容器, プラスチックパイプ, ビニールフィルムをしいた溝中の稀釈液肥の毛管移動による地下灌漑の開発試験(農学科)

Exploratory Studies on Subirrigation by Capillary Movement of Diluted Liquid Fertilizer in Containers, Plastic Pipes, and a Ditch underlaid by Plastic Film

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I. INTRODUCTION

THE authors studied the feasibility of subirrigation by capillary movement of diluted fertilizer using sand and soil as media. The studies were made at the horticultural farm of Kyoto University from May 1967 to March 1968.

In conducting the experiments, sand was brought from Biwa Lake, Shiga Prefecture, which was blackish, fine-particles with some gravel and clay particles. It was sieved by a sieve of 6 *mm* open spaces for media. Soil was a sandy loam of the horticultural farm. Liquid fertilizer used was Sumitomo Ekihi No. 2 (10-5-8).

The authors are indebted to Drs. Yōtaro Tsukamoto, and Tadashi Asahira, Messrs. Masayoshi Hujita and Ikuo Kashiwagi and Mrs. Sachiko Matsubara of Kyoto University for their help and encouragement for conducting the experiments.

In the following, the experiments conducted are not arranged in the order of their initiation dates but for convenience.

II. EXPERIMENTS

1. Preliminary Tests on Structures of Sand Beds and Concentrations of Liquid Fertilizer

A. Materials and methods

Sixteen sand beds surrounded by concrete blocks, as shown in Fig. 1 ("pipe-beds") were made annexed to each other in two rows. The water-conducting pipes were made by cutting plastic pipes (inner diameter: 13 *mm*) into pieces of 15 *cm* long, plugging each with a piece of artificial sponge at one end, and then filling them with fine sands. The fine sand was obtained by screening sand through plastic screen (open spaces of 1.1 *mm*). The water storage pipes were made by cutting plastic pipes (inner diameter of 10 *cm*) into pieces of 80 *cm* long and attaching elbows to the both ends, making 1 *m* between the inner edges of the both elbows, which had a capacity of 8 liters. Five holes of a size just large enough to make the water-conducting pipes

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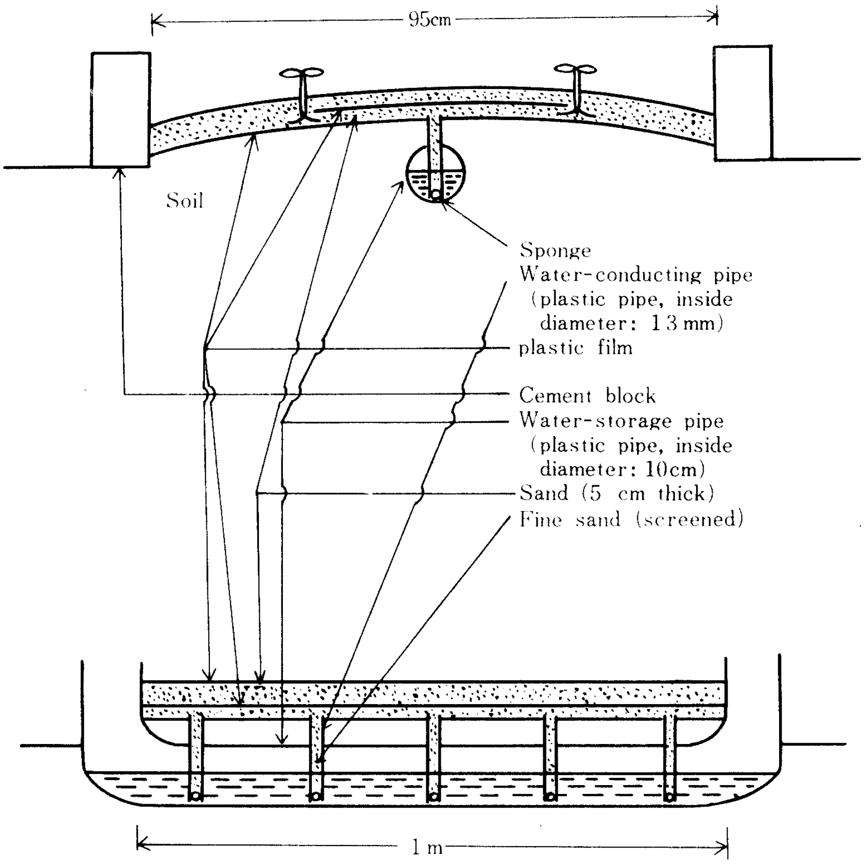


Fig. 1. The crosswise and longitudinal cross sections of the sand bed subirrigated by capillary movement of liquid fertilizer ("pipe-bed", B-type in Table 1).

inserted were drilled at 20*cm* intervals. The storage-pipe wath 5 witer-conducting pipes inserted was buried at a depth of 5 *cm* in the center of the bed. The center of the soil above the pipe was elevated 5 *cm* from the the both edges, so that drainage was efficient. Plastic film (1 *m* x 95*cm*) was placed on the soil, making the conducting pipes extrude a little from the film. Sand, 2 *cm* thick, was placed on the film and plastic film (1 *m* x 47.5*cm*) was placed on the sand to cover the central half area of the bed, and then sand, 3 *cm* thick, was placed, making the medium a total of 5 *cm* thick. The purpose of placing the film was to disperse liquid uniformly, to reduce the loss of fertilizer by rainfall, and to prevent rain water from getting in the storage pipe.

Table 1. The types of "pipe-beds" and liquid fertilizer concentrations used for the radish culture.

Concentration of fertilizer / Type of bed	5*cc*/l	2.5*cc*/l	1.67*cc*/l	No fertilizer, no planting
Over-all mulching	A 1	A 2	A 3	A 4
Half mulching	B 1	B 2	B 3	B 4
No mulching	C 1	C 2	C 3	C 4

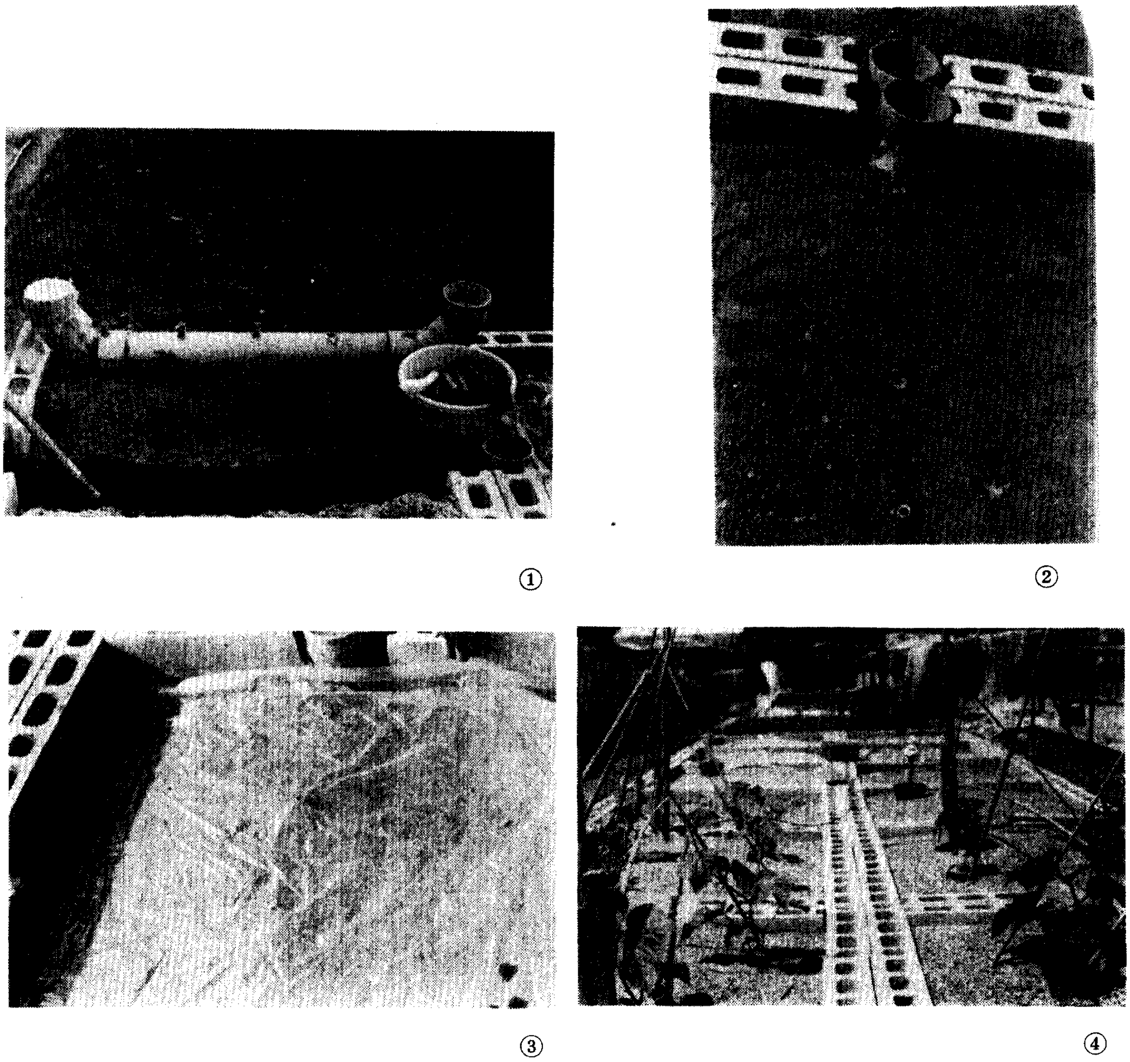


Fig. 2. The process of the construction of the "pipe beds" [(1)~(4)] and the early stage of the growths of the cucumber plants in B beds (4) : B1, front right; B2, front left; B3, behind right; and B4, behind left (see Table 1).

Of the sixteen beds, 12 beds of three types with 4 replications were used as showh in Table 1. The model type shown in Fig. 1 was modified by film in the media. A-bed was covered all the area of the bed by film at a depth 3 *cm* from the surface of the medium, leaving 10 holes of a diameter of 7 *cm* in two rows, 25 *cm* apart symmetrically from the central pipe line. The holes on one side row were 20 *cm* apart from each other. B-bed was the same as Fig. 1. C-bed had no plastic film in the medium.

On May 26, radish seeds (var. Akamaruhatsuka-daikon) were sown at 10 spots in a bed, 20 seeds per spot in 1, 2, and 3 beds of each type of the beds. The 10 spots were arranged in two rows, 25 *cm* apart symmetrically from the central pipe line. The holes on one side row were 20 *cm* apart from each other.

Next studies were made on effects of 4 concentrations of liquid fertilizer on the growth of cucumber plants to find a general optimum fertilizer concentration for plant growth in B and C beds. Four concentrations were 5 *cc*, 2.5*cc*, 1.67*cc*, and 1.25 *cc* per liter. Four seedlings (2.5 leaf stage) were planted 50 *cm* apart from each other in each bed on June 6. And observations of the growths of the plants were made.

Tomato seedlings were planted in the 4 A-beds on June 7. The planting method was the same as that of the cucumber.

On initiating an experiment, the bed was thoroughly watered and drained for the ease of capillary movement and to get rid of accumulated salts in the surface layer of the medium. Eight liters of diluted liquid fertilizer with respective concentrations were supplied continually as the water levels lowered in the pipes to fill the capacity of 8 liters.

B. Results

As shown in Table 2, in the radish culture, the average highest temperatures of the media were, from the highest to the lowest, in the order of C2, B2, and A2, which were usually observed around 1 : 00 p. m. While the lowest ones were quite reverse, having been in the order A2, B2, and C2, which were usually recorded around 5 : 00 a.m. The variation of temperatures was the greatest in the sand medium without mulching with plastic film, which had the highest average temperature among the three types of beds. As the temperatures of all sand media were so high for radish culture, the emerged plants were stunted and did not survive more than 5 days after germination.

Table 2. The average temperatures of the media of the "pipe- beds", A1, B1, and C1 (Table 1, Fig. 1) from June 8 to 14, and the average losses of water per day from the water storage pipes (the averages of 1, 2, and 3 beds for mostly evapotranspiration and 4-bed for evaporation). The average temperatures are the means of the highest and lowest temperatures.

Bed type	Average highest temperature	Average lowest temperature	Average tempera- ture	Water used per day	
				1, 2, 3, bed	4-bed
A	33.9° C	18.9° C	26.4° C	0.78 *l*	0.70 *l*
B	34.4	18.4	26.4	0.80	1.40
C	37.8	17.3	27.6	1.00	1.40

There were very significant differences in the quantities of water used among the 3 types of the beds, "without mulch" having been the greatest, and they were in the order of "half mulch"and "over all mulch".

In the cucumber culture, the average and average highest temperatures were so high and the surface layers of the media were so dry in C-beds that the plants did not survive.

In the early stage of growth, the plants in B1 bed grew faster than the others of B beds, but as they grew brownish necrotic spots of sizes of 0.5 to 1.0 *cm* and finally holes appeared on lower leaves and gradually on upper leaves. And then they finally were stunted. In B 2 bed the plants grew normally and harvested a good crop of fruits, although in the later stage of growth the same symptom as in B 1 bed was observed on leaves. In B 3 and B 4 beds, symptoms of nutrient deficiencies were observed (Table 3).

Table 3. Results of cucumber culture in 4 B-type beds(Table 1, Fig. 1) with 4 varied concentrations of liquid fertilizer from May 5 to July 16 (The quantities of water used were recorded from June 10 to 29 and temperatures on July 14).

Bed	Concentration of fertilizer	Water used per day	Highest temperature	Lowest temperature	Growth in early stage	Growth in later stage
B 1	5.00cc/l	.95 l	34.5° C	17.0° C	Very good	Damaged
B 2	2.50	1.04	34.0	17.5	Good	Very good
B 3	1.67	.71	33.5	17.5	Poor	Moderate
B 4	1.25	.51	33.0	16.5	Very poor	Poor

Observations of the root growths were made on July 26. In B 1 bed most roots extended out of the bed into soil around the bed. In B 2 bed roots grew normally in the bed, and some were circulating on the water conducting pipes, although some extended out of the bed. In B 3 and B 4 beds, a great extent of slender roots were on the water-conducting pipes circulating round and round in a size of an egg (Fig. 3).

Fig. 3. The pattern of root extension of the cucumber plants in B2 (left) and B3 (right) beds.

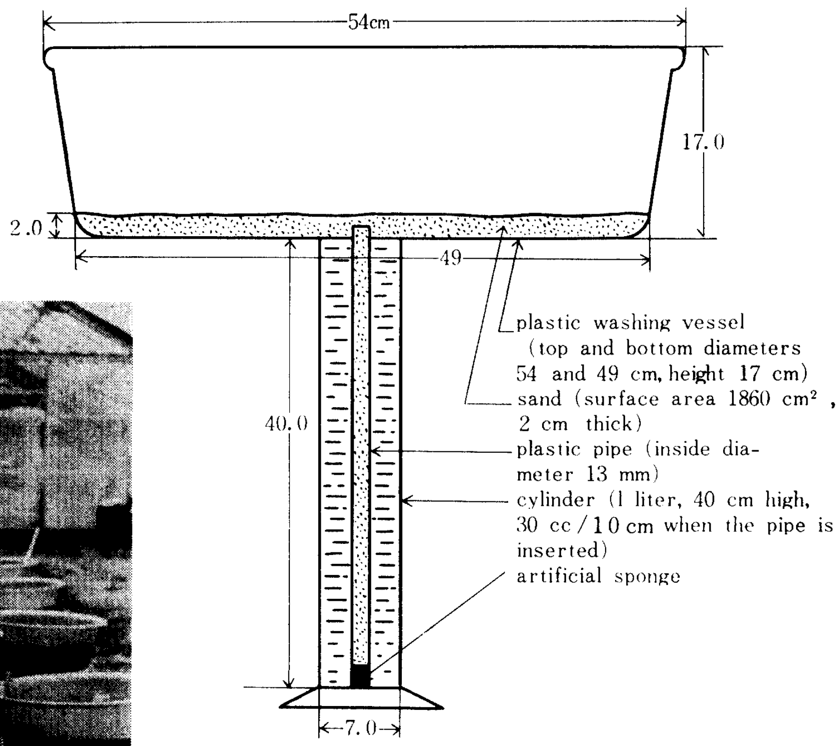
The tomato plants in A beds did not grow well. It was observed that the media were too wet and of poor aeration

Through this experiment, it was found that B-type beds were the best for the cultivation of warm-season crops in summer, although proper ways of fertilizer application remained unsolved.

2. Capillary Conductibity of Various Materials in Relation to Evaporation and Water Levels

A. Materials and methods

Two sand pots (plastic washing vessels) were set under a plastic roof as shown in Fig. 5. Four holes besides the central hole for inserting the water conducting pipe, a diameter of 17 mm. were made on the bottom of the pot for drainage. And a piece of screen was placed on the hole. The area of the surface of the medium when sand in 2 *cm* thick was placed was 1860 cm^2.



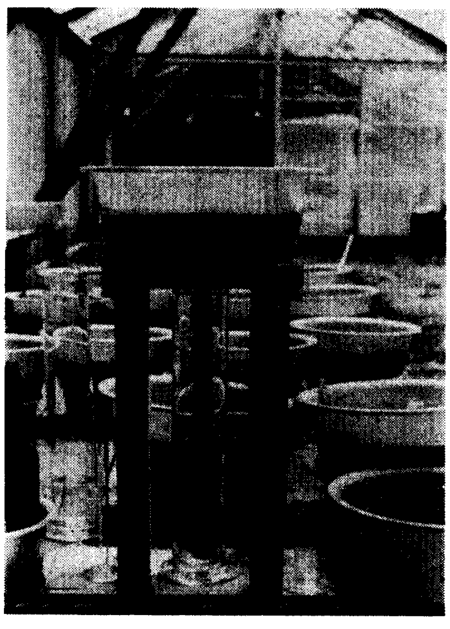


Fig. 4. A photograph of Fig. 5 and Fig. 7.

Fig. 5. The structure of a device for measuring capillary conductibity of materials in the water conducting pipe.

Materials used in the water conducting pipe were "coarse sand" (size: below 3 *mm* in diameter), "fine sand", "fine sand non-washed", sandy loam, and "very fine sand". Also artificial sponge cut in a piece of 2 cm x 2 cm x 41 cm was used.

"Fine sand non-washed" was obtained by screening sand through a piece of plastic screen (1.1 *mm* open spaces), and "fine sand" by stirring "fine sand non-washed" in water vigorously and discarding water with drifting soil particles several times. "Very fine sand" was obtained by stirring "fine sand" vigorously in water and discarding water with drifting very fine sand particles into a piece of cloth and collecting them.

In starting an experiment, the medium was irrigated with sufficient water by a watering can. For an evapotranspiration test, 7 g of radish seeds (var. Minowase) were sown on the initial date.

B. Results

As shown in Table 4, sandy loam, coarse sand, and artificial sponge were poor materials for capillary conductibity in the water conducting pipe to the sand medium.

Table 4. Capillary conductibity of various materials in relation to periods, evaporation and evapotranspiration, and environmental factors using two sand "pots" (plastic washing vessels) on cylinders (Fig. 5).

No.	Material	Evapo- or eva- potran- spi- ration	Depth of water level from the surface when it was drying	Days by which the depth reached	Period from initia- tion to medium's drying	Ave. tem- pera- ture (°C)	Ave. light dura- tion (hrs.)	Ave. humi- dity (%)	Ave. eva- pora- tion (*mm*)
1.	Fine sand non-washed	E.	22.8*cm*.	6 days	June 13 — 19	27.6	3.35	75.9	4.23
2.	〃	〃	22.3	10	July 5 — 15	26.8	1.04	93.9	1.48
3.	Coarse sand	〃	10.1	2	〃				
4.	Fine sand non-washed	E. T.	27.0	5	July 19 — 24	29.4	7.30	63.1	6.10
5.	Sandy loam	E. T.	8.0	4	〃				
6.	Fine sand	E. T.	25.3	5	July31 —Aug.5	29.3	5.66	66.7	5.04
7.	Fine sand non-washed	〃	23.0	5	〃				
8.	Fine sand	E.	25.3	3	Aug. 25 — 28	29.1	3.41	75.3	4.60
9.	Artificial sponge	E.	7.5	1	〃				
10.	Fine sand	E. T.	22.0	5	Aug. 30 —Sep. 4	27.1	4.45	73.0	4.30
11.	〃	E.	16.5	5	〃				
12.	Fine sand	E.	18.5	7	Sep. 6 — 14	26.0	3.10	74.6	3.13
13.	〃	E.	19.2	4	Sep. 22 — 26	20.9	6.38	66.8	3.74
14.	Very fine sand	E.	20.0	4	〃				
15.	Fine sand	E.	11.2	20	Nov. 6 — 26	9.91	2.93	78.7	1.39
16.	〃	E. T.	11.7	〃	〃				

(Note) The data of the last four columns were taken from Demonstration Forest's Meteorological Table of Kyoto University.

As water levels lowered, the rates of water rise were reduced gradually, although some meteorological effects were observed. "Very fine sand" and "sand non-washed" were better in constancy of capillary conductibity with the lowering of water levels than "fine sand" (Fig. 6).

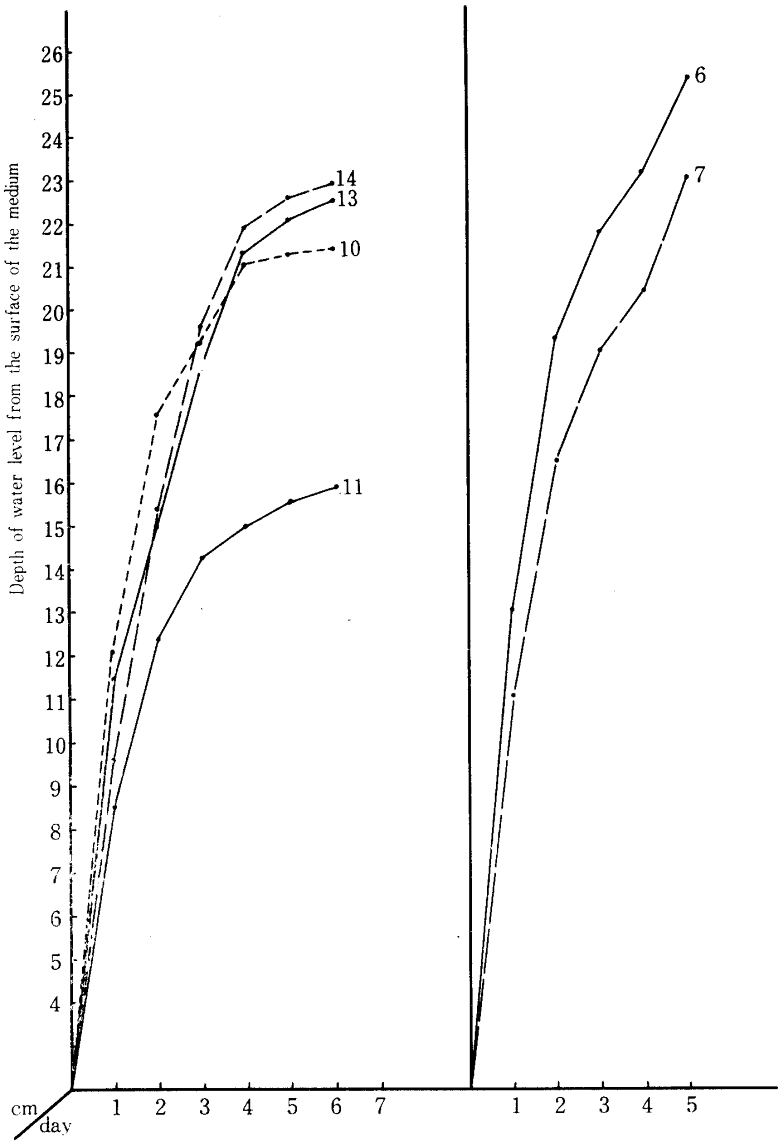


Fig. 6. Daily water levels for evaporation and evapotranspiration in Table 4-No. 6, 7, 10, 11, 13, and 14.

In the evapo- and evapotranspi- ration tests, the pot with radish seeds sown exerted better constancy of capillary rise, and the depth of water risen was greater for evapotranspiration than for evaporation (Fig. 6).

3. Evaporation Tests using Sand Pots (Fig.7)

A. Materials and methods

Sixteen sand pots (Fig. 7) were set under a plastic roof. In the bottom of the pot (plastic washing vessel), 2 holes of 17 *mm* in diameter were drilled open besides the central one to insert the water conducting pipe for drainage. On the holes pieces of plastic screen were placed.

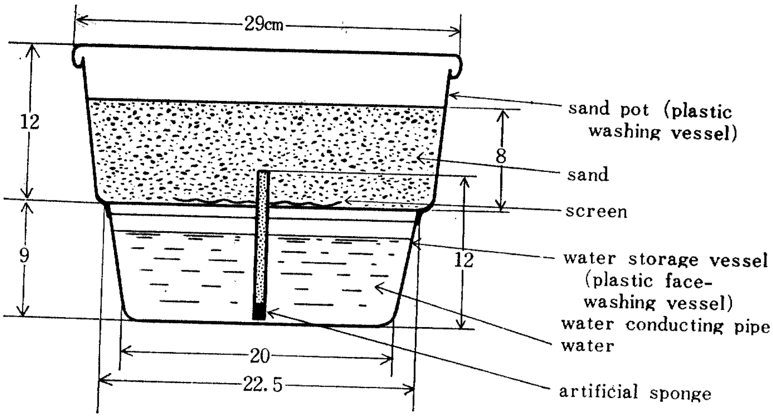


Fig. 7. The structure of the sand pot subirrigatad by capillary rise of water

The quantity of evaporation was measured by putting 2 liters of water in each water storage vessel and measuring the quantity of water lost. The first test was conducted for 6 days from August 8 to 11, and the second test for 4 days from August 29 to September 2.

B. Results

As seen in Table 5, individual pots had quite different abilities of capillary movement due to small differences in the packedness and texture of sand in the water conducting pipes and the pots, the thicknesses of the media, and microenvironmental effects. The correlation coefficient between the 1st and 2nd quantities of evaporation in the table was $r = +0.73$ (95% confidence interval: 0.70 ~0.76). It can

Table 5. The correlation of the first and second quantities of evaporation from the same sand pots (Fig. 5) at the same position.

Period / Pot No.	Aug. 5 — 11	Aug. 29 —Sep. 2
1	56*dl.*	78*dl.*
2	54	97
3	72	84
4	123	120
5	70	93
6	78	91
7	73	85
8	65	139
9	75	90
10	70	104
11	77	88
12	68	87
13	74	90
14	65	152
15	80	98
16	59	94

$r = +0.73$ (95% confidence interval : 0.70—0.76) be said that the rate of evaporation from the pot was partly (about half) attributed to the pot and its position and partly to the microenvironmental factors. Capillary movement is so sensitive that a slight microenvironmental effect can greatly change its movement and the rate of evaporation in a sand medium. Therefore, further tests for evapotranspiration, fertilization, and others could not be efficiently conducted using the pots.

4. Seedling Raising in a Bed on a Water Storage Ditch ("Ditch-bed", Fig. 8 and 12) using Broccoli

A. Materials and methods

A "ditch-bed" was constructed as shown in Fig. 8 and 12. The water conducting pipes were spaced 10 *cm* in the center of the bed. The ditch had a length of 7.1 *m*; a depth, 19 *cm*; an upper width, 55 *cm*; a bottom width, 45 *cm*; and a capacity, 675 liters. The bed was divided into 8 beds, making the area of a bed 150 *cm* x 70*cm*.

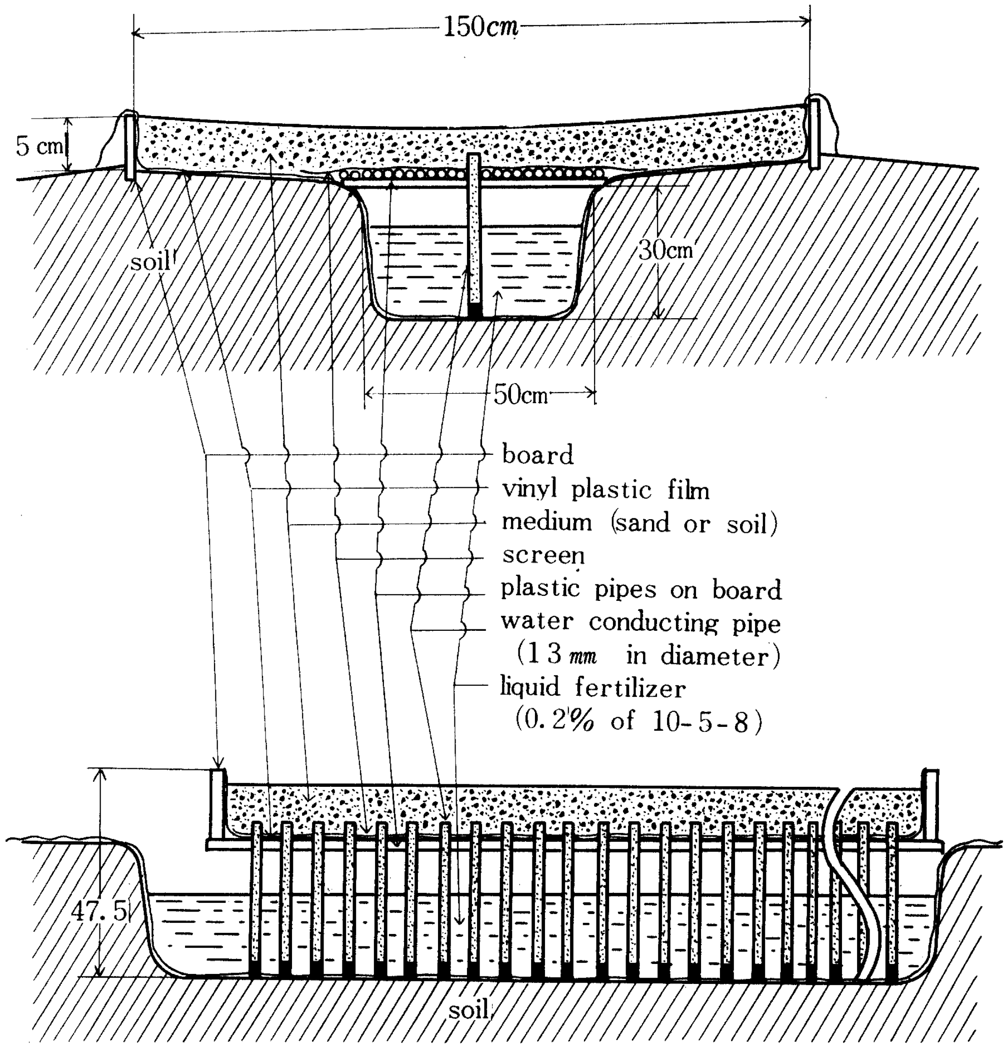


Fig. 8. The crosswise (above) and longitudinal (below) views of the bed used for subirrigation by capillary rise of liquid fertizer ("ditch-bed").

Broccoli seeds (var. Nagaokakohai-nakate) were sown in two of the 8 beds mentioned above. One bed was filled with sand of 5 *cm* thick, and another with soil of 4 *cm* thick on sand of 1 *cm* thick. The seeds were sown in rows on August 4. Twelve rows were made, the 1st two rows having been 5.25 *cm* apart from the central pipe line, the 2nd two rows 10.5 *cm* from the 1st rows, and so on to the sixth rows.

Initially, diluted liquid fertilizer, 0.2% of 10-5-8, was put into the ditch up to the level, 13 *cm* under the surface of the media. The diluted liquid fertilizer was supplied once in 3 or 4 days so that the water level might be maintained between 13 to 18 *cm* below the surface of the media. Since evapotranspiration and rainfall change the concentration of the liquid fertilizer in the ditch, it was checked weekly to let its concentration be around 0.2%. This was done with an instrument used in the gravel culture.

B. Results

On August 29, 3 seedlings taken from each row of both beds were measured as to plant height, number of leaves, total weight, and T/R ratio as shown in Table 6. As the seedlings were not thinned, those of good performance were selected from each row for measurements. There was apparent difference between the sand and soil beds in weight, the soil bed having been far superior to the sand bed. There was no significant difference among the rows in each bed, although it was observed that some trend of poorer growth as the rows became apart from the central pipe line except the last rows on both sides, of which seedlings performed better than those of the adjacent two rows.

Table 6. Results of broccoli seedling raising in the "ditch- bed" (Fig. 9) (Sown on August 4 and measured on August 29. Under the column "row" the figures indicate the distance from the central pipe line, the 1st row being 6.25*cm* apart from the central pipe line, the 2nd row 12.5*cm* from the 1st, and so on. The data are the averages of 3 plants in each row).

Medium & row		Height (*cm*)	No. of leaves	Weight (*g*)	T/R ratio	Temperature of medium		
						Ave. highest	Average	Ave. lowest
sand	1	15.5	5.3	57.7	8.01	33.5	27.7	21.9
	2	14.7	6.1	57.3	12.32			
	3	14.7	5.9	56.7	13.17			
	4	14.5	5.5	61.0	3.35			
	5	14.4	5.7	54.3	5.31			
	6	16.0	5.8	57.3	6.53			
soil	1	23.7	6.0	107.0	6.81	29.3	25.5	21.7
	2	22.5	5.8	86.3	8.27			
	3	22.1	5.6	89.3	6.44			
	4	20.5	6.0	83.3	2.68			
	5	20.4	5.7	75.3	7.09			
	6	21.1	6.0	85.7	9.32			

It is interesting to note that, in both sand and soil beds, the T/R ratio declines as a row becomes apart from the central pipe line and rises as it approaches to the last row. It might indicate the distribution of fertilazer in the media.

Prior to the broccoli seedling raising, eggplant seedlings were raised in both beds in the similar ways for Experiment 5 below. No data were taken, but it was observed that the eggplant seedlings showed the similar trend of growth as the broccoli seedlings.

5. Eggplant Culture in Seven Types of Beds (Fig. 1, Table 7) with Two Concentrations of Liquid Fertilizer.

A. Materials and methods

Of the 16 beds mentioned in Experiment 1, 14 beds (7 types with 2 replications) were used. Their structures are shown in Table 7.

Table 7. The structures of the pipe-beds (Fig. 1) used for the eggplant culture.

Bed	No. of pipes	Medium	placement of medium
A	5	sand	vinyl plastic film
B	〃	sand	compacted soil
C	〃	soil	〃
A′	9	sand	vinyl plastic film
B′	〃	sand	compacted soil
C′	〃	soil	〃
D′	〃	soil	cultivated soil

Type A: The same as B-bed in Experiment 1.

Type B: Sand (5 *cm* thick) was placed directly in contact with packed soil.

Type C: Soil (5 *cm* thick) was placed on packed soil.

Types A′, B′, and C′ : Similar to Types A, B, and C, respectively, except that 9 water-conducting pipes at a distance of 10 *cm* were inserted instead of 5.

Type D′ : Similar to Type C′ except that soil underneath the medium was cultivated.

In all beds, sheets of plastic film of 1 *m* x 47.5 *cm* were placed 3 *cm* below the surface over the central water-storage pipes.

Eggplant seeds were sown in the sand bed in Experiment 4 on June 16, 1967. On July 14, seedlings were transplanted in 15 *cm* pots, and the pots were buried half their heights in A′- type beds. And 8 liters of liquid fertilizer (5 *cc* of 10-5-8 per liter) were poured into the water-storage pipe every day till they were planted on July 27. Four seedlings were planted in a bed spacing 50 *cm*. Two of them were planted directly in the bed removing from the pots, and two were planted with the pots buring in the bed. The purpose of not removing pots was to raise harmful salts to the upper edges of the pots.

As to fertilizer concentrations, 2 replications of each type of bed were treatad as follows:

Concentration 1 (as A1, B1, etc.): 5 *cc* of 10-5-8 per liter
Concentration 2 (as A2, B2, etc.): 2.5 *cc* of 10-5-8 per liter

The diluted liquid fertilizer was continually poured into the water-storage pipes to fill the capacity of 8 liters once in 1 or 5 days from July 27 to August 4, thereafter only water was supplied till August 24 when they were harvested and measured. Temperatures for the depth of 5 *cm* from the surface of the media were recorded daily from August 9 to 29 by an automatic electric resistance thermometer.

B. Results

As the experiment proceeded, it was felt that the method of fertilizer application was not reasonable. For the period, the temperatures were so high that the evaporation rates were rapid and excessive salts rose with the capillaries from the pipes in A and A′ beds. Harmful effects of high salt concentration were found in these beds (Fig. 9).

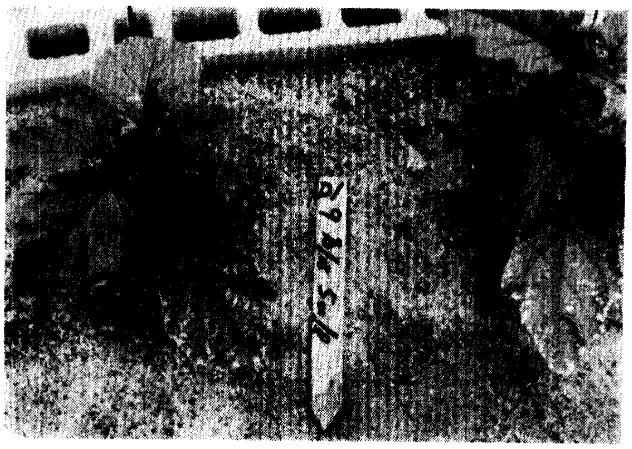


Fig. 9. The symptom of the effect of a high concentration of fertilizer in A′1 bed in the eggplant culture (Table 8).

The root growths of the potted plants buried in the media were so poor that these plants could not be measured for reasonable data.

Whereas, the growths of the rest of the plants were excellent. They were measured as shown in Table 8.

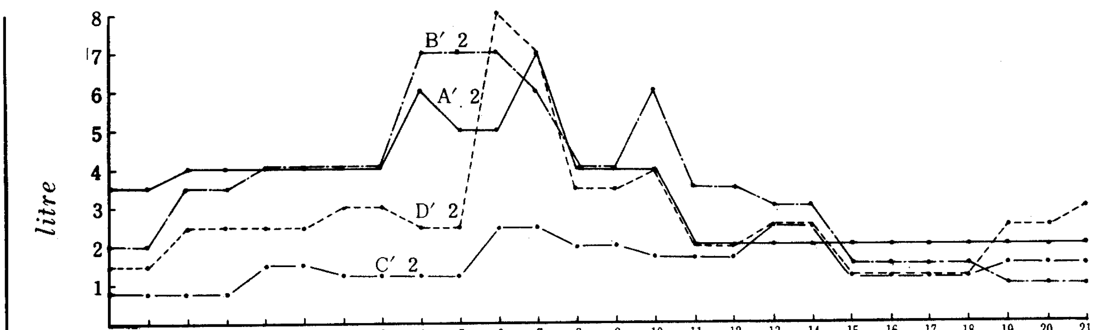
In general, the quantities of water used, which correspond to the amounts of evapotranspiration to a large extent, were highest in A-type beds, and in the order of A′, B′, D′, A, B, C′, and C (Table 8, Fig. 10). Obviouslv there is very significant difference between beds with 5 and 9 water-conducting pipes. And more water was lost from the sand beds than from the soil beds, and from the beds with plastic sheets separating the media from the soil underneath than the others.

As to the average highest temperatures of the media for the surface layers of 5 *cm*, their descending order was B, A, D′, A′, C, B′ and C′. Generally the sand beds had higher temperatures than the soil beds. Comparing the beds, A and A′, B and B′, and C and C′, the more water moved into the media and evaporated, the lower the temperature. It is noted that B-bed had higher

Table 8. Results of eggplant culture in the 7 types of beds (Table 7) with 2 concentrations of liquid fertilizer- 0.5% of 10—5—8 for "1"- beds and 0.25% for "2"-beds (average of 2 plants out of 4 in a bed). Sown on June 16, transplanted on July 14, planted on July 27, and measured on August 24, 1967.

Bed	Height	Top weight	No. of branchs	No. of flowers	No. of fruits	Weight of fruits	Qauntity of water used	Quantity of fertilizer	Temperature	
									Ave. highest	Ave. lowest
A1	31.0 *cm*	24.5 *g*	4.0	0.5	0.5	14.0 *g*	58 *l*	150.0cc	34.9°C	21.7°C
A2	42.5	100.0	4.0	6.5	5.0	24.7	64	77.5		
B1	56.5	434.5	11.0	16.0	6.0	107.0	20	100.0	36.6	22.4
B2	47.5	250.0	10.0	5.0	2.5	27.5	29	50.0		
C1	50.5	368.0	12.5	12.0	4.5	23.5	19	70.0	31.9	22.2
C2	56.5	488.5	13.5	14.5	6.0	55.0	14	35.0		
A′1	44.0	151.0	8.5	11.5	6.5	35.0	101	180.0	34.5	22.5
A′2	43.5	115.5	9.0	8.0	4.0	35.5	94	97.5		
B′1	58.5	490.5	16.5	13.5	6.0	68.0	55	110.0	31.5	22.2
B′2	62.5	564.0	14.5	13.5	6.0	68.5	91	102.5		
C′1	53.5	515.5	16.0	10.5	3.5	42.0	30	85.0	31.1	21.6
C′2	59.0	568.0	17.0	15.5	6.0	40.0	41	47.5		
D′1	60.0	621.0	15.0	12.5	6.0	37.0	75	175.0	34.8	22.5
D′2	64.5	492.0	16.0	19.0	6.0	25.5	52	85.0		

Note : The diluted fertilizers had been continually supplied from July 27 to August 4, thereafter only water supplied. Temperatures were measured daily from August 9 to 29 for the depth of 5 cm from the surfaces of the media.



Date	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
E. (mm)	6.0	7.4	4.7	6.0	4.1	4.8	5.1	5.2	4.0	4.9	7.2	7.5	7.0	6.7	7.0	3.1	4.4	4.3	1.5	2.9	4.2	7.0	7.9	6.4	3.1	1.7
R. H. (%)	63	54	70	71	69	70	67	64	67	69	66	63	60	61	70	62	65	68	52	69	83	75	65	51	60	79
L. (hr)	7.2	5.4	1.6	7.0	2.6	5.4	4.9	6.0	5.8	6.0	8.9	10.1	10.2	6.8	10.8	0.3	2.8	2.0	0.5	3.2	4.1	9.8	10.0	2.5	3.7	0
P. (mm)									9.0	24.8									0.5	8.2						2.3
A. T. (℃)	29.0	28.8	29.0	29.6	29.2	28.8	28.3	29.5	29.9	30.0	29.9	27.8	27.0	27.5	29.8	29.8	31.6	29.8	27.3	29.8	30.2	29.8	29.7	28.0	28.0	25.5

Fig. 10. Daily quantities of water used (mostly due to evapotranspiration) in the beds, A′2 B′2, C′2, and D′2 (Fig. 1, Table 7) in relation to the growing days and meteorological factors—evaporation (E), relative humidity (R.H.), hours of light (L.), precipitation (P), and atmospheric temperature at 150 *cm* high (A. T.) (The meteorological data were taken from Demonstration Forest's Meteorological Table of Kyoto University)—in the eggplant culture from July 27 to August 21, 1967.

temperatures than A as compared with that A′ had higher than B′. It was observed that surface layers of B-beds were drying.

In comparison of D′ and C′ beds, the cultivated soil beneath the medium attributed to a greater loss of water than compacted soil. Whereas, the temperatures of the former were much higher than the latter.

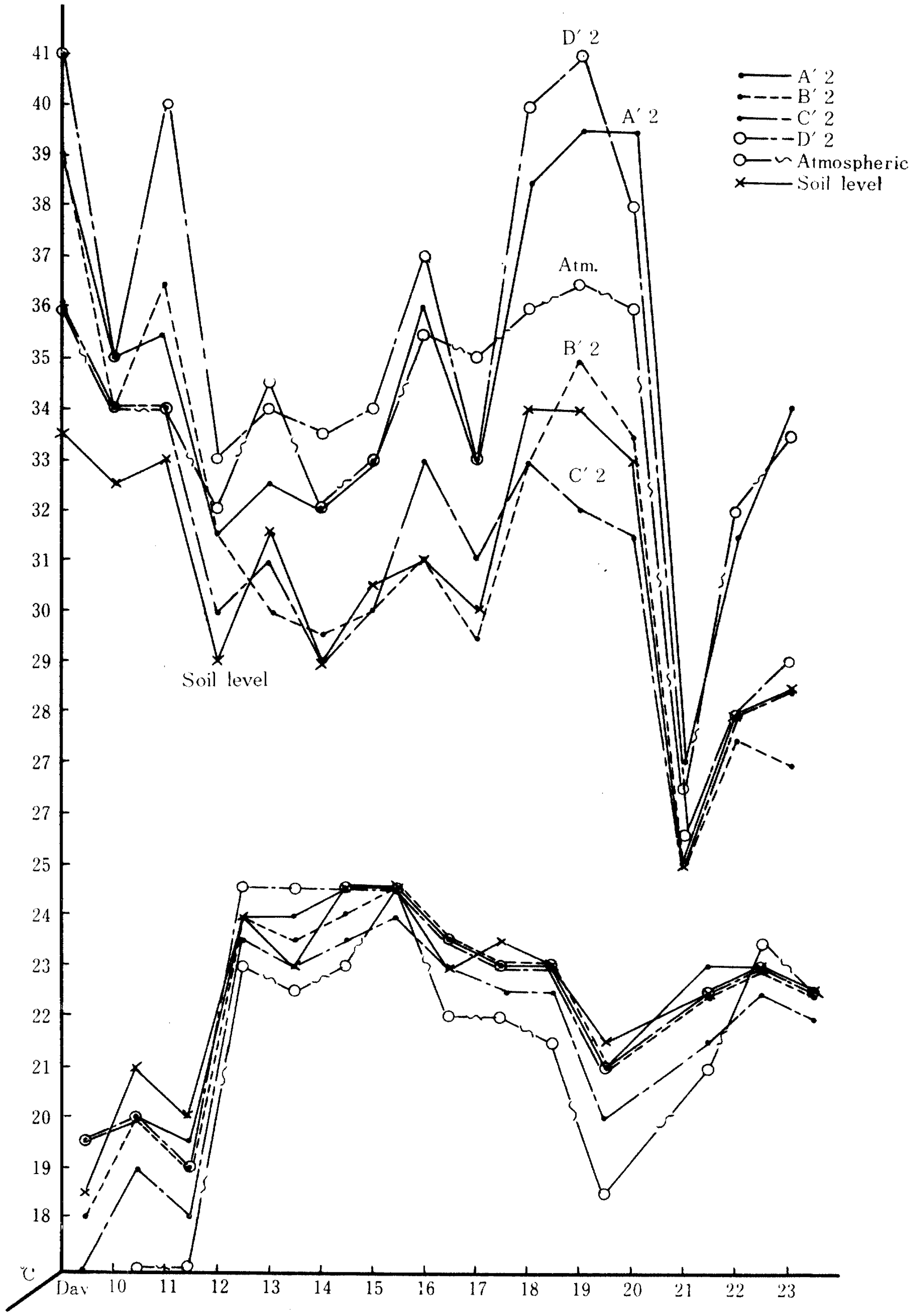


Fig. 11. Daily highest and lowest temperatures in beds, A′2, B′2, C′2, and D′2 (Table 7), atmospheric (85 *cm* above the soil) and the soil level from August 9 to 23, 1967 in the eggplant culture.

As mentioned before, as the method of fertilizer application was unreasonable, the growths of plants can not be reasonably compared. But in general, excepting A and A′ beds, plant growth was better in beds with 9 water conducting pipes than 5. No apparent difference between sand and soil media could be found, since in both types of beds, roots extended into the soil underneath the media. In the earliness of flower and fruit development, B1-bed was best, but B′, C′ and D′ had great potentialities of development. There was no significant difference between the 2 concentrarions of fertilizer in earliness and growth.

6. Broccoli Culture in Sand and Soil Media in the "Ditch-bed "(Fig. 8 and 12).

A. Materials and methods

Three 70 *cm* x 150 *cm* beds mentioned in Experiment 4 were used (Fig. 12). Bed A was filled with sand 5 *cm* thick, Bed B with sand 5 *cm* thick with a polyethylene plastic sheet (70 *cm* x 75 *cm*) covering the central half area of the bed, 2 *cm* below the surface of the medium, and Bed C with soil 5 *cm* thick.

Table 9. Media for seedling raising and for culture of the broccoli in the"ditch-bed"(Fig. 8 & 12).

Plant No.	Medium seeded	Medium planted
1	sand	sand
2	soil	〃
3	sand	sand with plastic sheet
4	soil	〃
5	sand	soil
6	soil	〃
7	soil	soil non-subirrigated bed used for eggplant seedling raising

Note : In the medium, "sand with plastic sheet," a sheet of polyethylene plastic film (70 *cm* x75*cm*) was placed in the sand 2 *cm* below the surface of the medium covering the central half area of the bed (70 *cm* x 150 *cm*).

Three seedlings taken from the sand bed in Experiment 4 were planted 35 *cm* apart from the centers of the beds on one sides, one plant in one bed, and 3 plants from the soil bed on the other sides. As a control plant, one seedling taken from the soil bed was planted in a bed used for eggplant seedling-raising by usual method without subirrigation. The bed contained abundant manure and chemical fertilizer for broccoli culture.

The concentration of the liquid fertilizer had been maintained as in Experiment 4 (around 0.2% of 10-5-8).

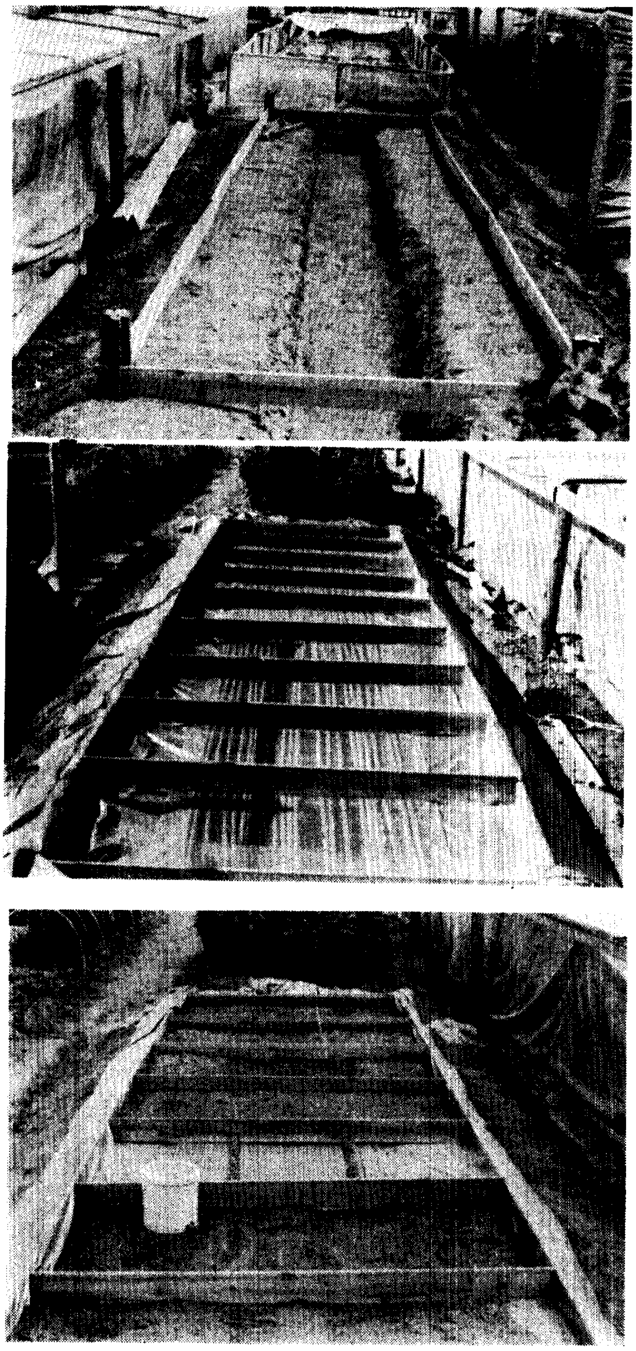


Fig. 12. The process of the construction of the "ditch bed" (Beds with water conducting pipes arranged in one line in the center of the ditch were used in Experiments 4 and 6).

B. Results

The results are shown in Tables 10 and 11. Since no replications were made for each treatment, no statistical significance could be found among the treatments. As to the earliness of head crops, seedlings raised in the sand beds produced earlier crops than those in the soil bed,

Table 10. The average highest and lowest temperatures of sand and soil beds for 5 *cm* deep in the "ditch-bed" (Fig. 8 and 12).

Period / Medium	Sept. 2—3			Sept. 15—16			Oct. 1—2		
	high	low	ave.	high	low	ave.	high	low	ave.
Sand	35.0	21.5	28.3	28.3	18.3	23.3	23.0	14.5	18.8
Soil	34.0	21.5	27.8	26.3	18.5	22.4	22.3	14.0	18.2

Note : The average temperatures are the averages of the highest and lowest temperatures.

Table 11. Results of broccoli culture in the "ditch-ded" (sown on Aug. 4, planted on Aug. 29, and measured on Nov. 29).

Plant No.	Height	Weight of head	No. of branches	Top weight	Root weight	T/R ratio
1	70*cm*	590 *g*	8	3.10*kg*	220 *g*	14.09
2	75	100	15	3.40	300	11.33
3	75	500	3	2.10	200	10.50
4	85	700	22	2.60	500	5.00
5	113	280	35	4.60	360	12.77
6	116	240	31	4.16	220	18.90
7	116	930	23	5.78	340	17.00

Whereas, the potentialities of development were quite reverse as shown in the columns of "No. of branches" and "top weight" of Table 11, excepting Plant 5 of which seedling was raised in the sand bed and grown in the soil bed, which was the heaviest and had the largest number of branches. In Experiment 4, seedling raised in the soil bed were much better than those in the sand bed. But it is doubtful whether the former excel the latter after planting in a soil medium. Further tests are to be made.

It is interesting to note the T/R ratios, but the sample was so small and the method of measurement was so rough that they could not be so reliable.

7, Quantities of Water loss (for mostly Evaporation and Evapotranspiration) from the "Pipe-beds" in Relation to their Structures (Fig.1)

The eight beds used in Experiment 1 (A and B- beds) were used in this experiment (Table 12, Fig. 1). In Test 3, 4 grams of radish seeds (var. Minowase) were sown in each bed (1 g in each spot, 4 spots in each bed, 25 *cm* apart symmetrically from the central crossing line, i. e., 50 *cm* apart from each other). In Test 5, 1 gram of Chinese leaf cabbage seeds was sown broadcast in E1, 4, 5, and 8.

The medium (sand or soil), 5 *cm* thick, was placed on a sheet of vinyl plastic film or on packed soil.

The lengths of the water conducting pipes were varied from 11 to 15 *cm*. As the

Table 12. Quantities of water loss from the water storage pipes (for mostly evaporation and evapotranspiration) in relation to the structures of the "pipe beds" (Fig. 1).

Bed	Medium	Material under-neath	Water conducting pipes		Depth of water storage pipe	Average quantiy of water per day	Average highest tempe-rature	Average lowest tempe-rature	Meteorological data (daily average)
			Length	Number					
Test 1. Evaproation for 3 days from August 28 to 31.									
A1	sand	soil	11*cm*	5	10*cm*	8.00 *l*			1. 3.4*mm*
A2	〃	〃	11	5	5	7.33			2. 27.9°C
A3	〃	vinyl	15	5	10	2.66			3. 68.0%
A4	〃	〃	15	5	10	3.33			4. 2.31%
A5	〃	soil	12.5	5	10	6.33			5. 4.5*mm*
A6	〃	〃	15	5	10	3.66			
A7	soil	〃	12.5	5	10	4.00			
A8	〃	〃	11.0	5	10	7.00			
Test 2. Evaporation for 4 days from September 1 to 5									
B1	sand	soil	14	5	10	5.25			1. 4.6*mm*
B2	〃	〃	14	5	10	4.73			2. 27.7°C
B3	〃	vinyl	15	5	10	3.25			3. 74.0%
B4	〃	〃	15	5	10	3.50			4. 5.25%
B5	〃	soil	13	5	10	3.50			5. 2.0*mm*
B6	〃	〃	12.5	5	10	3.75			
B7	soil	〃	12.5	5	10	4.93			
B8	〃	〃	14	5	10	2.00			
Test 3. Evapotranspiration for 7 days from September 6 to 13 (4 *g* of radish seeds were sown).									
C1	sand	soil	14	5	10	4.50			1. 3.0*mm*
C2	〃	〃	14	5	15	4.71			2. 26.0°C
C3	〃	vinyl	14	5	10	3.86	34.3	20.9	3. 77.0%
C4	〃	〃	15	5	10	3.29			4. 3.0%
C5	〃	soil	13	5	10	3.57	35.6	20.4	5. 5.0*mm*
C6	〃	〃	15	5	10	3.01	33.8	20.9	
C7	soil	〃	12.5	5	10	4.43	33.9	20.7	
C8	〃	〃	14	5	10	3.01	32.8	20.8	
Test 4. Evaporation for 10 days from September 23 to October 2.									
D1	sand	soil	11	1	10	1.1	33.0	13.2	1. 3.4*mm*
D2	〃	〃	11	2	10	1.7	32.7	11.8	2. 21.3°C
D3	〃	vinyl	11	1	10	1.2	32.0	11.7	3. 64.0%
D4	〃	〃	11	2	10	2.6	31.5	12.6	4. 5.00%
D5	soil	〃	11	1	10	0.6	31.8	13.8	5. 0.23*mm*
D6	〃	〃	11	2	10	0.3	31.0	12.0	
D7	〃	soil	11	1	10	0.9	32.5	12.2	
D8	〃	〃	11	2	10	1.9	31.0	12.0	
Test 5. Evaporation and evapotranspiration for 8 days from Oct. 19 to 26. In E-1, 4, 5, and 8 beds, one gram of Chinese leaf cabbage seeds was sown (In E-1 bed no germination occurred).									
E1	sand	soil	11	1	10	0.58	21.1	8.6	1. 1.9*mm*
E2	〃	〃	11	1	10	0.51	21.2	8.4	2. 15.0°C
E3	〃	vinyl	11	1	10	0.72	19.7	7.8	3. 70.1%
E4	〃	〃	11	1	10	0.84	19.3	8.1	4. 3.19%
E5	soil	〃	11	1	10	0.45	18.7	8.5	5. 0.06*mm*
E6	〃	〃	11	1	10	0.45	19.6	8.1	
E7	〃	soil	11	1	10	0.40	21.9	7.8	
E8	〃	〃	11	1	10	0.64	20.1	8.6	

Note : The meteorological data (daily average) were taken from Demonstration Forest' s Meteorological Table of Kyoto University. One (1.) refers to evaporation; 2, atmospheric temperature; 3, humidity; 4, light duration, and 5, precipitatation.

inner diameter of the water storage pipe was 10 *cm*, the minimum length of the pipe to be used was 11 *cm*.

In Tests 1, 2, and 3, the number of the conducting pipes was 5, 20 *cm* apart from each other. In Test 4, it was 1 or 2, one (1) pipe having been in the center of the storage pipe, and 2 pipes 20 *cm* apart from the center toward both sides In Test 5, one conducting pipe was inserted in the center of the storage pipe.

In D7, D8, E7, and E8 beds, sand of 7 *cm* thick and 10 *cm* wide was placed on the storage pipe. In D and E 5, 6, 7, and 8 beds, the polyethylene plastic film covering the central half of the beds 3 *cm* deep which was theretofore used in all beds was removed.

Temperatures of the media for 5 *cm* deep were recorded by an electric resistance thermometer. The meteorological data were taken from the Demonstration Forest's Meteorological Table of Kyoto University.

Water was continually supplied into the water storage pipe as the water level lowered. Twenty (20) *cc* of liquid fertilizer (10-5-8) were supplied once a week into the storage pipe of the bed planted to Chinese cabbage(E1, 4, 5, and 8).

The results are shown in Tables 12 and 14, and Fig. 13, and an inference thereon in Table 13.

Table 13. Comparisons of the "pipe-beds" (Fig. 1) as to water loss (evaporation and evapotranspiration) in relations to temperature of media, water levels, length and number of the "water-conducting pipes", the presence of plastic film separating media from packed soil underlying, inferred from Table 16

Relative magnitude of water loss	Comparison of beds	
Media sand > soil	A 1 vs. A 8, C 4 vs. C 6, D 2 vs. D 8,	B 1 vs. B 8 D 1 vs. D 7 E 2 vs. E 7
Length of water conducting pipes shorter > longer	A 5 vs. A 6, B 6 vs. B 5, C 5 vs. C 6,	A 8 vs. A 7 B 7 vs. B 8 C 7 vs. C 8
Temperature of media higher > lower	General view of Table 16 A 4 vs. D 4, D 3 vs. E 3,	 A 6 vs. C 6 D 7 vs. E 7
Number of water conducting pipes many > small (depends on moisture contents and capillary potential of media)	Test 4	
Materials underlaid (incomparable, interactions with other factors be concerned)	A 6 vs. A 4, D 4 vs. D 2,	D 3 vs. D 1 E 3 vs. E 2
Evaporation vs. evapotranspiration ET > E	D 7 vs. D 5, Test 5.	D 8 vs. D 6

Table 14. Results of radish young plant culture in the "pipe-beds" (Sown on September 6 and measured on the 13th).

Bed	No. of germination	Average weight	Total weight
C1	189	281 mg	47.5 g
C2	148	296	43.3
C3	161	303	48.8
C4	161	329	53.0
C5	138	391	53.9
C6	159	304	48.3
C7	152	551	83.8
C8	146	549	80.2

Fig. 13. The growing patterns of Chinese leaf cabbage (var. santosai) in the beds: top, E4, middle, E5 and bottom, E8 (see Table 12). Seeds were sown on October 14 and the pictures were taken on December 25.

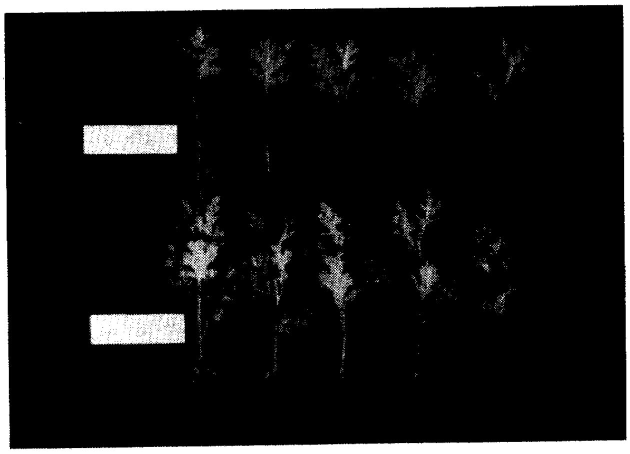
In Test 4 (Table 14), there was apparent difference between the sand and the soil beds in the growth of the plants. Little appeciable difference was found among the sand beds.

As seen in Fig. 13, the growth and pattern of growth of Chinese cabbage (the rate and distance of capillary movement of liquid fertilizer) in E8 bed (without film underneath the soil medium) were superior to those of E5 (with vinyl film). In the sand bed without plastic film beneath the medium (E1), the seeds did not germinate. As the temperature of the medium was so low that capillary water could not rise to the surface, and the surface layer was dry. The small seeds could not absorb sufficient water to germinate.

8. Rooting of Chrysanthemum Cuttings in Pots Subirrigated vs. Misted.

Ten chrysanthemum cuttings, 12 *cm* long (var. No. 640 of Kyoto University), were inserted half the stem length in each of two "sand pots" (Fig.7). One was placed on a mist box on which mist was spread for 15 seconds per 30 minutes for 24 hours a day under a plastic house. The subirrigated one (Fig. 7) was placed outdoors, and covered by the same kind of vessel as the sand pot, which was blue in color.

The experiment was started on May 12 and finished on June 21. A height of 6 *cm* of water was put into the subirrigating vessel.



Misted

Subirrigated

Fig. 14. Rooting of Chrysanthemum cuttings. (The cuttings were made on May 12 and the pictures were taken on June 21).

A picture of the rooted cuttings was taken 40 days after the cuttings were made (Fig. 14). In uniformity of rooting, subirrigated ones were better than misted. Many fibrous roots elongated in the subirrigated pot in contrust to stout roots in the misted pot. The stem elongation was much greater in the subirrigated pot than in the misted, the average stem length of 5 cuttings in the misted having been 17.0 *cm* and that in the subirrigated 21.0 *cm*. But the latter was feeble. It might have been due to low light intensities and high humidity. It might have been corrected by covering the pot with a transparent plastic sheet and controlling humidity.

Water in the vessel on which the subirrigated pot was placed did not appreciably decreased, since the loss of water by evapotranspiration was checked by the vessel covering the pot.

9. Water Losses due to evaporation or evapotranspiration in Relation to the Depth of Water Level from the Device shown in Fig. 5 at 20 and 30°C in the Phytotron in Kyoto University.

Studies were made on the daily amounts of evaporation and evapotranspiration using the device shown in Fig. 5, measuring the depth of water level at an interval of 24 hours.

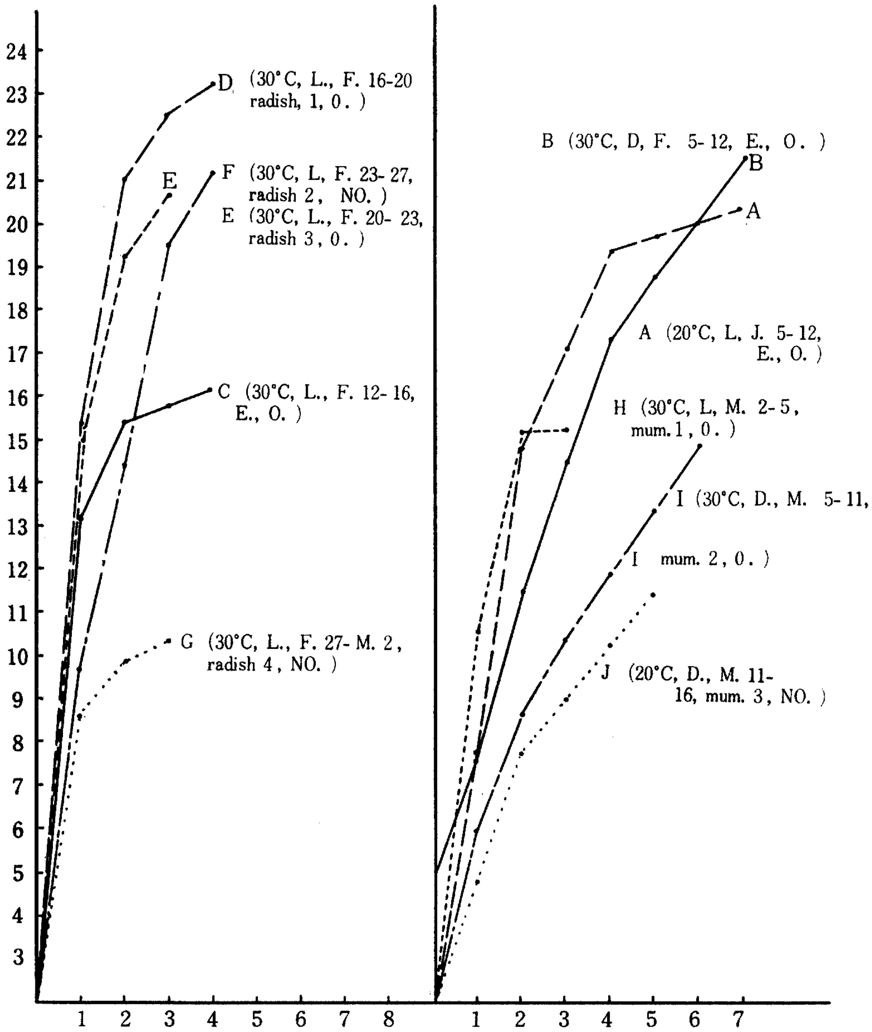


Fig. 15. Daily amounts of evaporation and evapotranspiration with the lowering of water levels from the device shown in Fig. 5 in the phytotron of Kyoto University (In the parenthesis after the symbol of a test, the cabinet temperature ; L. for under natural light and D. for dark room ; date ; J. for January, F. for February, and M. for March,1968; E. for evaporation, and radish 1, 2, 3, and 4 and mum (Chrysanthemum) 1, 2, and 3 for evapotranspiration ; O. for initial overhead irrigation and No. for not initial overhead irrigation, are indicated).

Initially the cylinder was filled with water. When the surface of the medium was dry, the test was finished and the next test was started, the cylinder having been filled with water again.

Tests A, B, J, and K were for evaporation. Tests C, D, E, and F were for evapotranspiration using radish continuing from sowing 7 *g* of seeds on February 16 in Test C. Tests G, H, and I were for evapotranspiration using commercially grown Chrysanthemum plants in sand, 3 *cm* thick. At first, as the thickness of the sand medium was 2 *cm*, the initial water level was 2 *cm* deep. And it was 3 *cm* for tests for Chrysanthemum.

As the period of our studies were limited, satisfactory tests were not conducted.

The results are shown in Fig. 12. They are discussed in the following "III. Discussion".

III DISCUSSION

An unsaturated soil is one in which the larger pores are filled with air and, consequently, where movement is closely dependent upon a large number of air-water interfaces. The distribution and movement of water may be lateral, vertically upward, vertically downward, or at any angle between the vertical and horizontal.

The fundamental basis of the capillary-tube hypothesis, with respect to the movement of capillary water in soils, is the well known height-of-capillary-rise equation:

$$h = 2T/gDr$$

where h is the height of the meniscus above the water level, T is the surface tension and D, the density of the liquid, g is the acceleration due to gravity, and r is the radius of the capillary tube. Interpreting this equation in terms of the soil, we see that the height of rise is inversely proportional to the radius of the pores. The presence of many small pores in the soil would therefore suggest considerable capillary movement of water in soils.

In 1884, Wollny studied various factors that affected the capillary movement of water in soils. He found that the rate of capillary rise in a loam soil increased with temperature, with the looseness of packing, and with the original moisture content of the soil. He also observed that the rise was faster in a column of sand particles of mixed sizes than in columns having particles of uniform size. He came to the conclusion that soil capillaries from 0.05 to 0.10 *mm* in diameter conducted water the most rapidly and that capillary movement reached a minimum limit with quartz particles larger than 2.0 *mm*. He showed that coarse-textured soils had a rapid initial rate of capillary movement but that the finer-textured ones eventually had the highest rise. This is in conformity with our experimental data. Loughridge (1894) studied that a granular soil possesses capillary properties (water-holding capacity) within the granules and at the same time permits the ready movement of water in the larger pores between them. King (1907) showed that capillary movement through a wet soil is faster than through one that is dry.

Harris and Turpin (1917) showed that the greatest rise and descent of water into a dry soil from a moist one always took place in the case of the greatest initial moisture content of the source. Capillary movement downward was slightly faster than upward or laterally. The rate of movement from one soil type into another varied considerably with differences in texture. Only a small rise was observed from a moist clay soil into a dry loam that was brought in contact with the clay; an exceedingly large and rapid rise occurred from moist sand into a dry loam.

Capillary properties of the soil must be evaluated in terms of rate as well as distance of movement. The capillary-tube hypothesis has emphasized distance of movement rather than rate. Experiments show that the rate of capillary rise is very slow in those soils where the pore size mathematically suggests a high rise.

Moore (1939), in studying the advance of the wetting front as water rises in a soil column from shallow water tables, has characterized the wetting front as follows: (1) Water advances in a front from wet to drier soil under the influence of capillarity. Beyond the front, the soil remains apparently dry, and immediately at and behind the front the soil is apparently completely wetted. Macroscopically, there is a sharp line of demarcation between the obviously wet soil and the obviously dry oil. (2) The moisture content of the wetting front determined by sampling is constant, indicating a constant radius of curvature.

The movement of capillary water downward takes place under the combined influences of the gravitational-potential gradient and the capillary-potential gradient. Upward movement of capillary water takes place against the gravitational potential when the influence of the capiillary-potential gradient is of sufficient magnitude to cause movement in this direction. Upward flow from a water table is maintained in the presence of evaporation. Lateral movement of water takes place under the influence of the capillary-potential gradient only. Gardner and coworkers (1922) have suggested that it be defined as the work required to move a unit mass of water from a point where the potential is zero to the point in question. The capillary potential is proportional to the height above the water table.

In views of the above studies and our experimental data, C type of the "pipe-bed" used in the eggplant culture is satisfactory for most crops except root crops. For root crops D type bed can be used. For the purpose of harvesting early crops, B or A types can be used.

It is considered to be better to make the water conducting pipes 11 *cm* long inserted in the water-storage pipe at intervals of 10 *cm*.

For preventing heavy loss of water by evaporation, a medium on the storage pipe may be better to make around 10 *cm* thick to maintain a thin layer of dry media on the surface to act as mulch. But for raising seedlings, E8 A type in Experiment 7 or ditch-bed with sand or soil medium is better. Although a ditch-bed can store rain water, the loss of water is great since underground capillary water can not be utilized.

In fields, where heavy growth of weeds is a problem a B-type pipe-bed can be used, and where soil-borne diseases are a problem an A-type bed with medium sand or sterilized soil can be used. For practical purposes no concrete blocks are necessary.

Fertilizer tests should be done hereafter using various crops.

It was found later that gibberellin can be effectively applied by dissolving it in liquid fertilizer. But further studies should be made in comparison with foliar spray.

Although the studies are still on the exploratory stage, it is expected to be practical for the use by research workes and general crop producers. The method of fertilizer and water application is not only very effective and efficient for plant growth and for saving labor but also not too expensive for construction and operation and also durable. The bed can be set in outdoors as well as in a plastic house or in a greenhouse in small or large scale. Water and fertilizer can be economically used. In a greenhouse the accumulation of harmful salts on the surfaces of media may be a problem.

IV SUMMARY

Sixteen "pipe-beds" (Fig. 1 and 2), two of a device for measuring evapotranspiration (Fig. 4 and 5), 16 sand pots (Fig. 7), and a "ditch-bed" (Fig. 5) were established. These were devised to subirrigate by capillary movement of water or diluted liquid fertlizer through "water-conducting pipes" in "water-storage pipes", cylinders, containers, and a ditch. Sand and soil were used for media. Sumitomo Liquid Fertilizer No. 2 (10-5-8) were diluted in water. With the device for measuring evapotranspiration, experiments were made on the adaptability of various materials for conductibity of water. Fine sand screened through plastic screen (1.1 *mm* open spaces) was satisfactory.

The sand pots were made for the purpose of conducting fertilizer tests, but the individual pots had greatly different evaporation rates due to microenvironmental factors, and fertilizer tests could not be done.

The ditch-bed was good for raising seedlings. Although a ditch-bed can store rain water, capillary water from underground can not be utilized. Therefore, water may not be economically used.

The C-type of pipe-beds used in the the eggplant culture are considered to be satisfactory for most crops. For root crops the D-type should be used. In weedy fields the B-type is better. And in soils where soil-borne diseases are problems the A-type can be advantageously used. It is considered that water-conducting pipes are made just to extrude from the water-storage pipes (11 *cm* long) and spaced 10 *cm* when inner diameter thereof is 13 *mm*.

Although the studies are on the exploratory stage, it is expected to be practical. The method of water and fertilizer application is not only effective and efficient for plant growth and saving labor but also not too expensive for constrution and operation and also durable.

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容器，プラスチックパイプ，ビニールフィルムをしいた溝中の稀釈液肥の毛管移動による地下灌漑の開発試験(要的)

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パイプ式ベッド（図1，2）16，蒸発散量測定装置（図4，5）2，砂ポット（図7）16個，溝式ベッド（図8）1つを設置した。これらは水あるいは稀釈液肥が毛細管現象により自然給水されるようにした。

パイプ式ベッドでは廿日大根，キュウリ，ナスを用いてベッドの構造と肥料試験を行なった。溝式ベッドではナスとブロッコリーの育苗試験とブロッコリーの栽培試験を行なった。培地には砂と砂壌土を用いた。肥料は住友液肥2号（10－5－8）を用いた。蒸発散量測定装置では導水管の中につめる材料の適否を試験した。砂ポットは肥料試験をする目的で造ったが，個々のポットの蒸発量が微気象的な要因により著しく異なっていたため，肥料試験はできなかった。

溝式ベッドは蒸発量が激しく，地中からの毛管水を利用することができないので，雨水を貯めることはできても節水にならないと思う。水位は床面下13～18cmに保つようにし，肥料濃度は0.2％前後に保つようにした。

導水管につめる材料は「細砂」が最もよく「微細砂」と「土まじりの細砂」もよい。粗砂，スポンジは急速に水を上げるが深くはあげない。砂壌土は水の上がる速度がおそく蒸発量に追っつかない。「土まじりの細砂」は砂をスクリーン（孔1.1mm大）から通したもので，これに混ざっている土の粒子を洗い流したものが「細砂」で，さらに細砂を水中でかくはんし，急速に水を流した時，水中にゆうえいしていた砂を集めたのが「微細砂」である。砂が石灰岩質である場合には年月が経つと固結して水が上昇しなくなることがある。

パイプ式ベッドはナス栽培のCベッドが造り易く多くの作物の栽培に適している。根菜類の栽培にはDベッドが適している 。この場合蒸発量は多くなる。導水管は貯水管より少しつき出る長さ（11cm）にして間隔を10cmにした方がよいと思う。雑草の多い畑地ではBベッドも効果的に使える。土壌病害のひどい畑地でAベッドで砂または消毒された土を用土としたものも利用できる。

苗を定植する場合には貯水管は地表下10cm程度にし，地表が乾燥して蒸発量が少なくなるようにした方がよいと思う。直播する場合には貯水管を地表下5cmにし，常に地表がぬれているようにした方がよい。高温時に地表がぬれ，蒸発量が多いと地表温は低くなる。育苗には実験7のE8ベッドか溝式ベッドが適している。

この施肥給水法は作物の生育，労力の節減において非常に効果的であり，堆肥を必要とせず，設置費，運営費も安く，耐久力もあると思われる。実用的にはコンクリートブロックを必要とせず，大規模でも小規模でも設置できる。露地でもハウス内でも設置できるが，ハウス内では塩類の集積が問題となろう。

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