The fate of yearlings of *Pinus Thunbergii* in relation to the chlorine content of soil.

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田崎忠良：クロマツ當年生稚苗の生育と土壌中のクロール含有量との關係

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1. Introduction

In sandy soils of coastal sand dune areas, the existence of considerable amount of chlorine (Cl) has been reported by various investigators. Cl in soil has much to do with the water economy of plants as it naturally enters into the soil moisture and increases the diffusion pressure deficit (D. P. D.) of soil moisture, thus affecting the water absorption of plants. The fate of yearlings of *Pinus Thunbergii* germinated in sand dune areas may therefore be connected with the Cl in soil moisture. Experiments were carried out in which the relationship between the Cl content in sand and the growth of yearlings was tested and the upper limit of Cl content permitting the growth was determined. From the result of the experiment and the measured Cl content in the soils of dune area, the place of chlorine in the fate of yearlings was examined.

2. Methods

Hitherto, the relationship between the Cl content and growth has been investigated by various land plants and most of them adopted water culture. In field conditions, the seeds or roots are rarely immersed in water and the amount of soil moisture surrounding them is usually at field moisture capacity. For this reason, yearlings were cultured in sand taken from the dune area and the sand moisture in containers was set up in field capacity. In field conditions, soil constants concerning water relations were as follows: wilting percent 2%*, field moisture capacity 7%*, maximum moisture capacity 30%*, volume weight 1.5. NaCl solution or diluted sea water was applied to the air dry sand and the moistened sand was packed in glass containers (diameter 3 cm, height 8 or 12 cm). 10 seeds were sowed in each container and 2 or 4 sets of containers in each Cl concentration class were prepared in each run. After germination, the containers were put in a green house made of vital glass. Every day or every other day, distilled water was quantitatively applied by injector. Just after the application of water, the sand moisture in the upper layer of containers (seed layer) was about 11% and reduced to 4% at 1 or 2 days after

* in oven dry basis.

application, but at the bottom of containers (root layer) the sand moisture was nearly constant (about 5%). The seeds, therefore, were exposed to wide change of sand moisture but the root tips from which water may chiefly be absorbed always lay in constant sand moisture. After the experiment was finished, the length of stem, cotyledon, root, primary leaf and the green weight, of yearlings were measured and the upper and lower part of the sand in containers were soaked in 100 ml of distilled water, and the obtained solutions were titrated with AgNO_3 using KCrO_4 as an indicator. The titration gave values from which milligrams of Cl in 100 gr of dry sand could be calculated. Cl concentration (%) of sand moisture was computed from the amount of Cl in oven dry sand assuming that all Cl had been dissolved in soil moisture.

3. Experimental part.

1) Germination of seeds.

The sand moisture surrounding the seeds in containers was, as mentioned, between 4–11%. In season for germination, the seeds lying near the soil surface of dune area can scarcely germinate because of the lack of sufficient moisture for germination, and the germination occurs chiefly at the depth of 2–4 cm from the soil surface, the soil moisture in this germination layer varying nearly in the same range as in the containers. (See Table 1.)

Table 1. Soil moisture distribution

Date \ Depth cm	Soil moisture in %.							Remarks
	0	1	2	3	5	7	10	
Apr. 26	0.91	1.52	4.26	6.94	7.60	6.50	7.11	5 days after rainfall
June 21	14.4	11.7	—	9.53	11.2	9.67	10.7	Just after rainfall

In consequence, the concentration of Cl in sand moisture varies daily in wide range in containers as well as in field conditions. The Cl amount in seed layer, on the contrary, seems nearly constant during the germination period as conjectured from the distribution of Cl after the experiment. So the Cl amount in 100 gr of dry sand at the beginning of experiment was taken as the Cl condition of sand during the germination.

An example of the course of germination under different Cl amount in sand is shown in Table 2. From this and several other experiments, it was confirmed that the germination rate diminishes and germination is retarded when the Cl amount

was over 20 mg. and the germination scarcely occurs when the Cl amount is over 60 mg. In consideration of the variation of moisture amount, the concentration of Cl in sand moisture is 0.20—0.50 % and 0.55—1.50 % when the Cl amount is 20 mg and 60 mg respectively.

Cultures applied with sea water showed similar results.

Table 2. Cl amount and seed germination.

No.	Cl amount*	Number of seed germinated**					
		Aug. 31	Sept. 3	5	10	13	20
1.	1.46	2	5	7	8	15	18
2.	6.29	1	3	5	11	11	13
3.	9.10	1	3	4	10	13	16
4.	26.2			1	7	9	12
5.	34.5		1	3	3	4	8
6.	41.3		2	2	2	3	(1)***
7.	53.4	2	3	2	(1)	(1)	10
8.	56.9		2	(1)	2	(4)	(1)
9.	62.2		2	3	(2)	(2)	(4)
				2	(2)	(2)	1
				2	2	2	(4)
				2	(2)	(2)	4
				2	(2)	(2)	2
				2	(1)	(2)	(2)

*mg Cl in 100 gr oven dry sand.

**20 seeds were sown on Aug 23 in each class.

***died after germination.

2) Growth of yearlings

If yearlings were killed shortly after germination in Cl containing sand, germination has no significance in the survival of yearlings. It is therefore important to ascertain the upper limit of Cl concentration permitting the survival. The root tip of yearlings soon reaches to the bottom part of containers after germination, so the amount of Cl at the bottom in which the absorption part of roots lies may be closely related to the survival. The moisture content at the bottom of containers being as mentioned nearly constant, that is, about 5% during the experiment, the relationship between the survival and the Cl concentration in sand moisture was considered. An example of this relation is shown in Table 3.

The rate of survival is almost similar as the control when the Cl concentration was below 0.3%, and was remarkably reduced over 0.3% and no seedlings survived when the Cl concentration was over 1%. The condition of yearlings was almost equal when the Cl concentration was below 0.7%. The yearlings raised from seeds

Table 3. Cl concentration in sand moisture at the bottom of containers and rate of survival.

No.	Cl amount mg. per 100 gr dry sand	Cl conc. %	Rate of survival %	Mean condition of an yearling				
				Green wt. mg.	Length (cm) of			
					Stem	Root	Cotyl- edon	Primary leaf
1*	1.85	0.037	85	100	4.6	5.5	3.2	0.3
2	8.24	0.165	70	94	4.3	5.5	3.0	0.6
3	12.80	0.256	85	96	4.3	6.4	2.8	0.3
4	28.80	0.576	35	85	3.5	7.1	2.7	0.4
5	30.60	0.612	20	75	3.5	5.2	2.0	—
6	36.30	0.726	25	99	4.3	5.8	2.6	0.2
7	54.10	1.082	5	63	2.3	2.5	—	—
8	64.00	1.280	0	—	—	—	—	—

Sowed on Aug. 23, 1949 and measured on Sept. 23, 1949.

*Control

Table 4. Cl concentration in sand moisture at the bottom of containers and rate of survival.

No.	Cl amount mg per 100 gr dry sand	Cl conc. %	Rate of survival %	Mean condition of an yearling				
				Green wt. mg.	Length (cm) of			
					Stem	Root	Cotyl- edon	Primary leaf
1*	1.60	0.032	95	94	5.2	5.8	3.2	0.3
2	7.47	0.149	90	102	4.6	6.2	3.0	0.4
3	10.00	0.200	90	101	4.7	6.2	3.2	0.4
4	16.00	0.320	60	92	3.6	5.4	3.6	—
5	20.80	0.416	40	103	4.9	6.0	2.6	0.3
6	26.50	0.530	30	—	3.4	4.7	—	—
7	39.00	0.780	5	—	2.2	—	1.4	0.2
8	43.50	0.870	0	—	—	—	—	—

Sowed on Aug. 17, 1949 on filter paper immersed with distilled water, transplanted on Aug. 23, 1949 in containers and measured on Sept. 22, 1949.

* Control

germinated on filter paper immersed with distilled water showed similar response to Cl condition. (Table 4)

In coastal field conditions, Cl in soil may be derived from sea water. So cultures applied with diluted sea water instead of NaCl solution were carried out. In this case, yearlings could resist higher concentration of Cl, that is, the rate of survival remained unchanged when the Cl concentration was about 0.5% and several yearlings could survive in such a high concentration as 1—1.4% (See Table 4), which may be the result of ion antagonism.

Table 4. Cl concentration in sand moisture at the bottom of containers and rate of survival. (Diluted sea water was applied).

No.	Cl amount mg. per 100 gr dry sand	Cl conc. %	Rate of survival %	Mean condition of an yearling				
				Green wt. mg.	Length (cm) of			
					Stem	Root	Cotyl- edon	Primary leaf
1*	1.28	0.026	95	110	5.0	6.2	3.9	0.4
2	19.20	0.384	90	120	5.3	7.2	3.1	0.2
3	27.00	0.540	95	110	4.7	6.1	2.5	0.2
4	59.00	1.180	30	110	4.8	5.0	1.9	0.2
5	71.00	1.420	5	—	4.3	3.2	1.6	—
6	102.30	2.046	0	—	—	—	—	—

Sowed on Aug 27 on filter paper immersed with distilled water, transplanted on Sept. 3 and measured on Sept 27.

Diluted sea water was used.

*Control

From above mentioned experiments, it was found that yearlings can hardly survive in sand moisture whose Cl concentration was about 1%. The D.P.D. of the 1% NaCl solution is 12 Atm. Taking into account that the D.P.D. of soil moisture at wilting percent of pine yearlings was 15 Atm, it seems that the absorption of water by roots may be rendered difficult in such Cl concentration in soil moisture.

By Tsuda's experiment (1937),⁽¹⁾ the root growth of the seedlings of two sand dune plants (*Calystegia Soldanella* and *Lathyrus japonicus*) in artificial sea water stopped when the Cl concentration was 1.3%. And the experiment about two mesophytes (*Zea Mays* and *Pharbitis Nil*) showed similar result. When we compare this result to the upper limit of Cl concentration permitting the growth of pine yearlings, the resistance of pine yearlings against Cl proved to be almost equal to those sand dune plants and mesophytes.

3). Chlorine content in the soil of sand dune area.

To determine whether the Cl in soil has something to do with the fate of yearlings or not, Cl amount in the soil of sand dune area must be measured. By our previous paper,⁽²⁾ the Cl amount of soil in sand dune as well as in coastal pine forests at Chigasaki in Kanagawa Prefecture was 0.2—0.5 mg. for 100 gr. of oven dry soil, except in the ocean side of the fordune. Recent measurement by Kadota (unpublished data) in this area showed that the Cl amount was 20—100 mg. in some places of fordune (within 100m from the beach) and barrens including rear dune (100—240m from the beach). Such Cl amount, of course, injures the germination and growth as above mentioned experiments shows.

By the report of Tsuda (1936)⁽³⁾ at Taito beach in Chiba Prefecture, the Cl amount in the soil of communities of sand dune plants near the beach was 1.8—3.6 mg. with one exception of *Carex Kobomugi* community suffering occasionally the spray of sea water. Hara (1935)⁽⁴⁾ reported that the Cl amount in various part of Tottori sand dune was 0.5—1.0mg., exclusive of the places washed by sea water in high tides.

In conclusion, the amount of Cl in the soil of sand dune area is generally very small except in some special places and the Cl condition does not seem to injure the germination and growth of pine yearlings in sand dune areas, although they are equally sensitive to Cl as sand dune plants.

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