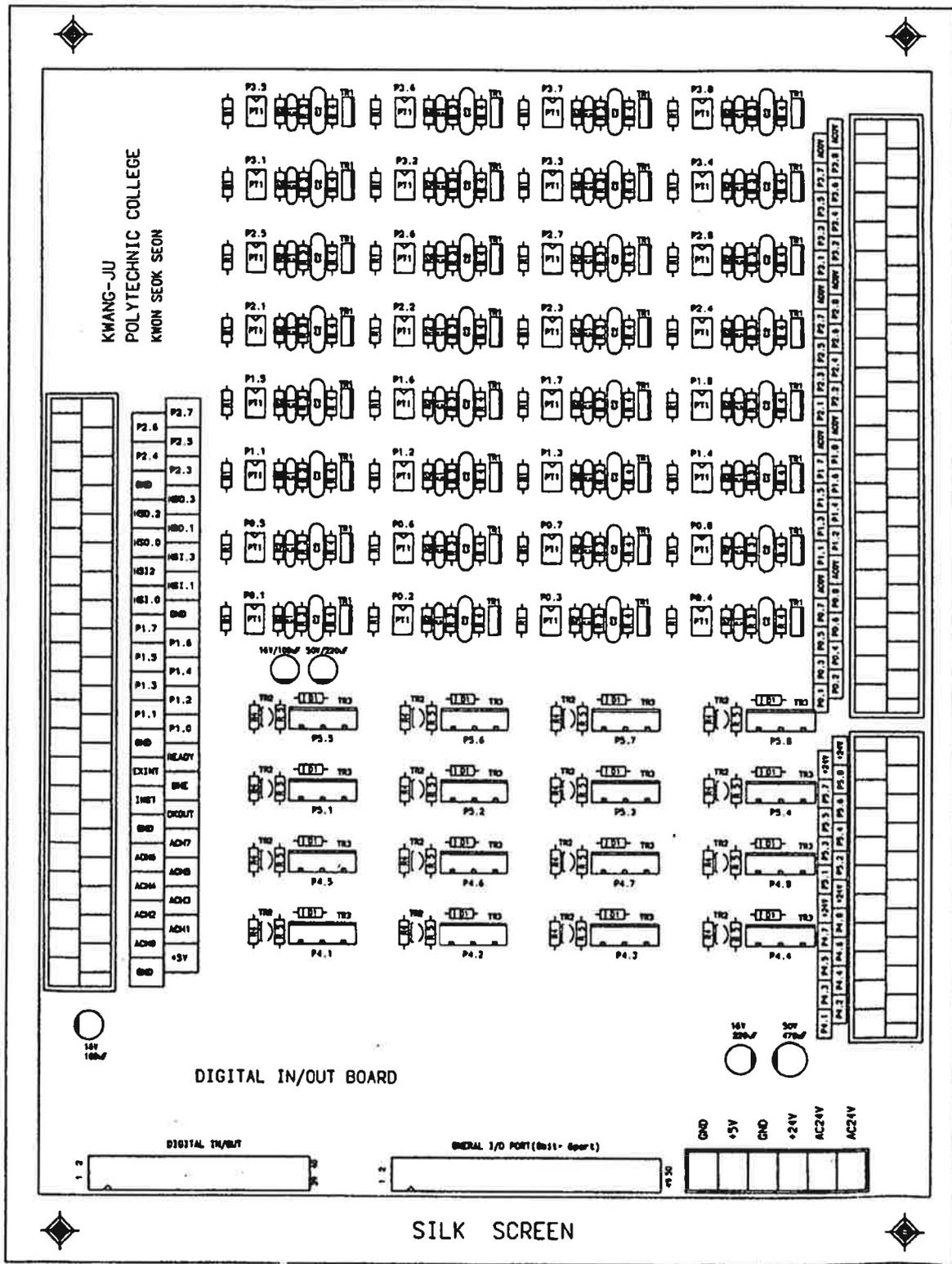
7-10. Sub board의 solder mask



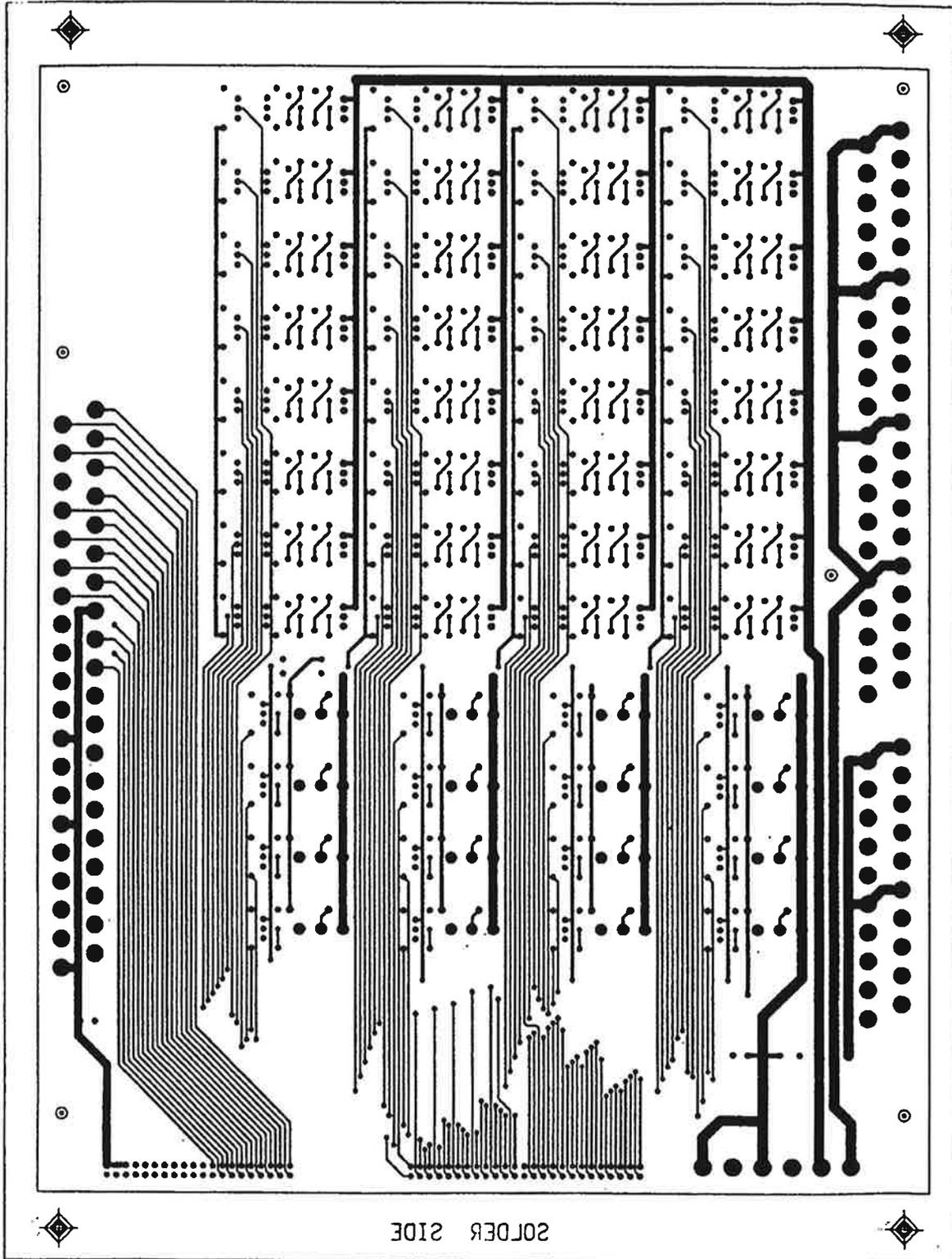
7-11. Key board의 silk screen



7-12. Key board의 solder mask



7-13. Digital in/out board의 silk screen



7-14. Digital in/out board의 solder side

. Plant()

. Controller

Sol- Valve motor

0.1ton

1 ton

, 가 .
motor bed

motor가

1

Sol- Valve

Plant()

S1, S3

P1

P1

. T1

Data- base

가 S4 S6

P1

가

S4, S5

P1

가

7- 15

7- 16

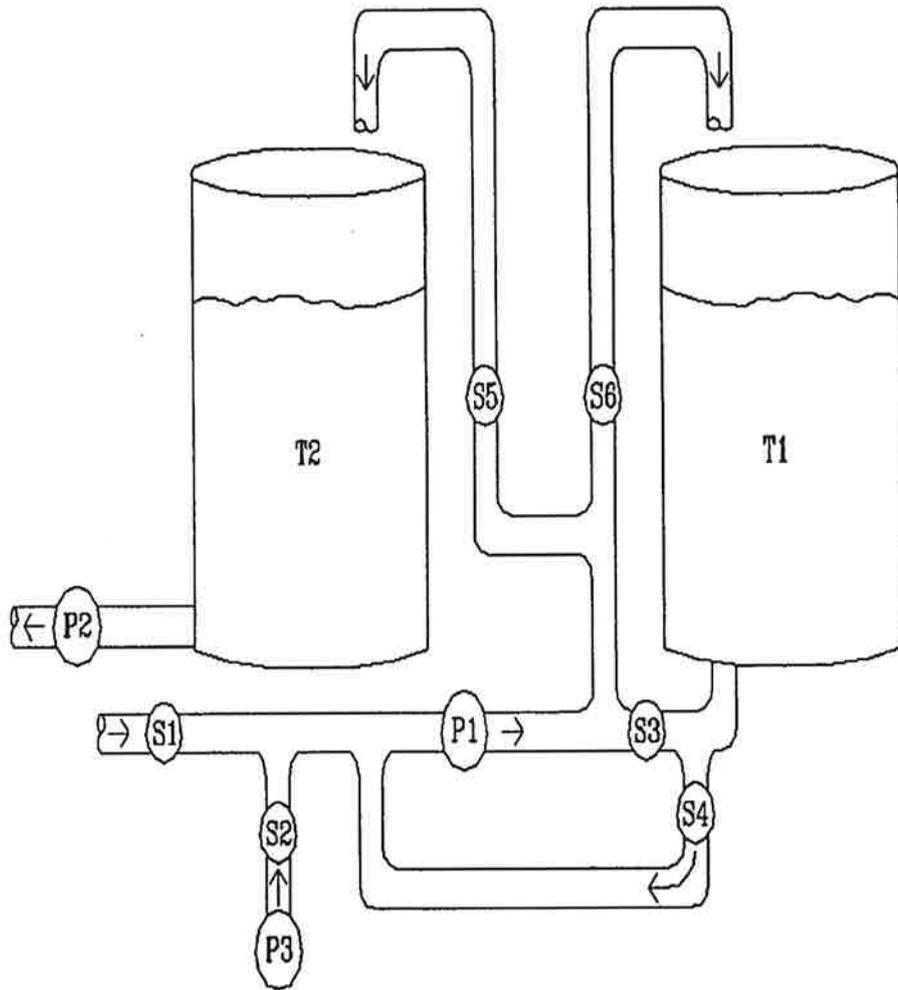
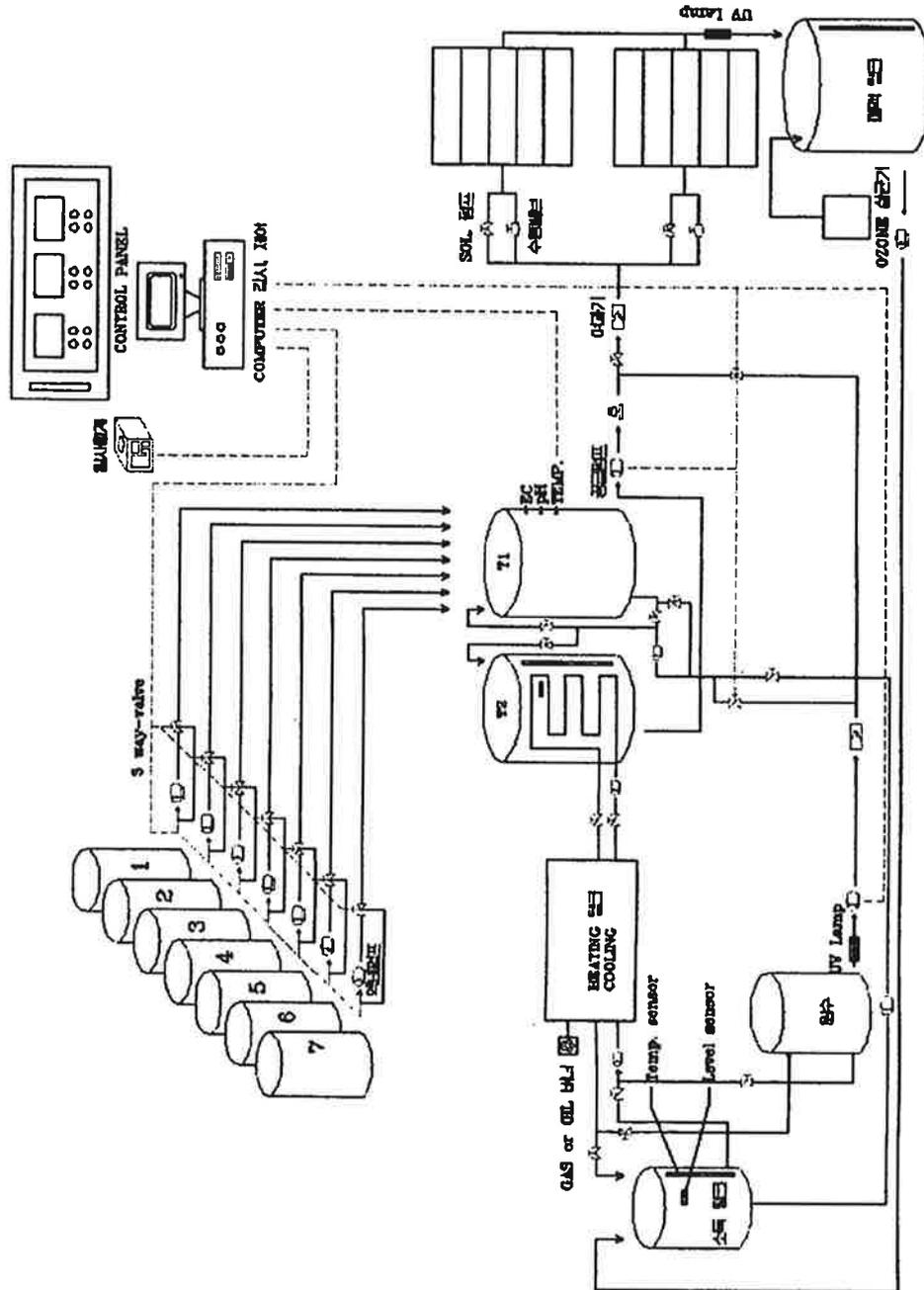


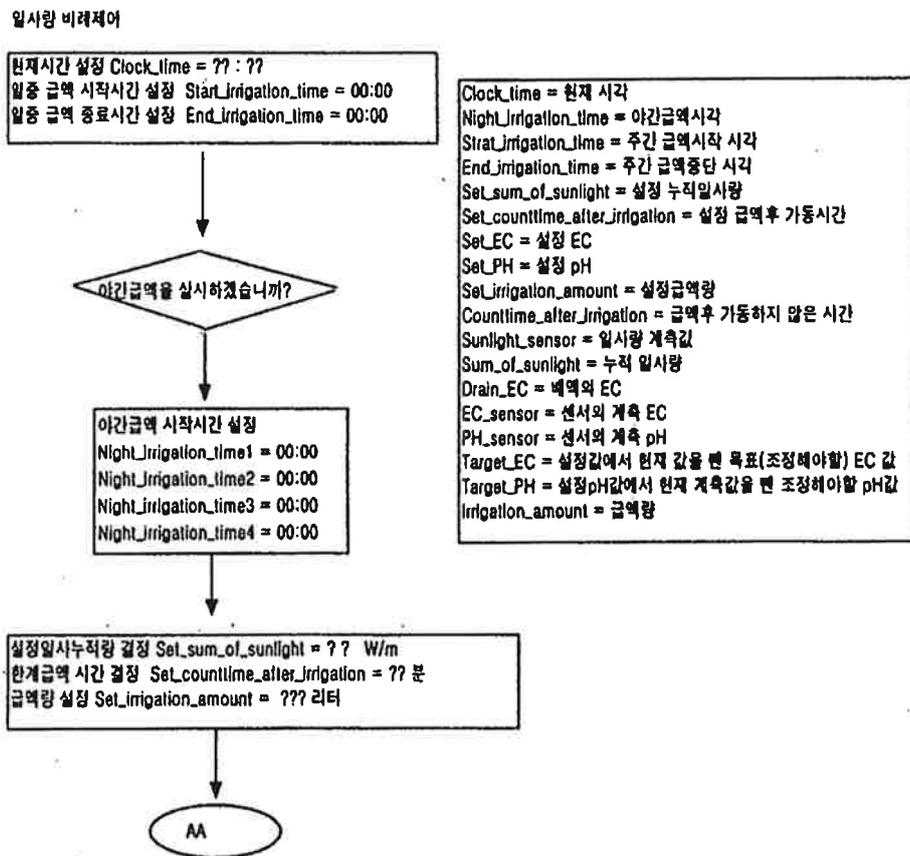
그림 7-15. 양액회석탱크의 세부 배관도

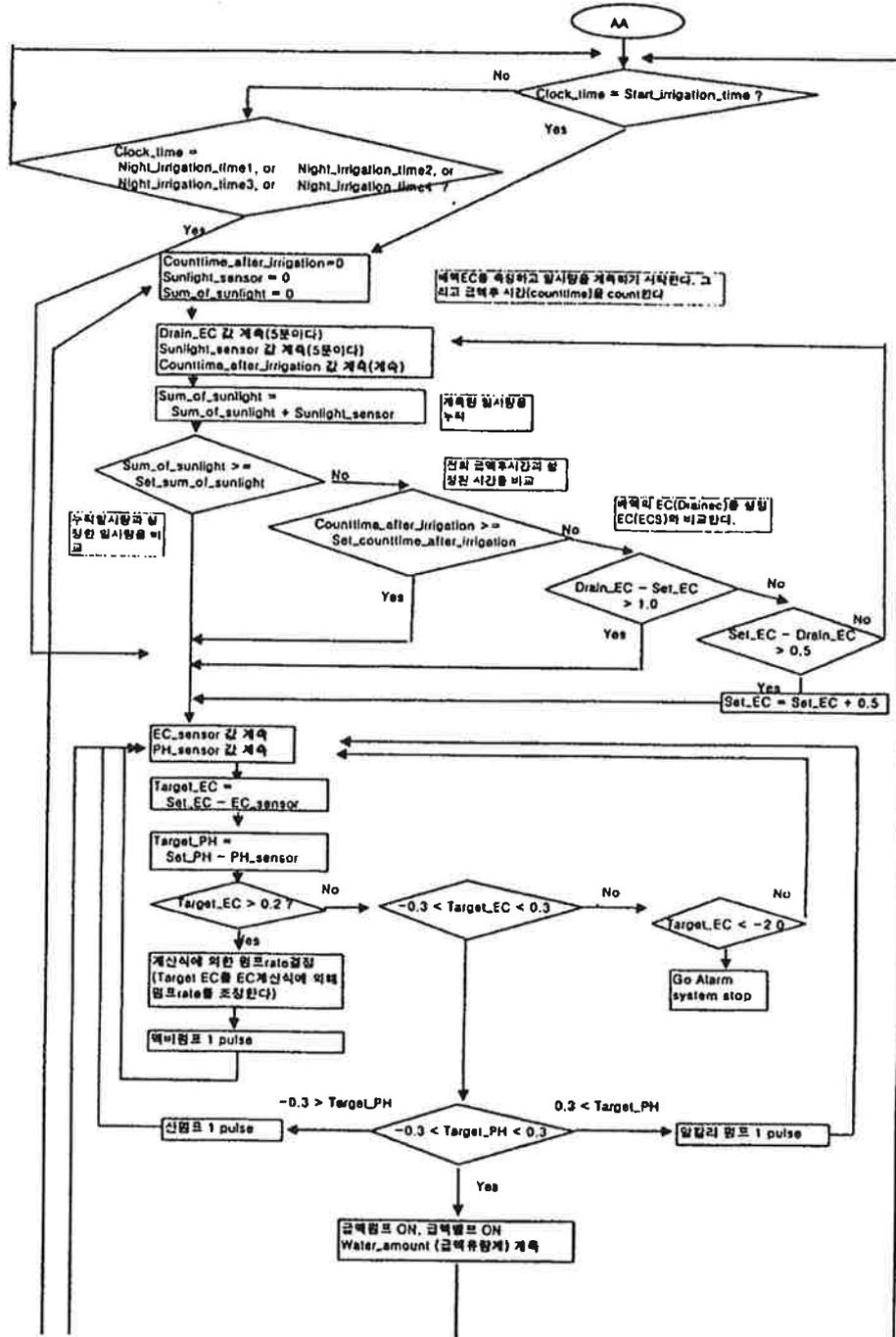


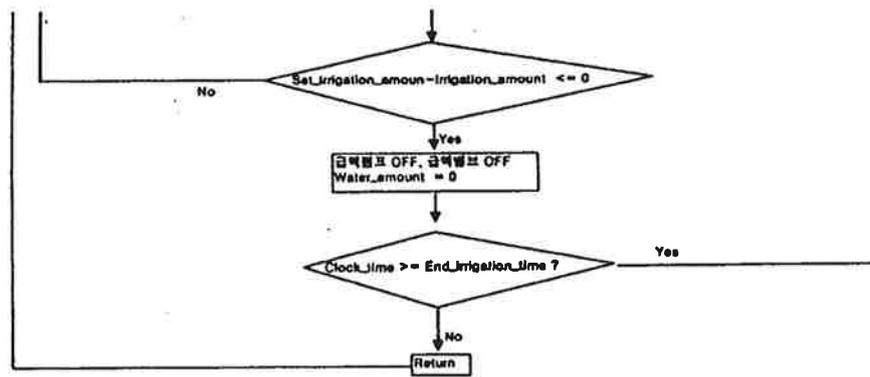
7-16. 양액관리기기의 구성도

4. 관비지령장치를 위한 프로그램

각종 하드웨어의 전원장치 관리 시스템의 제어를 하게되며 각 board의 구동을 위한 프로그램으로 구성되는 하드웨어의 운용프로그램이다. 하드웨어의 초기화 프로그램이 선행되어야 하며, 그 후에 각종 자료들의 수집, 제어, 가공, 저장, 전송, 관리 등의 Sub 프로그램들로 구성되어진다.







5.

가

,

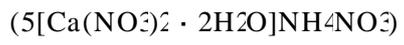
가

,

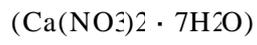
가

가

10



5



.

.

가

가

A

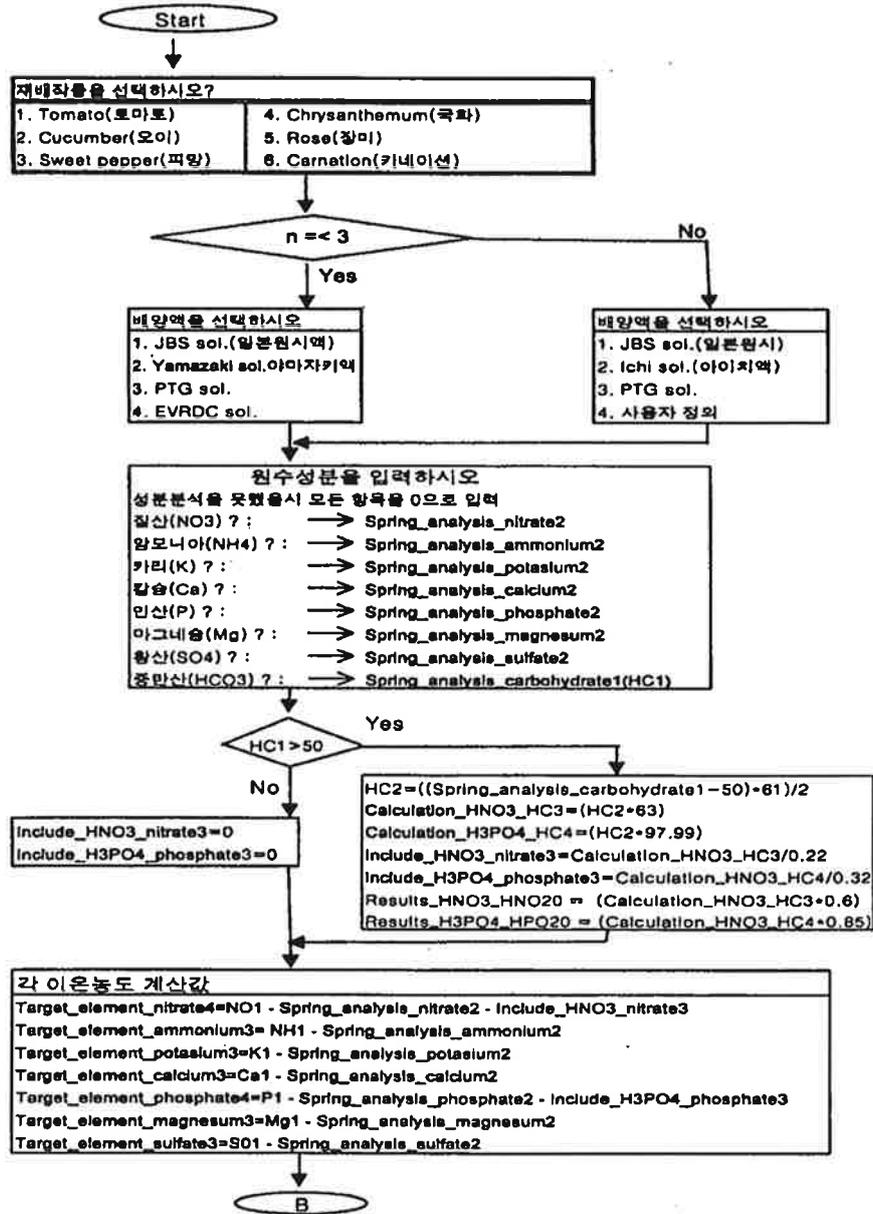
B

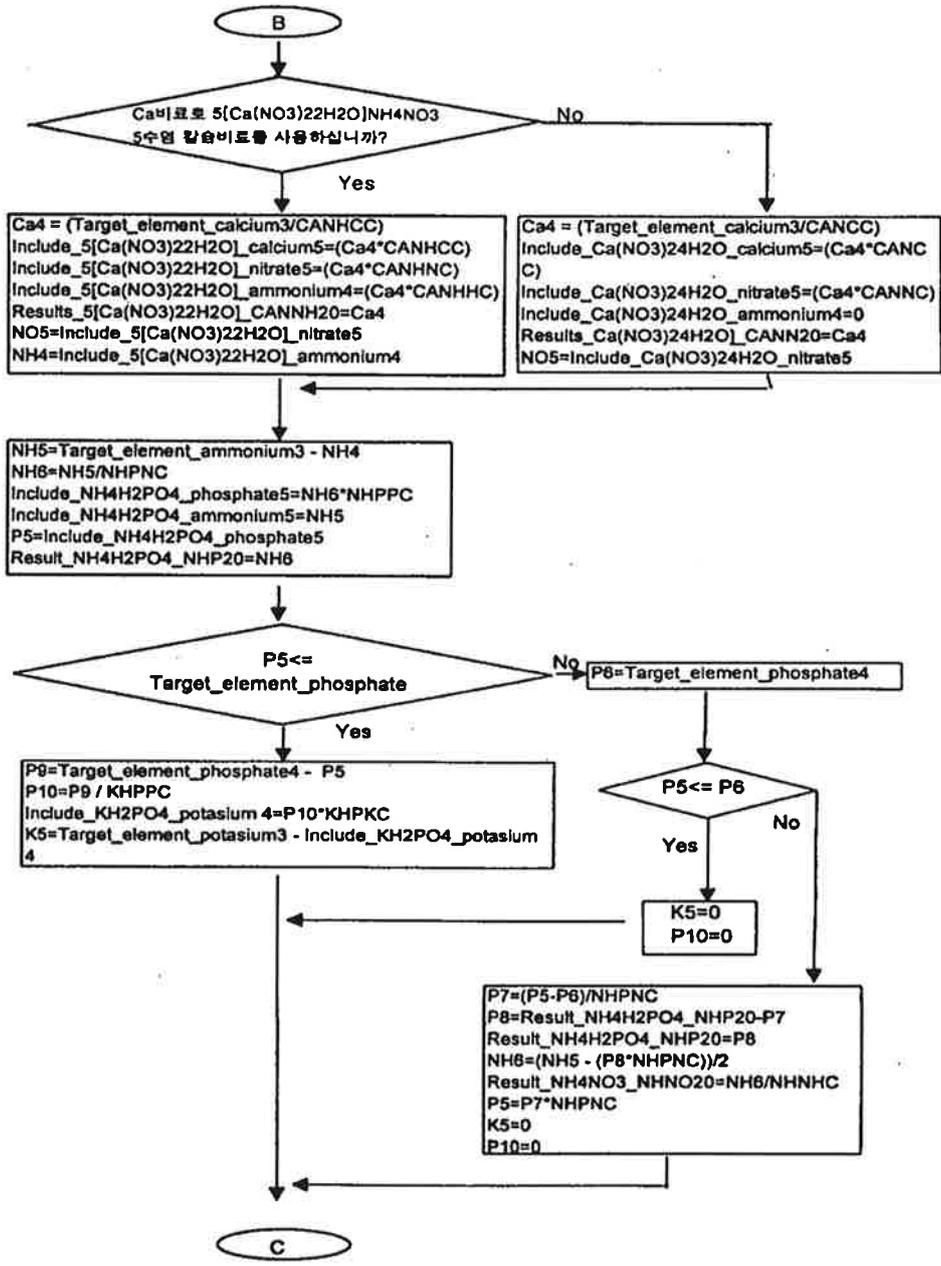
,

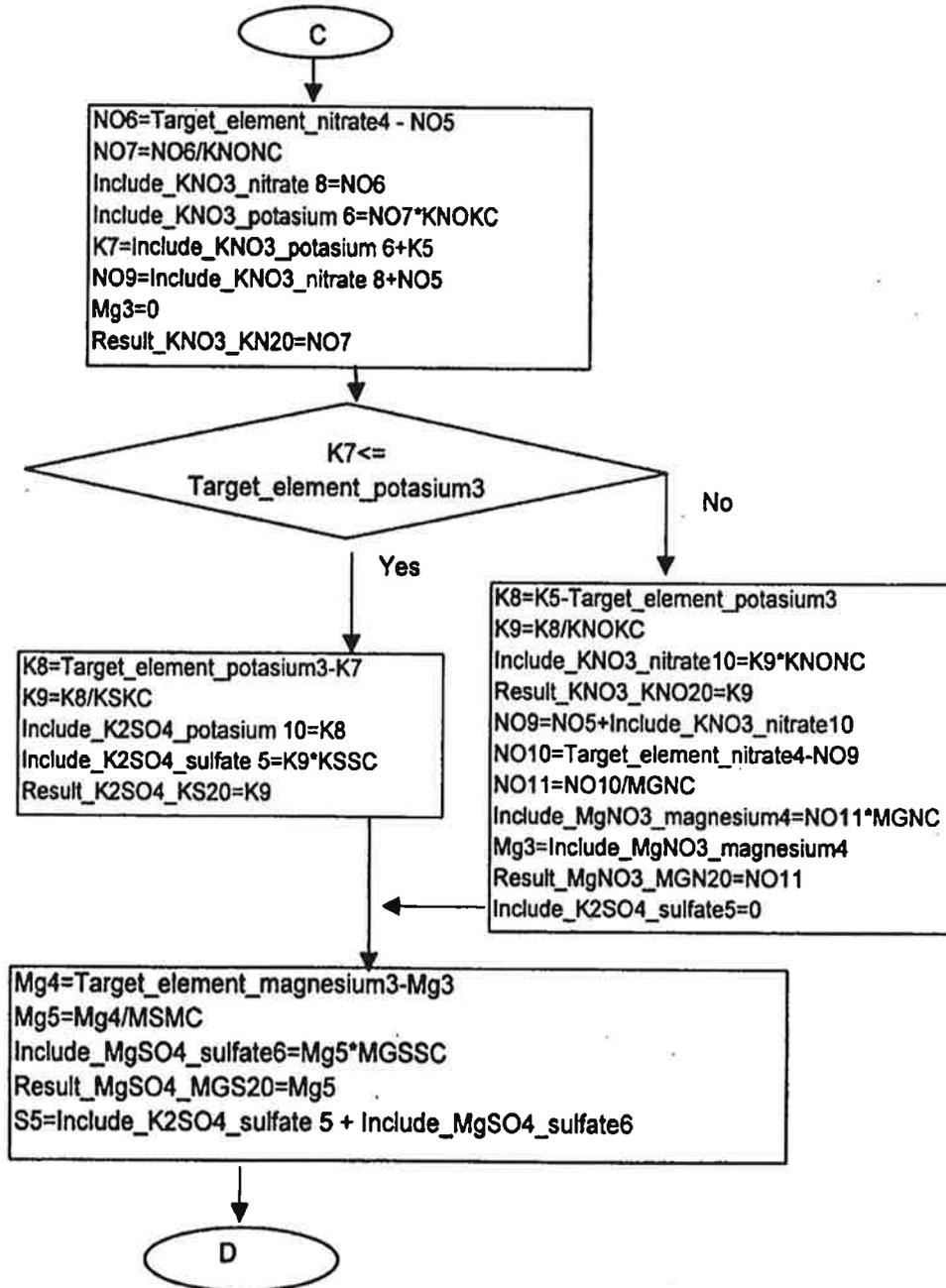
,

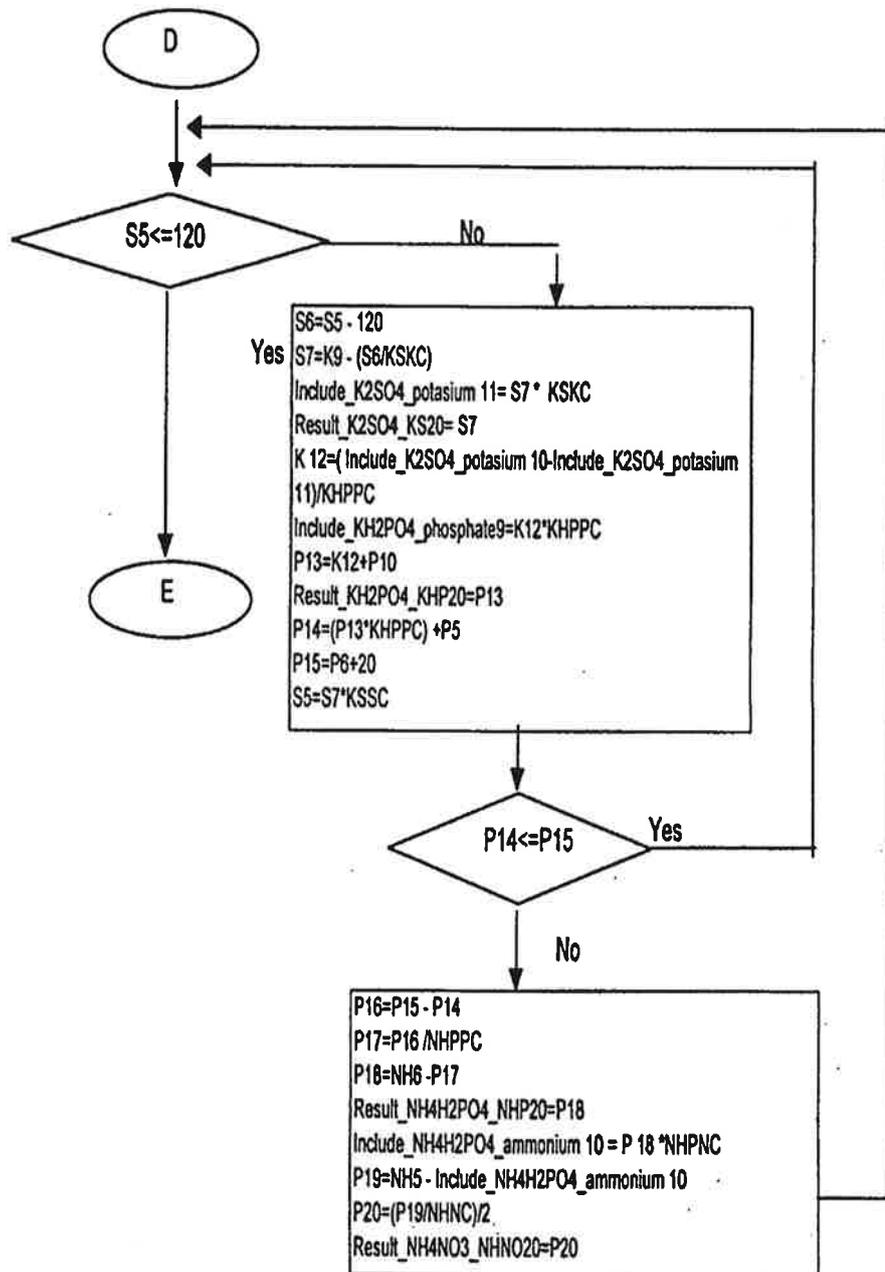
,

flow chart









E

비료 투입량 출력

- * 5[Ca(NO₃)₂·2H₂O]NH₄NO₃ 이나 Ca(NO₃)₂·7H₂O의 비료량 = Result_5[Ca(NO₃)₂·2H₂O]_CaN20, "ppm 또는 g/ton"
- * MgSO₄의 비료량 = Result_MgSO₄_MgS20, "ppm 또는 g/ton"
- * KH₂PO₄의 비료량 = Result_KH₂PO₄_KHP20, "ppm 또는 g/ton"
- * KNO₃의 비료량 = Result_KNO₃_KN20, "ppm 또는 g/ton"
- * K₂SO₄의 비료량 = Result_K₂SO₄_KS20, "ppm 또는 g/ton"
- * NH₄H₂PO₄의 비료량 = Result_NH₄H₂PO₄_NHP20, "ppm 또는 g/ton"
- * NH₄NO₃의 비료량 = Result_NH₄NO₃_NHNO20, "ppm 또는 g/ton"
- * MgNO₃의 비료량 = Result_MgNO₃_MGN20, "ppm 또는 g/ton"
- * HNO₃ 비료량 = Result_HNO₃_HNO20, "ppm 또는 g/ton"
- * H₃PO₄ 비료량 = Result_H₃PO₄_HPO20, "ppm 또는 g/ton"

$KN21 = [(Result_KNO3_KN20 + Result_5[Ca(NO3)2 \cdot 2H2O]_CaN20 + Result_MgSO4_MgS20 + Result_KH2PO4_KHP20 + Result_NH4NO3_NHNO20 + Result_NH4H2PO4_NHP20 + Result_K2SO4_KS20) / 2 - (Result_5[Ca(NO3)2 \cdot 2H2O]_CaN20 + Result_NH4NO3_NHNO20) + MgN20]$

A액에 투입할 비료량은 다음과 같다.
(100배액 1톤기준임)

- * 5[Ca(NO₃)₂·2H₂O]NH₄NO₃ = CaN20 * 0.1, "kg/ton"
- * KNO₃ = KN21 * 0.1, "kg/ton"
- * NH₄NO₃ = NHNO20 * 0.1, "kg/ton"
- * HNO₃ = HNO20 * 0.1, "kg/ton"
- * FeEDTA = 조성표의 량(ppm) x 0.1 을 하여 kg 단위로 넣으시오"

B액에 투입할 비료량은 다음과 같다.
(100배액 1톤기준임)

- * KNO₃ = (KN20 - KN21) * 0.1, "kg/ton"
- * MgSO₄·7H₂O = MgS20 * 0.1, "kg/ton"
- * KH₂PO₄ = KHP20 * 0.1, "kg/ton"
- * NH₄H₂PO₄ = NHP20 * 0.1, "kg/ton"
- * K₂SO₄ = KS20 * 0.1, "kg/ton"
- * MgNO₃ = MGN20 * 0.1, "kg/ton"
- * H₃PO₄ = HPO20 * 0.1, "kg/ton"
- * 미량요소는 조성표의 량(ppm) x 100 을 하여 g단위로 넣으시오"

END

6. 관비지령장치를 이용한 양액조절

본 관비지령장치를 이용하여 각 작물에 따른 배양액을 선택하여 먼저 액비펌프의 작동횟수에 따른 EC변화를 추적하였다.

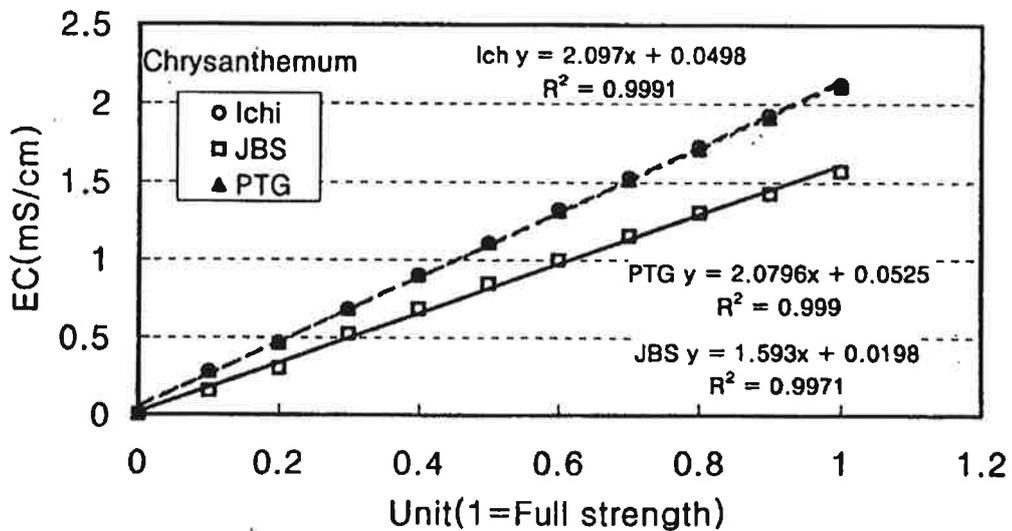


그림 7-17. 국화 배양액의 처방별 액비펌프의 작동시 EC의 변화

그림 7-17은 국화의 배양액 처방별 액비펌프의 작동시 EC변화를 회귀식으로 나타낸 것이다. 국화의 배양액은 Ichi 배양액과 PTG배양액이 거의 같은 수준의 EC를 나타냈으며 원시배양액이 더 낮은 EC를 나타냈다. 각 회귀선의 상관계수는 고도의 유의성을 나타내 액비펌프가 정확하게 작동하였다는 것을 나타내주었다.

그림 7-18은 오이의 경우로 EVRDC처방이 가장 높은 EC를 나타냈으며, 다음이 일본원시배양액, PTG, Yamazaki배양액 순으로 나타났다. 이것 역시 고도의 유의성을 나타냈다.

그림 7-19는 토마토의 경우이다. 토마토 역시 오이와 유사한 반응을 보였으며 고도의 유의성을 나타냈다.

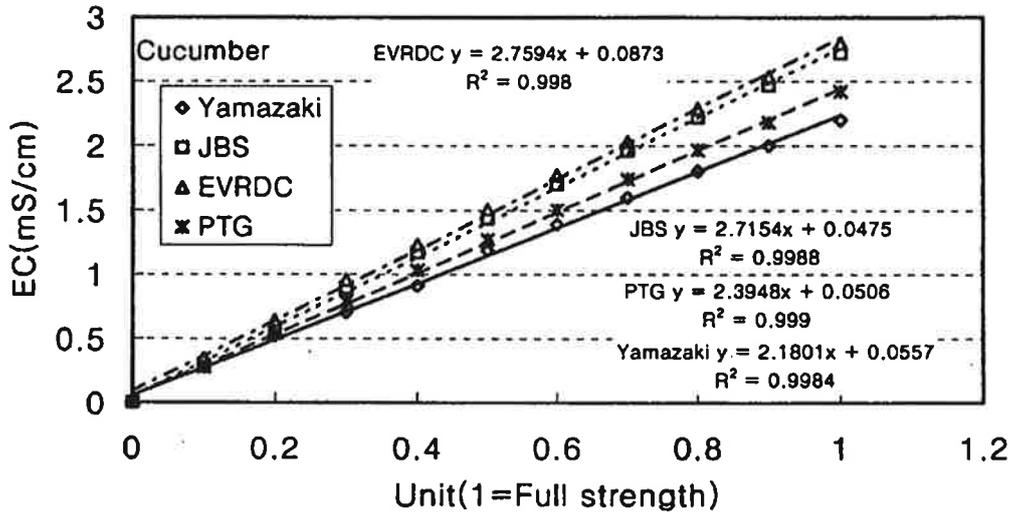


그림 7-18. 오이 배양액의 처방별 액비펌프의 작동시 EC의 변화

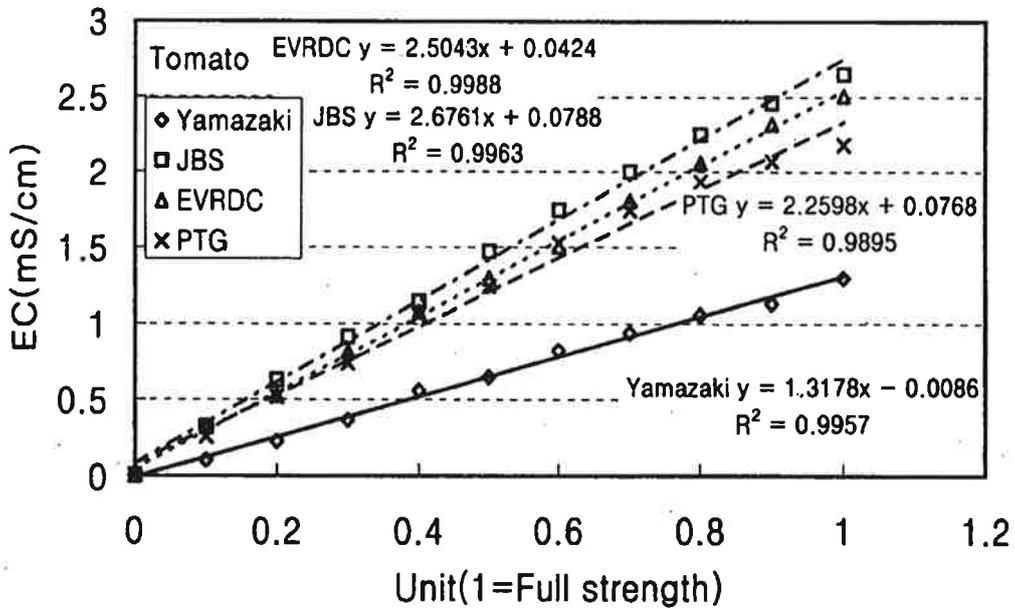


그림 7-19. 토마토 배양액의 처방별 액비펌프의 작동시 EC의 변화

4

1.

1997 5 16 () 2-3

가 7:3

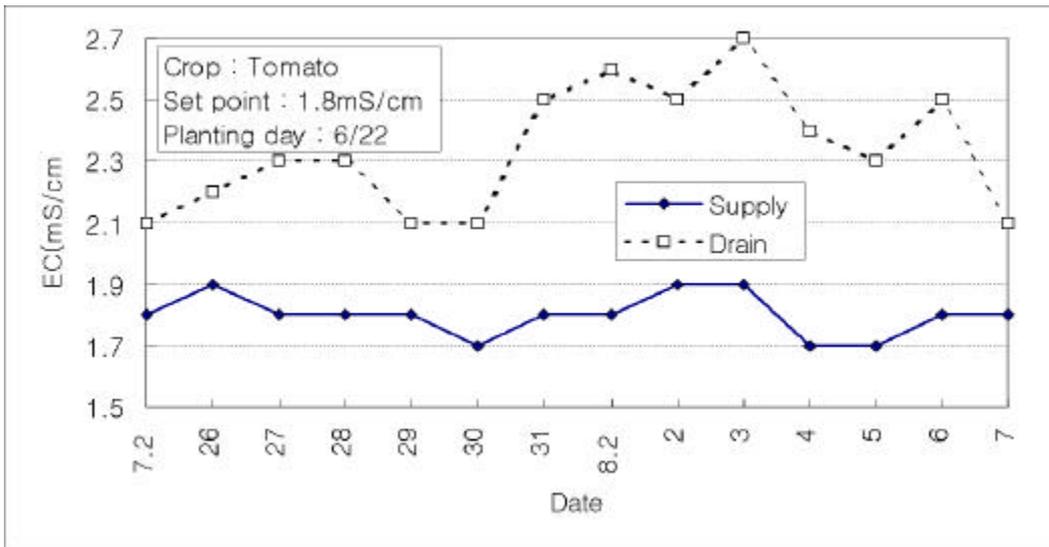
. 6 22

2

가

25cm, 10cm 6

가



7-20.

EC

EC

10 7 2

7-20 .

EC 1.8mS/cm

EC ±0.1

EC

±0.7

0.3

EC

2.1 2.7mS/cm

7 31

8 3

가

가

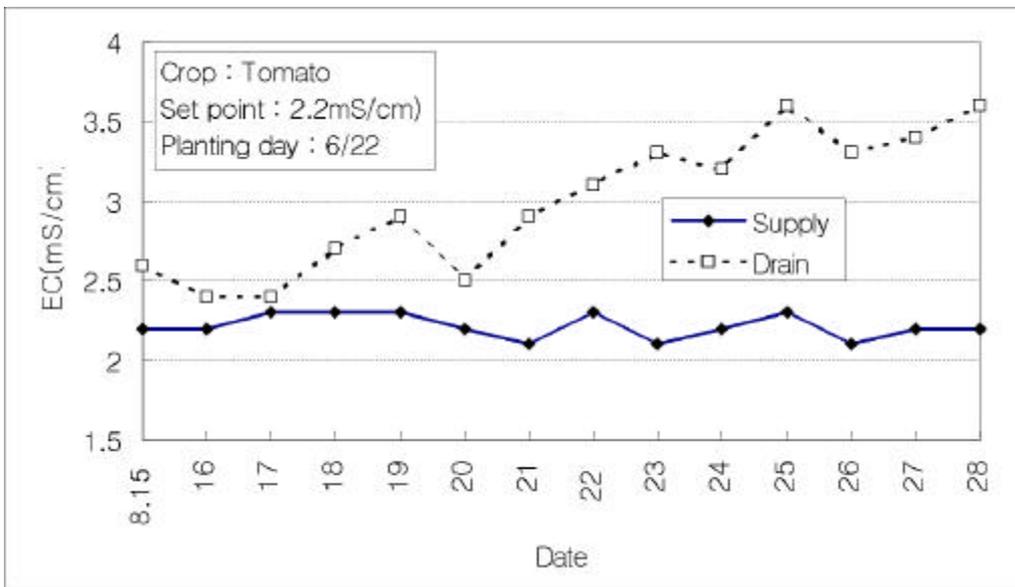
가

EC

EC

가 1.5

가



7-21 .

EC

EC

7-21

50

가

8 15

EC

EC

EC

가 1.0

8 25

2.0

가

가

2.

1997 5 16

()

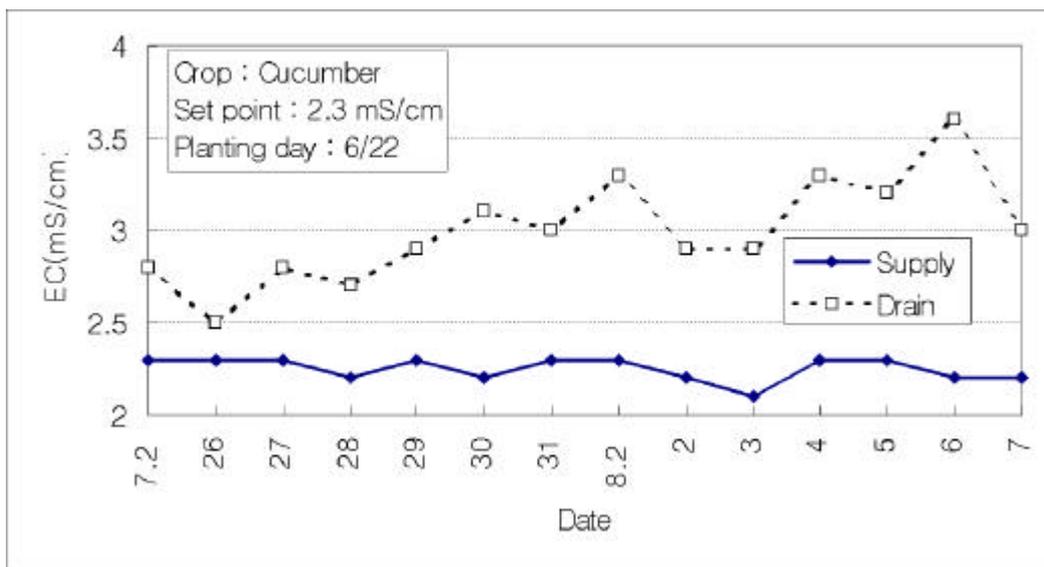
2-3

가 7:3

. 6 22

25cm, 10cm 6

가

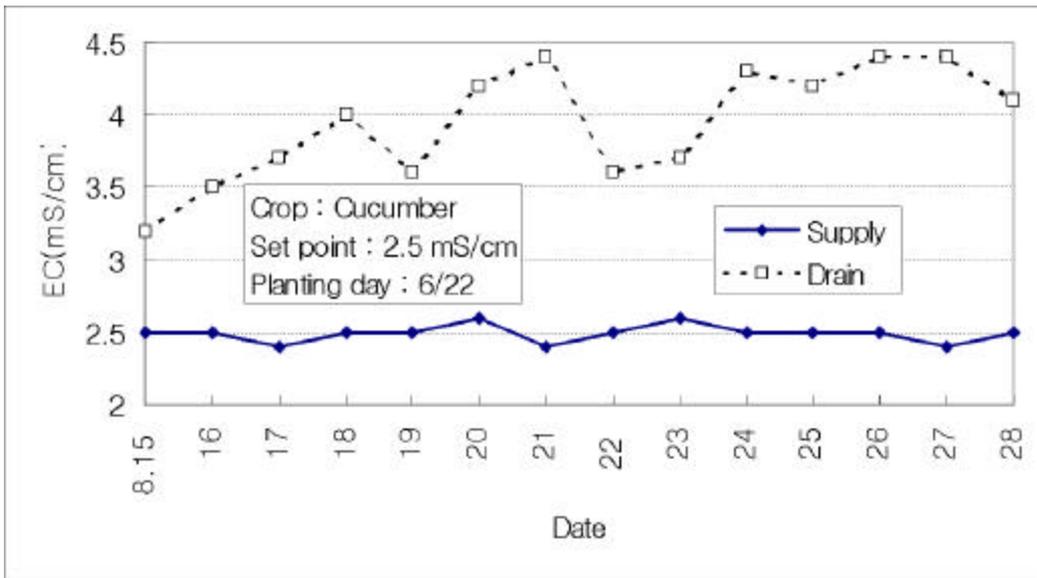


7-22 .

EC

EC

7-22 EC EC
 EC 2.3mS/cm ±0.1
 가 ±0.5
 ±0.3 EC 2.5 3.6
 가
 EC가



7-23. EC
 EC

7-23 8 15 8 28 EC
 2.5 EC 3.2 4.4

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pp. 238- 301.
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34. Yasushi Hashimoto, Gerard P.A. Boot, W. Day, H.J. Tantau and Hiroshi Nonami. 1993. The computerized greenhouse. Academic Press, Inc.

< >

```
// MainFrm.cpp : implementation of the CMainFrame class
```

```
//
```

```
#include "stdafx.h"
```

```
#include "culture.h"
```

```
#include "MainFrm.h"
```

```
#ifdef _DEBUG
```

```
#define new DEBUG_NEW
```

```
#undef THIS_FILE
```

```
static char THIS_FILE[] = __FILE__;
```

```
#endif
```

```
////////////////////////////////////
```

```
// CMainFrame
```

```
IMPLEMENT_DYNCREATE(CMainFrame, CFrameWnd)
```

```
BEGIN_MESSAGE_MAP(CMainFrame, CFrameWnd)
```

```
//{{AFX_MSG_MAP(CMainFrame)
```

```

        //}}AFX_MSG_MAP
END_MESSAGE_MAP()

////////////////////////////////////
// CMainFrame construction/destruction

CMainFrame::CMainFrame()
{
}

CMainFrame::~CMainFrame()
{
}

BOOL CMainFrame::PreCreateWindow(CREATESTRUCT& cs)
{
    return CFrameWnd::PreCreateWindow(cs);
}

////////////////////////////////////
// CMainFrame diagnostics

#ifdef _DEBUG
void CMainFrame::AssertValid() const
{
    CFrameWnd::AssertValid();
}

void CMainFrame::Dump(CDumpContext& dc) const
{
    CFrameWnd::Dump(dc);
}

#endif // _DEBUG

```

```
////////////////////////////////////
```

```
// CMainFrame message handlers
```

```
-----
```

```

-----
// InputDlg.cpp : implementation file
//

#include "stdafx.h"
#include "culture.h"
#include "InputDlg.h"

#ifdef _DEBUG
#define new DEBUG_NEW
#undef THIS_FILE
static char THIS_FILE[] = __FILE__;
#endif

//////////////////////////////////////
// CInputDlg dialog

CInputDlg::CInputDlg(CWnd* pParent /*=NULL*/)
: CDialog(CInputDlg::IDD, pParent)
{
   //{{AFX_DATA_INIT(CInputDlg)
    m_ca = 0.0f;
    m_h2po4 = 0.0f;
    m_hco3 = 0.0f;
    m_k = 0.0f;
    m_mg = 0.0f;
    m_nh4 = 0.0f;
    m_no3 = 0.0f;
    m_plant = _T("");
    m_solution = _T("");
    m_so4 = 0.0f;
    m_h2o10 = 0;
    //}}AFX_DATA_INIT
}

```

```

void CInputDialog::DoDataExchange(CDataExchange* pDX)
{
    CDialog::DoDataExchange(pDX);
   //{{AFX_DATA_MAP(CInputDialog)
    DDX_Text(pDX, IDC_CA, m_ca);
    DDX_Text(pDX, IDC_H2PO4, m_h2po4);
    DDX_Text(pDX, IDC_HCO3, m_hco3);
    DDX_Text(pDX, IDC_K, m_k);
    DDX_Text(pDX, IDC_MG, m_mg);
    DDX_Text(pDX, IDC_NH4, m_nh4);
    DDX_Text(pDX, IDC_NO3, m_no3);
    DDX_CBString(pDX, IDC_PLANT, m_plant);
    DDX_CBString(pDX, IDC_SOLUTION, m_solution);
    DDX_Text(pDX, IDC_SO4, m_so4);
    DDX_Radio(pDX, IDC_H2O10, m_h2o10);
   //}}AFX_DATA_MAP
}

BEGIN_MESSAGE_MAP(CInputDialog, CDialog)
   //{{AFX_MSG_MAP(CInputDialog)
    ON_BN_CLICKED(IDC_OK, OnClickedOk)
   //}}AFX_MSG_MAP
END_MESSAGE_MAP()

////////////////////////////////////
// CInputDialog message handlers

void CInputDialog::OnClickedOk()
{
    // TODO: Add your control notification handler code here
    UpdateData(TRUE);
}

```

```

if(m_plant=="      " || m_plant=="      " || m_plant=="      ")
{
    if(m_solution=="Ichi"||m_solution=="")
    {
        MessageBox("      ");
        return;
    }
}
else if(m_plant=="      " || m_plant=="      " || m_plant=="      ")
{

if(m_solution=="Yamasaki"||m_solution=="EVRDC"||m_solution=="")
    {
        MessageBox("      ");
        return;
    }
}
else
{
    MessageBox("      ");
    return;
}

CDialog::OnOK();
}

```

```

BOOL CInputDialog::OnInitDialog()
{
// (CButton*)GetDlgItem(IDC_H2O10)->SetCheck(h2o10);
CDialog::OnInitDialog();

// TODO: Add extra initialization here

```

```
        return TRUE; // return TRUE unless you set the focus to a control
                    // EXCEPTION: OCX Property Pages should return
FALSE
}

void CInputDlg::OnOK()
{
    // TODO: Add extra validation here

}
```

```

-----
// cultureView.cpp : implementation of the CCultureView class
//

#include "stdafx.h"
#include "culture.h"

#include "cultureDoc.h"
#include "cultureView.h"
#include "inputdlg.h"

#ifdef _DEBUG
#define new DEBUG_NEW
#undef THIS_FILE
static char THIS_FILE[] = __FILE__;
#endif

////////////////////////////////////
// CCultureView

IMPLEMENT_DYNCREATE(CCultureView, CScrollView)

BEGIN_MESSAGE_MAP(CCultureView, CScrollView)
   //{{AFX_MSG_MAP(CCultureView)
    ON_COMMAND(ID_FILE_NEW, OnFileNew)
    ON_COMMAND(ID_FILE_EDIT, OnFileEdit)
   //}}AFX_MSG_MAP
    // Standard printing commands
    ON_COMMAND(ID_FILE_PRINT, CScrollView::OnFilePrint)
    ON_COMMAND(ID_FILE_PRINT_DIRECT, CScrollView::OnFilePrint)
    ON_COMMAND(ID_FILE_PRINT_PREVIEW,
    CScrollView::OnFilePrintPreview)
END_MESSAGE_MAP()

////////////////////////////////////

```

```

// CCultureView construction/destruction

CCultureView::CCultureView() : m_rectPrint(0,0,2000,3000)
{
}

CCultureView::~~CCultureView()
{
}

BOOL CCultureView::PreCreateWindow(CREATESTRUCT& cs)
{
    return CScrollView::PreCreateWindow(cs);
}

////////////////////////////////////
// CCultureView drawing

void CCultureView::OnDraw(CDC* pDC)
{
    CFont bigfont,smallfont;
    CFont* poldfont;
    CCultureDoc* pDoc = GetDocument();
    CString str;
    int i;

    ASSERT_VALID(pDoc);

    bigfont.CreateFont(-
100,0,0,0,400,FALSE,FALSE,0,ANSI_CHARSET,OUT_DEFAULT_PRECIS,
CLIP_DEFAULT_PRECIS,DEFAULT_QUALITY,DEFAULT_PITCH
FF_ROMAN,"
");
    smallfont.CreateFont(-

```

50,0,0,0,400,FALSE,FALSE,0,ANSI_CHARSET,OUT_DEFAULT_PRECIS,

CLIP_DEFAULT_PRECIS,DEFAULT_QUALITY,DEFAULT_PITCH
FF_ROMAN,"

");

```
poldfont = (CFont*)pDC->SelectObject(&bigfont);  
pDC->TextOut(700,- 200,"");  
pDC->Rectangle(650,- 300,1350,- 310);
```

```
(CFont*)pDC->SelectObject(&smallfont);  
pDC->TextOut(150,- 400,"1.");  
pDC->TextOut(600,- 400,pDoc->m_strPlant);  
pDC->TextOut(150,- 500,"2.");  
pDC->TextOut(600,- 500,pDoc->m_strSolution);  
pDC->TextOut(1000,- 500,"[");  
if(pDoc->m_whichh2o==0) str.Format("10");  
else str.Format("4");  
pDC->TextOut(1400,- 500,str);
```

```
pDC->Rectangle(130,- 680,1980,- 850);  
for(i=0;i<8;i++)  
    pDC->Rectangle(380+i*200,- 680,580+i*200,- 850);  
pDC->Rectangle(130,- 760,1980,- 770);
```

```
pDC->TextOut(150,- 600,"3.");  
pDC->TextOut(150,- 700,"");  
pDC->TextOut(150,- 780,"");  
pDC->TextOut(400,- 700,"Ca");  
pDC->TextOut(600,- 700,"NO3");  
pDC->TextOut(800,- 700,"NH4");  
pDC->TextOut(1000,- 700,"K");  
pDC->TextOut(1200,- 700,"H2PO4");  
pDC->TextOut(1400,- 700,"SO4");  
pDC->TextOut(1600,- 700,"Mg");
```

```

pDC->TextOut(1800,- 700,"HCO3");
str.Format("%.2f",pDoc->m_Sca);
pDC->TextOut(400,- 780,str);
str.Format("%.2f",pDoc->m_Sno3);
pDC->TextOut(600,- 780,str);
str.Format("%.2f",pDoc->m_Snh4);
pDC->TextOut(800,- 780,str);
str.Format("%.2f",pDoc->m_Sk);
pDC->TextOut(1000,- 780,str);
str.Format("%.2f",pDoc->m_Sh2po4);
pDC->TextOut(1200,- 780,str);
str.Format("%.2f",pDoc->m_Sso4);
pDC->TextOut(1400,- 780,str);
str.Format("%.2f",pDoc->m_Smg);
pDC->TextOut(1600,- 780,str);
str.Format("%.2f",pDoc->m_Shc3);
pDC->TextOut(1800,- 780,str);

pDC->Rectangle(130,- 980,1900,- 1470);
// for(i=0;i< 8;i++)
//     pDC->Rectangle(380+i*200,- 680,580+i*200,- 850);

pDC->Rectangle(130,- 760,1950,- 770);
pDC->TextOut(150,- 900,"4.          ");
pDC->TextOut(150,- 1000,"A      ");
pDC->TextOut(150,- 1080,"          ");
pDC->TextOut(150,- 1160,"      가      KNO3");
pDC->TextOut(150,- 1240,"          NH4NO3");
pDC->TextOut(150,- 1320,"      HNO3");
pDC->TextOut(150,- 1400,"          FeEDT A(12.5%)");
str.Format("%.2f",pDoc->m_Acanh4no3);
pDC->TextOut(1000,- 1080,str);
str.Format("%.2f",pDoc->m_Akno3);
pDC->TextOut(1000,- 1160,str);

```

```

str.Format("%.2f",pDoc->m_Anh4no3);
pDC->TextOut(1000,- 1240,str);
str.Format("%.2f",pDoc->m_Ahno3);
pDC->TextOut(1000,- 1320,str);
str.Format("%.2f",pDoc->m_Acanh4no3/10);
pDC->TextOut(1500,- 1080,str);
str.Format("%.2f",pDoc->m_Akno3/10);
pDC->TextOut(1500,- 1160,str);
str.Format("%.2f",pDoc->m_Anh4no3/10);
pDC->TextOut(1500,- 1240,str);
str.Format("%.2f",pDoc->m_Ahno3/10);
pDC->TextOut(1500,- 1320,str);

pDC->TextOut(1000,- 1000,"ppm");
pDC->TextOut(1500,- 1000,"100      1      ");
pDC->TextOut(1000,- 1400,"20.0");
pDC->TextOut(1500,- 1400,"20.0");
pDC->TextOut(1800,- 1080,"Kg");
pDC->TextOut(1800,- 1160,"Kg");
pDC->TextOut(1800,- 1240,"Kg");
pDC->TextOut(1800,- 1320,"Kg");
pDC->TextOut(1800,- 1400,"Kg");

pDC->Rectangle(130,- 1480,1900,- 2130);

pDC->TextOut(150,- 1500,"B      ");
pDC->TextOut(150,- 1580,"      가      KNO3");
pDC->TextOut(150,- 1660,"      MgSO4*7H2O");
pDC->TextOut(150,- 1740,"      1      가      KH2PO4");
pDC->TextOut(150,- 1820,"      1      MH4H2PO4");
pDC->TextOut(150,- 1900,"      가      K2SO4");
pDC->TextOut(150,- 1980,"      H3PO4");
pDC->TextOut(150,- 2060,"      MgNO3");
str.Format("%.2f",pDoc->m_Bkno3);
pDC->TextOut(1000,- 1580,str);

```

```
str.Format("%.2f",pDoc->m_Bmgs04);
pDC->TextOut(1000,- 1660,str);
str.Format("%.2f",pDoc->m_Bkh2po4);
pDC->TextOut(1000,- 1740,str);
str.Format("%.2f",pDoc->m_Bnh4h2po4);
pDC->TextOut(1000,- 1820,str);
str.Format("%.2f",pDoc->m_Bk2so4);
pDC->TextOut(1000,- 1900,str);
str.Format("%.2f",pDoc->m_Bh3po4);
pDC->TextOut(1000,- 1980,str);
str.Format("%.2f",pDoc->m_Bmgno3);
pDC->TextOut(1000,- 2060,str);
```

```
str.Format("%.2f",pDoc->m_Bkno3/10);
pDC->TextOut(1500,- 1580,str);
str.Format("%.2f",pDoc->m_Bmgs04/10);
pDC->TextOut(1500,- 1660,str);
str.Format("%.2f",pDoc->m_Bkh2po4/10);
pDC->TextOut(1500,- 1740,str);
str.Format("%.2f",pDoc->m_Bnh4h2po4/10);
pDC->TextOut(1500,- 1820,str);
str.Format("%.2f",pDoc->m_Bk2so4/10);
pDC->TextOut(1500,- 1900,str);
str.Format("%.2f",pDoc->m_Bh3po4/10);
pDC->TextOut(1500,- 1980,str);
str.Format("%.2f",pDoc->m_Bmgno3/10);
pDC->TextOut(1500,- 2060,str);
```

```
pDC->TextOut(1000,- 1500,"ppm");
pDC->TextOut(1500,- 1500,"100      1      ");
pDC->TextOut(1800,- 1580,"Kg");
pDC->TextOut(1800,- 1660,"Kg");
pDC->TextOut(1800,- 1740,"Kg");
pDC->TextOut(1800,- 1820,"Kg");
pDC->TextOut(1800,- 1900,"Kg");
```

```

pDC->TextOut(1800,- 1980,"Kg");
pDC->TextOut(1800,- 2060,"Kg");

pDC->Rectangle(130,- 2140,1900,- 2630);
pDC->TextOut(150,- 2160,"");
pDC->TextOut(150,- 2240,"H3BO3");
pDC->TextOut(150,- 2320,"CuSO4*5H2O");
pDC->TextOut(150,- 2400,"ZnSO4*7H2O");
pDC->TextOut(150,- 2480,"MnSo4*H2O");
pDC->TextOut(150,- 2560,"Na2MoO4*2H2O");
pDC->TextOut(1000,- 2160,"ppm");
pDC->TextOut(1500,- 2160,"100 1");
pDC->TextOut(1800,- 2240,"g");
pDC->TextOut(1800,- 2320,"g");
pDC->TextOut(1800,- 2400,"g");
pDC->TextOut(1800,- 2480,"g");
pDC->TextOut(1800,- 2560,"g");
pDC->TextOut(1000,- 2240,"2.86");
pDC->TextOut(1000,- 2320,"0.08");
pDC->TextOut(1000,- 2400,"0.22");
pDC->TextOut(1000,- 2480,"1.57");
pDC->TextOut(1000,- 2560,"0.03");
pDC->TextOut(1500,- 2240,"286.00");
pDC->TextOut(1500,- 2320,"8.00");
pDC->TextOut(1500,- 2400,"22.00");
pDC->TextOut(1500,- 2480,"157.00");
pDC->TextOut(1500,- 2560,"3.00");

pDC->TextOut(150,- 2700,"5.
(062- 520- 6484)");
pDC->TextOut(150,- 2800," ( ) (062- 511- 0281)
.");

//int x, y, xx, yy;

```

```

        pDC->SelectObject(poldfont);
    }

void CCultureView::OnInitialUpdate()
{
    CScrollView::OnInitialUpdate();
    CSize sizeTotal(m_rectPrint.Width(),m_rectPrint.Height());
    CSize sizePage(sizeTotal.cx/2,sizeTotal.cy/2);
    CSize sizeLine(sizeTotal.cx/100,sizeTotal.cy/100);
    SetScrollSizes(MM_LOMETRIC, sizeTotal,sizePage,sizeLine);
}

////////////////////////////////////
// CCultureView printing

BOOL CCultureView::OnPreparePrinting(CPrintInfo* pInfo)
{
    // default preparation
    return DoPreparePrinting(pInfo);
}

void CCultureView::OnBeginPrinting(CDC* /*pDC*/, CPrintInfo* /*pInfo*/)
{
}

void CCultureView::OnEndPrinting(CDC* /*pDC*/, CPrintInfo* /*pInfo*/)
{
}

////////////////////////////////////
// CCultureView diagnostics

#ifdef _DEBUG
void CCultureView::AssertValid() const
{

```

```

        CScrollView::AssertValid();
    }

void CCultureView::Dump(CDumpContext& dc) const
{
    CScrollView::Dump(dc);
}

CCultureDoc* CCultureView::GetDocument() // non-debug version is inline
{

ASSERT(m_pDocument->IsKindOf(RUNTIME_CLASS(CCultureDoc));
    return (CCultureDoc*)m_pDocument;
}
#endif // _DEBUG

////////////////////////////////////
// CCultureView message handlers

void CCultureView::OnFileNew()
{
    CInputDialog dlg;

    if(dlg.DoModal()==IDOK)
    {
        CCultureDoc *pDoc = GetDocument();
        pDoc->m_strPlant=dlg.m_plant;
        pDoc->m_strSolution=dlg.m_solution;
        pDoc->m_Sca=dlg.m_ca;
        pDoc->m_Sno3=dlg.m_no3;
        pDoc->m_Snh4=dlg.m_nh4;
        pDoc->m_Sk=dlg.m_k;
        pDoc->m_Sh2po4=dlg.m_h2po4;
        pDoc->m_Sso4=dlg.m_so4;
        pDoc->m_Smg=dlg.m_mg;
    }
}

```

```

        pDoc->m_Shc3=dlg.m_hco3;
        pDoc->m_whichh2o = dlg.m_h2o10;

        pDoc->CalculateCulture();
        pDoc->UpdateAllViews(NULL);
    }
}

void CCultureView::OnFileEdit()
{
    CInputDialog dlg;
    CCultureDoc *pDoc = GetDocument();
    // TODO: Add your command handler code here
    dlg.m_plant = pDoc->m_strPlant;
    dlg.m_solution=pDoc->m_strSolution;
    dlg.m_ca=pDoc->m_Sca;
    dlg.m_no3=pDoc->m_Sno3;
    dlg.m_nh4=pDoc->m_Snh4;
    dlg.m_k=pDoc->m_Sk;
    dlg.m_h2po4=pDoc->m_Sh2po4;
    dlg.m_so4=pDoc->m_Sso4;
    dlg.m_mg=pDoc->m_Smg;
    dlg.m_hco3=pDoc->m_Shc3;
    dlg.m_h2o10=pDoc->m_whichh2o;

    if(dlg.DoModal()==IDOK)
    {
        pDoc->m_strPlant=dlg.m_plant;
        pDoc->m_strSolution=dlg.m_solution;
        pDoc->m_Sca=dlg.m_ca;
        pDoc->m_Sno3=dlg.m_no3;
        pDoc->m_Snh4=dlg.m_nh4;
        pDoc->m_Sk=dlg.m_k;
        pDoc->m_Sh2po4=dlg.m_h2po4;
        pDoc->m_Sso4=dlg.m_so4;
    }
}

```

```
pDoc->m_Smg=dlg.m_mg;  
pDoc->m_Shc3=dlg.m_hco3;  
pDoc->m_whichh2o = dlg.m_h2o10;
```

```
pDoc->CalculateCulture();  
pDoc->UpdateAllViews(NULL);
```

```
}
```

```
}
```

// cultureDoc.cpp : implementation of the CCultureDoc class
//

#include "stdafx.h"
#include "culture.h"

#include "cultureDoc.h"

#ifdef _DEBUG
#define new DEBUG_NEW
#undef THIS_FILE
static char THIS_FILE[] = __FILE__;
#endif

////////////////////////////////////
// CCultureDoc

IMPLEMENT_DYNCREATE(CCultureDoc, CDocument)

BEGIN_MESSAGE_MAP(CCultureDoc, CDocument)
//{{AFX_MSG_MAP(CCultureDoc)
//}}AFX_MSG_MAP
END_MESSAGE_MAP()

////////////////////////////////////
// CCultureDoc construction/destruction

CCultureDoc::CCultureDoc()
{
 m_whichh2o=0;
 DeleteContents();
}

CCultureDoc::~~CCultureDoc()

```
{  
}
```

```
BOOL CCultureDoc::OnNew Document()  
{
```

```
    if (!CDocument::OnNew Document())  
        return FALSE;
```

```
    return TRUE;  
}
```

```
////////////////////////////////////////////////////////////////
```

```
// CCultureDoc serialization
```

```
void CCultureDoc::Serialize(CArchive& ar)  
{
```

```
    if (ar.IsStoring())
```

```
    {
```

```
        ar << m_strPlant << m_strSolution << m_whichh2o <<
```

```
m_Sca <<
```

```
m_Sh2po4 << m_Shc3 << m_Sk << m_Smg << m_Snh4 << m_Sno3 <<
```

```
m_Sso4 ;
```

```
    }
```

```
    else
```

```
    {
```

```
        ar >> m_strPlant >> m_strSolution >> m_whichh2o >>
```

```
m_Sca >>
```

```
m_Sh2po4 >> m_Shc3 >> m_Sk >> m_Smg >> m_Snh4 >> m_Sno3 >>
```

```
m_Sso4 ;
```

```
    }
```

```
}
```

```
////////////////////////////////////////////////////////////////
```

```

// CCultureDoc diagnostics

#ifdef _DEBUG
void CCultureDoc::AssertValid() const
{
    CDocument::AssertValid();
}

void CCultureDoc::Dump(CDumpContext& dc) const
{
    CDocument::Dump(dc);
}
#endif // _DEBUG

/////////////////////////////////////////////////////////////////
// CCultureDoc commands

void CCultureDoc::DeleteContents()
{
    m_strPlant="";
    m_strSolution="";

    m_Sca=m_Sno3=m_Snh4=m_Sk=m_Sh2po4=m_Sso4=m_Smg=m_Shc3=0;
    m_Acanh4no3=m_Akno3=m_Anh4no3=m_Ahno3=0;

    m_Bkno3=m_Bmgso4=m_Bkh2po4=m_Bnh4h2po4=m_Bk2so4=m_Bh3po4=m_Bm
gno3=0;
}

/////////////////////////////////////////////////////////////////
//          //
//          //
//          // Caculate Culture.   C file.
//          //
//          //

```

```

////
//

e           n           u           m
{TOMATO,CUCUMBER,PIMAN,CHRYSANTHEMUM,ROSE,CARNATION};

#define H2O_10 0
#define H2O_4  1

double NO1,NH1,K1,Ca1,P1,Mg1,SO1,Set_PH,Set_EC; /* Solution Elements */

struct SolutionValue
{
    double no3,nh4,k,ca,p,mg,so4,ph,ec;
};

static SolutionValue SolutionTable[6][4]=
{
    // 0: tomato
    {
        {225,  18.9,  313.2,  161.2,  41.7,  49.3,  65,
        6.2,  2.5},
        {84.1,  9.2,   117.6,  60.1,   20.4,  24.3,  32,
        6.2,  1.4},
        {192.5, 17.5,  341.25, 170,   38.75,  48.6,  112.3,
        6.2,  2.6},
        {213.5, 9.2,   221.4,  214.3,  84.6,  47.7,  53.2,
        6.2,  1.9}
    },
    // 1: cucumber
    {
        {225,  18.9,  313.2,  161.2,  41.7,  49.3,  65,
        6.2,  2.5},
        {182,  13.9,  234.3,  140.2,  30.7,  48.5,  64,
        6.2,  2.9},
    }
}

```

```

        {206.8, 12.3, 313.1, 144.3, 46.4, 34.8, 40.1,
6.2, 2.5},
        {234.8, 0, 341.1, 189.7, 50.5, 38, 43.7,
6.2, 2.7}
    },
    // 3: piman
    {
        {154, 14, 273.4, 80.1, 30.9, 24.3, 32,
6.2, 2.1},
        {126, 11.6, 234.3, 60.1, 25.6, 18.2, 24.1,
6.2, 1.8},
        {168, 3.5, 264.5, 127.3, 38.7, 27.3, 40.1,
6.2, 2.2},
        {354.9, 0, 660.1, 202, 50.5, 39.7, 52.4,
6.2, 3.5}
    },
    // 4: rose
    {
        {168, 14, 234, 120, 30.97, 36, 48,
6, 1.9},
        {154, 28, 175, 86, 36, 24.31, 32.06,
6, 1.6},
        {154, 17.5, 195, 140, 38.75, 18.23, 40,
6, 1.9},
        {0,0,0,0,0,0,0,0},
    },
    // 5: Carnation
    {
        {168, 14, 234, 120, 30.97, 36, 48,
6, 1.9},
        {189, 21, 234, 140, 39, 30, 40,
6, 1.9},
        {182, 14, 243.75, 150, 38.75, 24.3, 40,
6, 1.9},
        {0,0,0,0,0,0,0,0},
    }

```

```

    },
    // 6: Chrysanthemum
    {
        {168, 14, 234, 120, 30.97, 36, 48,
6, 1.9},
        {189, 21, 234, 140, 39, 30, 40,
6, 1.9},
        {178, 17.5, 239.25, 100.25, 31, 24.3, 32,
6, 1.9},
        {0,0,0,0,0,0,0,0},
    }
};

```

```

static double CANHNC = 0.1426,
            CANHHC = 0.0130,
            CANHCC = 0.1854,
            CANNC = 0.1187,
            CANCC = 0.1697,
            KNONC = 0.1386,
            KNOKC = 0.3867,
            NHNHC = 0.35,
            NHPNC = 0.1217,
            NHPPC = 0.2693,
            KHPKC = 0.2873,
            KHPPC = 0.2276,
            KSSC = 0.1840,
            KSKC = 0.2244,
            MSSC = 0.1301,
            MSMC = 0.0986,
            MGNC = 0.1094,
            MGMC = 0.0950;

```

```

void GetSolution(CString plant, CString solution)
{
    int iplant, isolution;

```

```

if(plant=="    ") iplant=0;
else if(plant=="  ") iplant=1;
else if(plant==" ") iplant=2;
else if(plant=="") iplant=3;
else if(plant==" ") iplant=4;
else if(plant==" ") iplant=5;
else iplant = 0;
if(solution == "JBS") isolution = 0;
else if(solution == "Yamasaki") isolution = 1;
else if(solution == "Ichi") isolution = 1;
else if(solution == "PTG") isolution = 2;
else if(solution == "EVRDC") isolution = 3;
else isolution = 0;

```

```

NO1 = SolutionTable[iplant][isolution].no3;
NH1= SolutionTable[iplant][isolution].nh4;
K1= SolutionTable[iplant][isolution].k;
Ca1= SolutionTable[iplant][isolution].ca;
P1= SolutionTable[iplant][isolution].p;
Mg1= SolutionTable[iplant][isolution].mg;
SO1= SolutionTable[iplant][isolution].so4;
Set_PH= SolutionTable[iplant][isolution].ph;
Set_EC= SolutionTable[iplant][isolution].ec;

```

```

}

```

```

void CCultureDoc::CalculateCulture()

```

```

{

```

```

    //local variables

```

```

    int whichh2o;

```

```

/* Spring Elements */

```

```

    double Spring_analysis_nitrate2,
           Spring_analysis_ammonium2,
           Spring_analysis_potassium2,

```

Spring_analysis_calcium2,
Spring_analysis_phosphate2,
Spring_analysis_magnesium2,
Spring_analysis_sulfate2,
Spring_analysis_carbohydrate1 /*HC1*/ ;

double

Target_element_nitrate4=0,
Target_element_ammonium3=0,
Target_element_potassium3=0,
Target_element_calcium3=0,
Target_element_phosphate4=0,
Target_element_magnesium3=0,
Target_element_sulfate3=0,
Calculation_HNO3_HC3=0,
Calculation_H3PO4_HC4=0,
Include_MgSO4_sulfate6=0,
Include_MgNO3_magnesium4=0,
Include_HNO3_nitrate3=0,
Include_H3PO4_phosphate3=0,
Include_NH4H2PO4_ammonium5=0,
Include_K2SO4_potassium11=0,
Include_KH2PO4_potassium9=0,
Include_KH2PO4_potassium4=0,
Include_KNO3_nitrate8=0,
Include_KNO3_potassium6=0,
Include_K2SO4_potassium10=0,
Include_K2SO4_sulfate5=0,
Include_KNO3_nitrate10=0,
Include_H3PO4_phosphate3=0,
Include_5CaNO322H2O_calcium5=0,
Include_5CaNO322H2O_nitrate5=0,
Include_5CaNO322H2O_ammonium4=0,
Include_NH4H2PO4_ammonium10=0,
Include_CaNO322H2O_calcium5=0,

Include_CaNO322H2O_nitrate5=0,
Include_CaNO322H2O_ammonium4=0,
Include_NH4H2PO4_phosphate5=0,
Result_HNO3_HNO20=0,
Result_H3PO4_HPH20=0,
Result_NH4H2PO4_NHP20=0,
Result_NH4NO3_NHNO20=0,
Result_KH2PO4_KHP20=0,
Result_KNO3_KN20=0,
Result_K2SO4_KS20=0,
Result_KNO3_KS20=0,
Result_MgNO3_MGN20=0,
Result_MgSO4_MGS20=0,
Result_5CaNO322H2O_CANNH20=0,
Result_CaNO322H2O_CANNH20=0,
CAN20=0,
 HC2=0,
Ca4=0,
NH4=0,
NH5=0,
NH6=0,
NH7=0,
NH8=0,
Mg3=0,
Mg4=0,
Mg5=0,
K5=0,
K7=0,
K8=0,
K9=0,
KN21=0,
NO5=0,
NO6=0,
NO7=0,
NO9=0,

```

NO10=0,
NO11=0,
S5=0,
S6=0,
S7=0,
K12=0,
P5=0,
P6=0,
P7=0,
P8=0,
P9=0,
P10=0,
P13=0,
P14=0,
P15=0,
P16=0,
P17=0,
P18=0,
P19=0,
P20=0;
//local variables

        whichh2o = m_whichh2o;
        GetSolution(m_strPlant, m_strSolution);

// Set Spring Elements //
Spring_analysis_nitrate2    = m_Sno3;
Spring_analysis_ammonium2   = m_Snh4;
Spring_analysis_potassium2  = m_Sk;
Spring_analysis_calcium2    = m_Sca;
Spring_analysis_phosphate2  = m_Sh2po4;
Spring_analysis_magnesium2  = m_Smg;
Spring_analysis_sulfate2    = m_Sso4;
Spring_analysis_carbohydrate1= m_Shc3;

```

```

if(Spring_analysis_carbohydrate1>50)
{
    HC2 = (Spring_analysis_carbohydrate1- 50)/122.0;
    Calculation_HNO3_HC3 = HC2*63;
    Calculation_H3PO4_HC4 = HC2*97.99;
    Include_HNO3_nitrate3 = Calculation_HNO3_HC3*0.22;
    Include_H3PO4_phosphate3 = Calculation_H3PO4_HC4*0.32;
    Result_HNO3_HNO20 = Calculation_HNO3_HC3/0.6;
    Result_H3PO4_HPH20 = Calculation_H2PO4_HC4/0.85;
}
else
{
    Include_HNO3_nitrate3 = 0;
    Include_H3PO4_phosphate3 = 0;
}
// Get Target Elements //
Target_element_nitrate4 = NO1 - Spring_analysis_nitrate2
                        - Include_HNO3_nitrate3;
Target_element_ammonium3 = NH1 - Spring_analysis_ammonium2;
Target_element_potassium3 = K1 - Spring_analysis_potassium2;
Target_element_calcium3 = Ca1 - Spring_analysis_calcium2 ;
Target_element_phosphate4 = P1 - Spring_analysis_phosphate2
                        - Include_H3PO4_phosphate3;
Target_element_magnesium3 = Mg1 - Spring_analysis_magnesium2;
Target_element_sulfate3 = SO1 - Spring_analysis_sulfate2;

if( whichh2o == H2O_10)
{
    Ca4 = Target_element_calcium3/CANHCC;
    Include_5CaNO322H2O_calcium5 = Ca4*CANHCC;
    NO5 = Include_5CaNO322H2O_nitrate5 = Ca4*CANHNC;
    NH4 = Include_5CaNO322H2O_ammonium4 = Ca4*CANHHC;
    CAN20 = Result_5CaNO322H2O_CANNH20 = Ca4;
}

```

```

NH8=0;
}
else /* H2O_4 */
{
    Ca4 = Target_element_calcium3/CANCC;
    Include_CaNO322H2O_calcium5 = Ca4*CANCC;
    NO5 = Include_CaNO324H2O_nitrate5 = Ca4*CANNC;
    NH4 = Include_CaNO324H2O_ammonium4 = 0;
    CAN20 = Result_CaNO324H2O_CANNH20 = Ca4;
}
NH5 = Target_element_ammonium3 - NH4;
NH6 = NH5/NHPNC;
P5= Include_NH4H2PO4_phosphate5 = NH6*NHPPC;
Include_NH4H2PO4_ammonium5 = NH5;
Result_NH4H2PO4_NHP20 = NH6;
NH8=0;

if(P5<=Target_element_phosphate4)
{
    P9 = Target_element_phosphate4 - P5;
    P10 = P9/KHPPC;
    Include_KH2PO4_potassium4 = P10*KHPKC;
    K5 = Include_KH2PO4_potassium4;
    Result_KH2PO4_KHP20 = P10;
}
else
{
    P6 = Target_element_phosphate4 + 30;
    if(P5<=P6)
    {
        K5 = 0;
    }
    else
    {
        P7 = (P5- P6)/NHPNC;

```

```

        P8 = Result_NH4H2PO4_NHP20- P7;
        Result_NH4H2PO4_NHP20 = P8;
        NH7 = (NH5- (P8*NHPNC))/2.0;
        NH8 = NH7*NHNHC;
        Result_NH4NO3_NHNO20 = NH8/NHNHC;
        P5 = P7*NHPNC;
        K5 =0;
        NH6 = P8;
        P10 = 0;
    }
}
NO6 = Target_element_nitrate4 - NO5;
NO7 = NO6/KNONC;
Include_KNO3_nitrate8 = NO6;
Include_KNO3_potassium6 = NO7*KNOKC;
K7 = Include_KNO3_potassium6 + K5;
NO9 = Include_KNO3_nitrate8 + NO5 + NH8;
Mg3 = 0;
Result_KNO3_KN20 = NO7;

if(K7<=Target_element_potassium3)
{
    K8 = Target_element_potassium3 - K7;
    K9 = K8/KSKC;
    Include_K2SO4_potassium10=K8;
    Include_K2SO4_sulfate5=K9*KSSC;
    Result_K2SO4_KS20=K9;
}
else
{
    K8 = Target_element_potassium3 - K5;
    K9 = K8/KNOKC;
    Include_KNO3_nitrate10=K9*KNONC;
    Result_KNO3_KS20=K9;
    NO9 = NO5 + Include_KNO3_nitrate10;
}

```

```

NO10 = Target_element_nitrate4- NO9;
NO11 = NO10/MGNC;
Include_MgNO3_magnesium4 = NO11*MGMC;
Mg3 = Include_MgNO3_magnesium4;
Result_MgNO3_MGN20 = NO11;
Include_K2SO4_sulfate5=0;
}

Mg4 = Target_element_magnesium3- Mg3;
Mg5 = Mg4/MSMC;
Include_MgSO4_sulfate6=Mg5*MSSC;
Result_MgSO4_MGS20=Mg5;
S5 = Include_K2SO4_sulfate5 + Include_MgSO4_sulfate6;

if(S5<=120)
{
}
else
{
S6 = S5- 120;
S7 = K9- (S6/KSKC);
Include_K2SO4_potassium11 = S7*KSKC;
Result_K2SO4_KS20 = S7;
K12=((Include_K2SO4_potassium10-
Include_K2SO4_potassium11)/KHPPC);
Include_KH2PO4_potassium9 = K12*KHPPC;
P13 = K12 + P10;
Result_KH2PO4_KHP20 = P13;
P14 = P13*KHPPC;
P15 = P6+20;

if(P14<=P15)
{
}
else
{

```

```

        P16 = P15 - P14;
        P17 = P16/NHPPC;
        P18 = NH6- P17;
        Result_NH4H2PO4_NHP20 = P18;
        Include_NH4H2PO4_ammonium10 = P18*NHPNC;
        P19 = NH5 - Include_NH4H2PO4_ammonium10;
        P20 = (P19/NHNHC)/2.0;
        Result_NH4NO3_NHNO20 = P20;
    }
}
KN21 = ( (Result_KNO3_KN20 + CAN20 + Result_MgSO4_MGS20
+ Result_KH2PO4_KHP20 + Result_NH4NO3_NHNO20
+ Result_NH4H2PO4_NHP20 + Result_K2SO4_KS20
+ Result_MgNO3_MGN20)/2
- (CAN20 + Result_NH4NO3_NHNO20) );

m_Acanh4no3 = (float)CAN20;
m_Akno3 = (float)KN21;
m_Anh4no3 = (float)Result_NH4NO3_NHNO20;
m_Ahno3 = (float)Result_HNO3_HNO20;
m_Bkno3 = (float)(Result_KNO3_KN20 - KN21);
m_Bmgso4 = (float)Result_MgSO4_MGS20;
m_Bkh2po4 = (float)Result_KH2PO4_KHP20;
m_Bnh4h2po4 = (float)Result_NH4H2PO4_NHP20;
m_Bk2so4 = (float)Result_K2SO4_KS20;
m_Bh3po4 = (float)Result_H3PO4_HPH20;
m_Bmgno3 = (float)Result_MgNO3_MGN20;
}

```

```

BOOL CCultureDoc::OnOpenDocument(LPCTSTR lpszPathName)
{
    if (!CDocument::OnOpenDocument(lpszPathName))
        return FALSE;

    // TODO: Add your specialized creation code here

```

```
CalculateCulture();
```

```
return TRUE;
```

```
}
```

```

-----
// culture.cpp : Defines the class behaviors for the application.
//

#include "stdafx.h"
#include "culture.h"

#include "MainFrm.h"
#include "cultureDoc.h"
#include "cultureView.h"

#ifdef _DEBUG
#define new DEBUG_NEW
#undef THIS_FILE
static char THIS_FILE[] = __FILE__;
#endif

////////////////////////////////////
// CCultureApp

BEGIN_MESSAGE_MAP(CCultureApp, CWinApp)
//{{AFX_MSG_MAP(CCultureApp)
ON_COMMAND(ID_APP_ABOUT, OnAppAbout)
//}}AFX_MSG_MAP
// Standard file based document commands
ON_COMMAND(ID_FILE_NEW, CWinApp::OnFileNew)
ON_COMMAND(ID_FILE_OPEN, CWinApp::OnFileOpen)
// Standard print setup command
ON_COMMAND(ID_FILE_PRINT_SETUP,
CWinApp::OnFilePrintSetup)
END_MESSAGE_MAP()

////////////////////////////////////
// CCultureApp construction

```

```

CCultureApp::CCultureApp()
{
}

////////////////////////////////////
// The one and only CCultureApp object

CCultureApp theApp;

////////////////////////////////////
// CCultureApp initialization

BOOL CCultureApp::InitInstance()
{
    // Standard initialization

#ifdef _AFXDLL
    Enable3dControls();           // Call this when using MFC
in a shared DLL
#else
    Enable3dControlsStatic();    // Call this when linking to MFC
statically
#endif

    // Change the registry key under which our settings are stored.
    SetRegistryKey(_T("Local AppWizard- Generated Applications"));

    LoadStdProfileSettings(0); // Load standard INI file options
(including MRU)

    // Register document templates

    CSingleDocTemplate* pDocTemplate;
    pDocTemplate = new CSingleDocTemplate(
        IDR_MAINFRAME,

```

```

        RUNTIME_CLASS(CCultureDoc),
        RUNTIME_CLASS(CMainFrame),           // main SDI frame
window
        RUNTIME_CLASS(CCultureView));
AddDocTemplate(pDocTemplate);

// Parse command line for standard shell commands, DDE, file open
CCommandLineInfo cmdInfo;
ParseCommandLine(cmdInfo);

// Dispatch commands specified on the command line
if (!ProcessShellCommand(cmdInfo))
    return FALSE;
m_pMainWnd->ShowWindow(SW_SHOW);
m_pMainWnd->UpdateWindow();

return TRUE;
}

////////////////////////////////////
// CAboutDlg dialog used for App About

class CAboutDlg : public CDialog
{
public:
    CAboutDlg();

// Dialog Data
//{{AFX_DATA(CAboutDlg)
enum { IDD = IDD_ABOUTBOX };
//}}AFX_DATA

// ClassWizard generated virtual function overrides
//{{AFX_VIRTUAL(CAboutDlg)
protected:

```

```

        virtual void DoDataExchange(CDataExchange* pDX);           //
DDX/DDV support
        //}}AFX_VIRTUAL

// Implementation
protected:
        //{{AFX_MSG(CAboutDlg)
            // No message handlers
        //}}AFX_MSG
        DECLARE_MESSAGE_MAP()
};

CAboutDlg::CAboutDlg() : CDialog(CAboutDlg::IDD)
{
        //{{AFX_DATA_INIT(CAboutDlg)
        //}}AFX_DATA_INIT
}

void CAboutDlg::DoDataExchange(CDataExchange* pDX)
{
        CDialog::DoDataExchange(pDX);
        //{{AFX_DATA_MAP(CAboutDlg)
        //}}AFX_DATA_MAP
}

BEGIN_MESSAGE_MAP(CAboutDlg, CDialog)
        //{{AFX_MSG_MAP(CAboutDlg)
            // No message handlers
        //}}AFX_MSG_MAP
END_MESSAGE_MAP()

// App command to run the dialog
void CCultureApp::OnAppAbout()
{
        CAboutDlg aboutDlg;

```

```
        aboutDlg.DoModal();  
    }
```

```
////////////////////////////////////
```

```
// CCultureApp commands
```

```
-----
```