Saline Soils Caused by Heavy Application of Fertilizers: Their Properties and Improvement

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Preface

In Japan most soils are slightly or strongly acid in reaction because leaching is remarkable under such characteristic conditions of climate as there is much rain without any distinct dry season.

There are almost neither alkaline nor calcareous soils in this country except that a small area of saline soils is found in reclaimed lands, etc.

In recent years, however, increased cases of the accumulation of salts have been observed in the upper layer of the soils sheltered from rain and heavily fertilized in house culture which has propagated to meet a demand for fresh vegetables throughout a year with the change in eating habit of Japanese. And the control of these new artificial saline soils has become a problem in the agricultural technique of Japan.

In the beginning house culture was made in simple wooden frames, and farmers changed the sites of these facilities every year in their farms. Under such conditions there was no special problem about soil management in house culture.

But when the facilities were fixed at certain places because of an increase in their size and a shortage of labor, an accumulation of salts in the soil comes into problem in house culture which was generally made under a roof of a transparent vinyl sheet.

In such a house it is natural that heavily applied fertilizers are not washed out of the soil by ordinary irrigation, and the evaporation of water from the soil is so great, owing to the high temperature not only in heated but also non-heated conditions, that the salts in the soil are accumulated in the upper layer.

Characteristics of soils in culturing houses

In 1959 Yoneda et al.[1] first noticed that salts were accumulated in house soil in Okayama Prefecture, in southwestern Japan where viticulture in green houses was extensively carried on and it was known that the vines were suddenly weakened about 20 years after planting.

Yoneda et al., who thought that this weakening of vines was caused by some conditions of soils, examined the electric conductivity (E.C.) of old soils in those green houses and found that the E.C. of the surface soils tested was not less than 4 *m moh*/cm in 63 per cent of the samples tested and 6 *m moh*/cm or more in 40 per cent of them. After that studies in this field have made great progress.

Culture in houses is generally made very intensively by applying much fertilizers, and heavy fertilization is one of the causes of the accumulation of salts in the surface soil. According to a recent investigation, the amounts

Table 1. Data on fetilization in house culture

(Fujinuma, Tanaka and Fukusima[2])

Prefecture		Crop	Number of cases	Amount of fertilizers in total (kg/10 ares)		
				N	P_2O_5	K_2O
Kochi		Cucumber (forcing)	24	69	71	52
		Green pepper (heated)	11	106	119	68
		Eggplant (heated)	5	176*	189	102
		Tomato (late)	5	49	50	47
Ibaraki		Cucumber (semi-forcing)	3	89	97	46
		Green pepper (wintering)	7	169	157	120
		Tomato (semi-forcing)	4	83	135	65
		Strawberry	6	28	52	32
Aichi	Atsumi County	Tomato (green hpuse)	3	30	28	17
		Melon (〃)	9	15	26	13
		Chrysanthemum (〃)	3	39	24	18
	Umibe County	Tomato (semi-forcing)	3	118	118	86

* About 3.8 ton/ha in terms of urea, and about 8.4 ton/ha in terms of ammonium sulfate

Table 2. Number of years under cultivation and electric conductivity

(Kanto House Soil Research Group[3])

Soils	Mean electric conductivity (m mho) and number of cases* tested			
Years	Alluvial soil	Volcanic ash soil	Sandy soil	In total
Less than 1	0.57 (8)	1.45 (1)	0.58 (1)	0.66 (10)
1~3	0.73 (10)	1.29 (8)	0.38 (4)	0.87 (22)
3~5	0.91 (21)	1.52 (10)	0.50 (9)	1.01 (40)
More than 5	1.23 (7)	2.64 (5)	1.46 (6)	1.53 (21)

* In parentheses

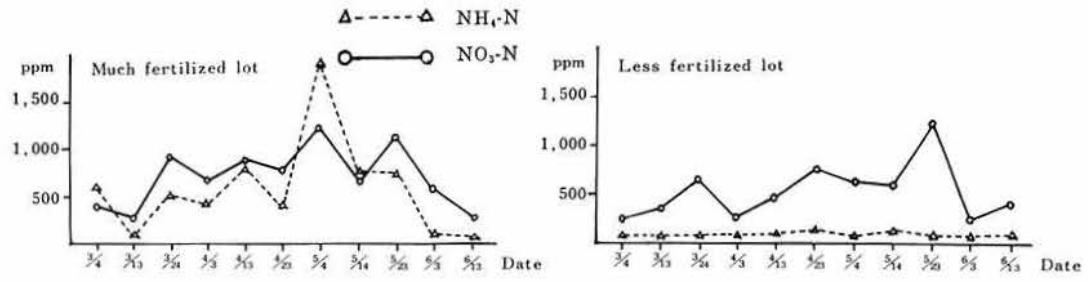

Fig. 1. Relation between the amount of fertilizers applied and the nitrogen (Shimada[7]) **content of solution in house culture**

Crop : Tomato
Yield: 7060 kg /10 ares
Fertilizers (per 10 ares): N 67.8 kg , P_2O_5 73.4kg , K_2O 65.8 kg

Crop : Tomato
Yield 800 kg /10 are
Fertilizers (per 10 ares) N 27.7 kg , P_2O_5 34.5 kg K_2O 25.5 kg

of fertilizers used for house culture are shown in Table 1.

Even if such large amounts of fertilizers are not applied, salts are found to accumulate in the surface soil during the continuation of house culture for many years as shown in Table 2[3),4)].

The salts accumulated in the soil are mainly calcium nitrate and magnesium nitrate, including some calcium chloride, magnesium sulfate and ammonium sulfate. And the substances observed on the soil surface as crystals are mostly sulfates[5),6)].

When much nitrogen is applied to house soil, the soil solution becomes higher in NH_4-N content than in NO_3-N content[7)], and new leaves of vegetable fruits in forcing or heated houses show yellowing, as a result of damage by NO_2 gas[8)]. These are phenomena caused by inhibited action of nitrifying bacteria[9)] and may be said to be the characteristic of house soils.

High concentration of salts and its effect on crops

When fertilizers are heavily applied to the soil, their water-soluble components are abundantly dissolved in the soil solution and make the salt content of it so high that the absorption of water by the roots is decreased or the water flow is changed in the opposite direction, that is, water is withdrawn from the roots into the soil solution, and the plants result in wilting to death.

Shimada[7)] explained the relation between the total concentration of salts in the soil and the growth of, or damage to, plants by classifying the processes of damage into four steps as shown in Fig. 2, and described the general features of the symptoms manifested by damaged plants as follows:

1) Leaves become lifeless and, in severe cases, wilt in the daytime and recover in the evening.
2) Not only are leaves abnormally dark in color but also their upper surface becomes glossy.
3) The growth of fruits become bad. And in the fruits of tomatoes, etc., the rind becomes glossy, coloring becomes bad, and red parts are sharply demarcated from the green ground.

(Shimada[7])

Total salt concentration (ppm)	3000	5000	10000
1st step	2nd step	3rd step	4th step
Almost no injury to common crops	Balanced absorption of nutrients is upset, and indirect injuries are observed	Leaves turn abnormally dark in color. Plants become dwarf. Growth of roots becomes bad	Direct injuries, as wilting and death, are observed

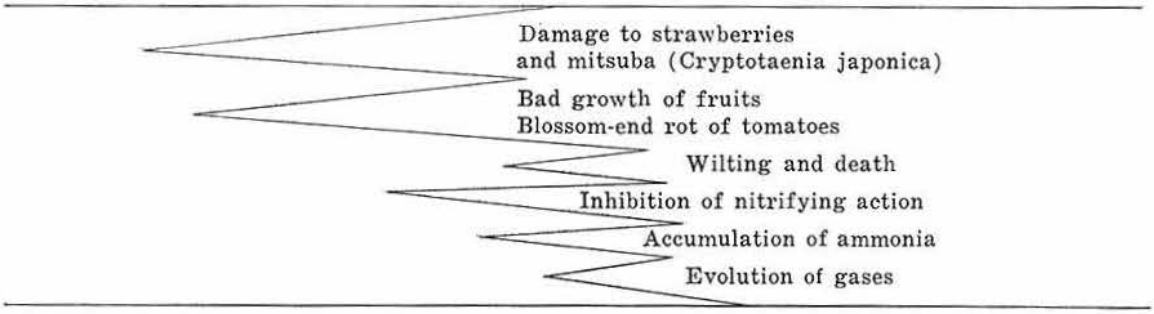

Fig. 2. Symptoms observed in each step of salt accumulation

Table 3. Limiting points of electric conductivitiy for vegetable crops
(Hashida and Yanai[9])

Item / Soil	Electric conductivity (*m moh*)					
	Inhibition of growth			Limit of survival		
	Cucumber	Tomato	Green pepper	Cucumber	Tomato	Green pepper
Sandy soil	0.6	0.8	1.1	1.4	1.9	2.0
Alluvial clay loam	1.5	1.5	1.5	3.0	3.2	3.5
Humous clay loam	1.5	1.5	2.0	3.2	3.5	4.8

The E. C. was measured in soil suspensions (dried soil 1: water 2)
Young plants were used as testers

4) A symptom of the injury first appears in the color of roots. Normal roots are white, while they become brown when injured.

The damage by a high salt concentration to crops is variable in grade according to the kinds of soils and crops[9] as shown in Table 3.

The above-mentioned is an explanation based on the osmotic pressure of the damage to roots caused by a high salt concentration. A high salt concentration in the soil also often upsets a balanced absorption of nutrients by plants or increases antagonistic actions between nutrients.

In addition, there are many cases where attacks of insect pests and diseases on crops were increased as a result of damage to roots or an unbalanced absorption of nutrients caused by a high salt concentration.

Improvement of salt-accumulated soils

When the E.C. of the surface soil is 2.0 *m moh*/cm or more, or the NO_3-N content of the soil is more than 40 to 50 mg per 100 g, it is necessary to examine the E.C. of each soil layer and consider how to desalt according to the result.

1) Desalting of the surface soil or deep plowing

Measure the E.C. of each soil layer after a harvest. When salts are found accumulated only on the surface of ridges, scrape down the surface soil two to three cm deep into the furrows, and let flow a considerable amount of water into the furrows to wash away the salts. If the E.C. is high in the surface soil but too low at a depth of 10 to 15 cm, plow the soil deeply with a cultivator to level the concentrations.

2) Cultivation of edible herbs, etc. without applying any fertilizer

When salts are not so accumulated that special desalting is necessary but the E.C. is a little higher than usual in every soil layer, cultivate edible herbs, etc. there. The E.C. will be decreased by a crop of them.

3) Removal of roofing vinyl sheets or moving of houses

When the house is of fixed type, remove the roofing vinyl sheet and expose the soil to rains several times after plowing or raise a crop of edible herbs there without covering with vinyl sheets. If the house is of movable type, you had better move it to another place every three or four crops.

4) Flooding or irrigation with a large amount of water

When salt concentration has been increased in the soil of a culturing house after a succes-

sion of crops, flood the place to mix the water with the plow soil in case the land is as flat as a paddy field, and then drain the supernatant water after the sedimentation of soil.

Repeat the same flooding and draining two or three times. When the land is sloping, irrigate the place with a large amount of water to wash away the accumulated salts.

If washed salts stay in lower layers of the soil, they will ascend to the surface layer with drying to be accumulated there again. Therefore, the water infiltrated into the lower layers must be allowed to flow away the site of the house.

5) Removal and replacement of the surface soil

When an abnormally large amount of salts is accumulated in the whole soil of a culturing house, the soil may be replaced with new soil. But this is a very laborious work. Therefore, it is bettetr to dry the soil to accumulate the salts in the surface layer and remove or replace them with the surface layer 3 to 5 cm deep.

Soil management and fertilizing technique in house culture in the future

In house culture, cultivation can be made more intensively and plants grow more vigorously than in the open. The plants, corresponding to the vigorous growth, absorb much water through their roots so that the soil is apt to show a shortage of water at a depth of 10 cm where much roots are distributed. And in such a place, the soil solution is increased in concentration, doing damage to the roots of plants.

In culturing houses, irrigation with a small amount of water is often insufficient to wet the soil throughout the area where roots are distributed, so it is desirable to set tensiometers and E.C. meters at several places in each soil layer to read the necessary amount of water and fertilizers to be applied.

In the open, the necessary amount of fertilizers to be applied and the suitable time for applying them are greatly influenced by rains, but in house culture these decisions can be made independent of rains.

Therefore we can intensionally apply fertilizers if the conditions of the soils and the E.C. values are carefully investigated. For example, Table 4 shows how to decide a suitable amount of fertilizer to be applied on the basis of the E.C. values measured[10].

In the electric conductivity method of fertilization, however, the relation between the NO_3-N content and the E.C. is variable according to not only the types of soils but also the kinds of crops and the growing period.

Table 4. Fertilization standard based on salt concentration

(Kanagawa Agr. Exp. Sta.)

Electric conductivity (*m moh*/cm)	Amount of base fertilizers
0.20	Apply the standard amount of fertilizers
0.52	Apply half the standard amount of fertilizers
0.84	〃 (Make allowance for amount of additional fertilizers)
1.16	Base fertilizers are not necessary, excepting the ones at the time of planting
1.80	Plow deeply. Base fertilizers are not necessary, excepting the ones at the time of planting
2.44	There is a fear of damage by a high salt concentration
3.40	(It is necessry to take measures for desalting)

The amount of nitrogen to be applied as base fertilizer is decided within the limits of 4–6 kg/330 m^2

Accordingly, you had better prepare a diagram of correlation between the NO_3-N content and the E.C. value for each soil together with an optimum E.C. table for each growing period by the group of crops of similar type as indexes to the establishment of a fertilization standard.

In a culturing house fixed at a certain place, it is estimated that an accumulation of salts may inhibit the growth of plants even if such an intensional fertilization is carried out. So it is desirable to provide a large culturing house with underdrains for desalting.

To keep the conditions of the soil good for the permeation of water and air, and favorable for the function of nitrifying bacteria, it is necessary to pay special attention to the application of organic matter in house culture.

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