Some Aspects of the Variation in Length of Needles of Pines on Eroded Land*

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Pine trees on extremely poor soils of badly eroded land show such an irregularity in growth that size of trees does not correspond to neither their age nor vigor. However, the length of needles of them is quite different among individual trees. Here is reported a study of the variation in the length of pine needles in relation to some of the external and internal conditions connected to growth.

1. Site of the study.

Studies were made on a badly eroded land of tertiary sediment in Minamiyama section of Tokyo University Forest in Aiti, located in the west of the City of Seto, Aiti-ken, Central Japan. Erosion in this area is said to be caused by the intense cutting of trees as fuelwood and excavation of clay for the famous pottery industry around there for centuries. The photograph of Fig. 1 shows the general view of the site of study which is a small "basin" covering a small area of about 560 square meters. The area was left untouched for long years since the University Forest was established there.

All higher plants found there are listed in Table 1. The most important vegetation there was scattered, stunted trees of two pines, *Pinus densiflora* and *P. thunbergii*, and others were of minor importance in number as well as in coverage. Many, if not

Fig. 1. The site of the study.

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Table 1.

	Trees larger than 0.3 m in height and 1 cm in diameter at 5 cm above ground					Samller trees
	Number	Max. Height	Max. Diam. at 5 cm	Sum of Diam². cm²	Sum of Diam². %	Number
Pinus densiflora	32	2.0 m	18.0 cm	1446.25	48.88	7
Pinus thunbergii	52	4.0	16.0	1329.00	44.92	29
Juniperus rigida	10	2.1	6.0	70.61	2.39	23
Eurya japonica	13	1.0	3.0	33.00	1.11	11
Rhododendron dilatatum	12	1.0	2.0	15.00	0.51	26
Rhododendron kaempferi	7	0.8	2.0	20.00	0.67	19
Quercus serrata	4	1.4	2.5	15.59	0.53	12
Pourthiaea villosa var. *laevis*	1	1.2	3.0	9.00	0.31	
Cleyera japonica	1	0.7	3.0	9.00	0.31	
Clethra barvinervis	2	1.4	2.5	7.25	0.25	2
Ilex pedunculosa	1	1.0	1.0	1.00	0.03	
Vaccinium bracteatum	1	0.3	1.0	1.00	0.03	
Vaccinium oldhami	1	1.4	1.0	1.00	0.03	2
Abelia serrata	1	1.0	1.0	1.00	0.03	2
Vaccinium usunoki						5
Rhododendron macrosepalum						1
Smilax china						13
Miscanthus sinensis						
Arundinella hirta?						

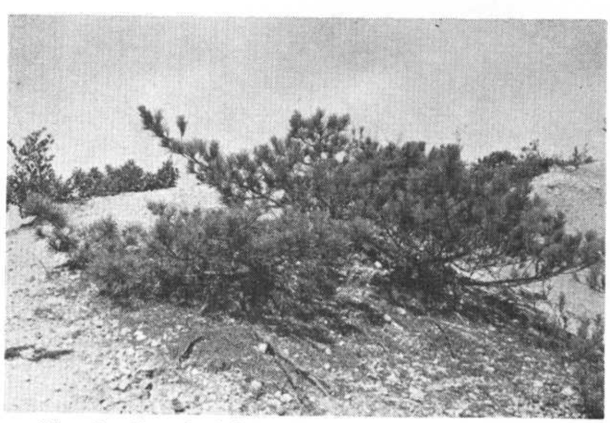

Fig. 2. Dwarf, deformed trees of *Pinus thunbergii*. Most of pine trees in the area were like these ones.

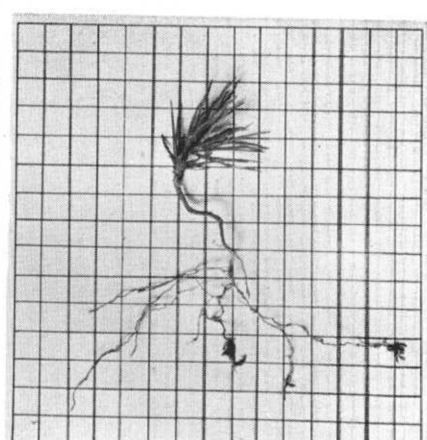

Fig. 3. A three-years-old tree of *Pinus thunbergii* grown in the area. Lines in the background are at intervals of 1 cm.

most, of pine trees there were such stunted and deformed trees as shown by the photograph of Fig. 2, and a part of root systems of some of them runs over the earth's surface as a result of gradually progressing surface erosion. One of the minor members of pine trees is shown by the photograph of Fig. 3. This tree was three-years-old, according to the examination of annual rings, despite its small size. In addition to the pines listed in Table 1, many seedlings appeared in spring but most of them disappeared during the summer.

2. Length of pine needles.

The length of needles of pine trees was quite different among trees. In August 1950, samples of needles were collected from all pine trees larger than 0.3 m in height and 1 cm in diameter at 5 cm above ground, except twelve smallest trees of *P. thunbergii* which had such a small number of needles that collection of needles from them might kill them. Each 20 pairs of needles of the current and the previous years were sampled from 32 trees of *P. densiflora* and 40 trees of *P. thunbergii.* Samplings were made from all parts of the upper crown. The length of needles were measured to the nearest millimeter. There were close correlations between the length of needles of the current and the previous years as shown by Fig. 4. Correlation coefficient was 0.96** for *P. densiflora* and 0.87** for *P. thunbergii.* This means that a tree that made longer needles in a year made also longer needles in the following year and a tree that made shorter needles in a year produced also shorter needles in the following year, thus the length of the needles is decided not by chance but by something determinant connected to each particular tree. As the determinant, there can be two alternatives of possibility, heredity and environment. However, if it were hereditary, there should also be such a large variation in needle length as in this case in the normal natural forests of pines. So one of the possibility, heredity, is not valid and to be discarded. The

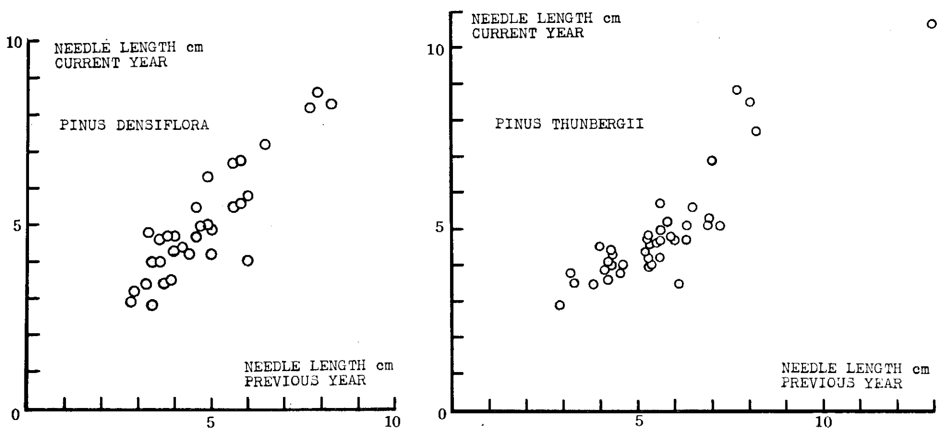

Fig. 4. Correlation between the length of needles of the current and the previous year. The length of needles is mean of 20 pairs.

difference of the length of needles probably reflects the difference in external as well as internal conditions of growth to which each tree is subjected.

3. Distribution of trees of different needle length and the topography.

A map of the "basin" with contour-lines of intervals of 1 meter was made and the location of each pine tree was shown on the map, with symbols representing the length of needles. As shown by Fig. 5, trees with longer needles were apt to be found in the lower part of the "bottomland", those with shorter needles were apt to be found on "ridges" and "hillsides", and those with needles of medium length grew in the uppar part of the "bottomland" and the foot of the "ridges". There was also a trend that trees surounded closely by other trees have rather longer needles than trees surrounding them; a tree of *P. thunbergii* with needles 8 cm long in the flatland of the top, and the one with needles 12 cm long in the foot of a "ridge" are among such examples.

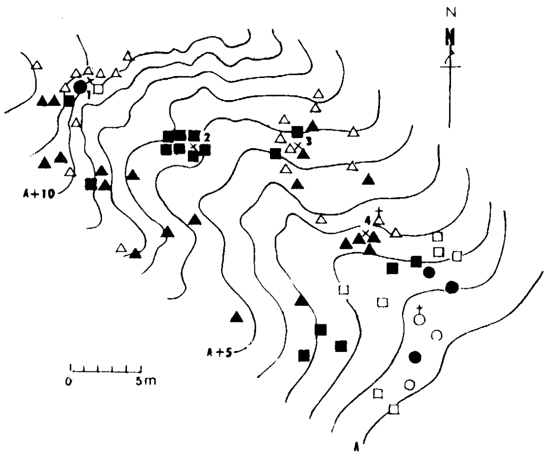

Fig. 5. A map showing the topography of the area and length of pine needles.
Triangle: needles from 25 to 50 mm.
Square: needles from 51 to 70 mm.
Circle: needles longer than 71 mm.
Open symbols: *Pinus densiflora*.
Solid symbols: *Pinus thunbergii*.
Symbols with + sign: trees of which transpiration rate and water content were determined.
× with numbers 1, 2, 3 and 4 show the spots where soil samples were taken.
A, A+5, and A+10 show relative elevations in meter, thus the contour-lines are at intervals of 1 m in elevation.

4. Needle length and some of soil conditions.

Soils at the depth of 0~10, 20~30, and 40~50 cm were sampled at four different spots where there were pine trees growing rather densely. The spots of soil sampling are shown as 1, 2, 3 and 4 on the map of Fig. 5. In this area, most of the roots of *P. thunbergii* distributed in the upper layer of the soil; about 70 percent of fine roots were in the layer down to 10 cm and 90 percent in the layer down to 30 cm (Satoo and Wakabayasi, 1955). Soil profile did not develop. As shown by Table 2, there was no significant vertical difference in soil texture and also no difference among spots 2, 3, and 4, but the texture of the soil of the spot 1, which is at the flatland of the top, was quite different from the others. Soil texture seemed not to affect the length of needles so much.

Nitrogen content of the soil, as shown by Table 3, differed by spots, but even the highest of them was far below the one found in natural forest of *P. densiflora* and even below the one in young plantations established on eroded land as reported by Tsutsumi

Table 2. Soil Texture (%)

Site*	Particle size, mm	4	2	0.25	0.02	0.002	
1	Average of 3 samples	0.05	0.07	49.97	30.69	11.15	8.07
	Maximum	0.06	0.11	56.60	35.09	12.21	9.10
	Minimum	0.04	0.04	44.49	30.71	9.96	6.66
2~4	Average of 9 samples	40.9	7.4	28.0	9.1	7.1	7.3
	Maximum	53.2	10.9	39.4	19.3	10.5	11.9
	Minimum	26.2	4.4	16.6	3.1	3.5	3.9

* Numbers of the site in the table correspond to those in Fig. 5.

Table 3. Nitrogen content of the soils (%)

Depth \ Site*	1	2	3	4
0~10 cm	0.034	0.036	0.002	0.024
20~30	0.027	0.034	0.002	0.003
40~50	0.025	0.024	0.002	0.002

* Numbers of the site in the table correspond to those in Fig. 5.

and TOKUMITSU (1957) and TSUTSUMI and ARIMITSU (1958). Around the sampling spot 4, where nitrogen content of the soil was practically null, pine trees were small and sparse, and needles were also short, around the spots 1 and 2 where nitrogen content of the soil was higher, pine trees were larger and grew rather closely together. It is possible that needle length has some connection with nitrogen content of the soil, but it is also possible that soils relatively rich in nitrogen has higher permeability to water which favor the growth of trees through water relations. Infiltration of water into the soil of this areas was far slower than the soil of similar texture of a nearby plantation of *P. thunbergii* established after hillside works (SATOO and WAKABAYASI 1955).

5. Length and nitrogen concentrations in needles.

As nitrogen content of the soils was extremely low, nitrogen concentration in the needles was studied. In August of the following year, current year needles were sampled from trees of *P. thunbergii* with needles of various length, and nitrogen concentrations were determined. Each tree produced needles of the similar length as the previous years. For comparison, needles were collected from some arbitarily chosen trees in a nearby plantation of *P. thunbergii,* and their nitrogen concentrations were determined. The plantation had been established on similar soils after hillside works. Root systems of trees in the plantation developed into deeper soils than in the eroded land. (SATOO and WAKABAYASI 1955). The needles from the plantation were also shorter than those found usually in the normally growing trees.

Nitrogen concentration of needles of *P. thunbergii,* not only from eroded land but also from the plantation, was far below the one in leaves of *P. densiflora* of usual plant-

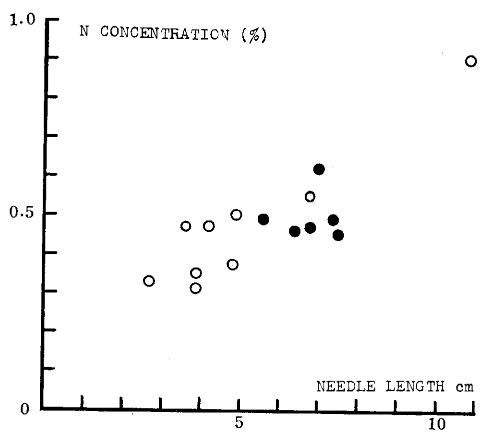

Fig. 6. Relation between nitrogen concentration (dry weight basis) and length of needles of *Pinus thunbergii*.
Open circles: trees on eroded land.
Solid circles: trees in a nearby plantation.

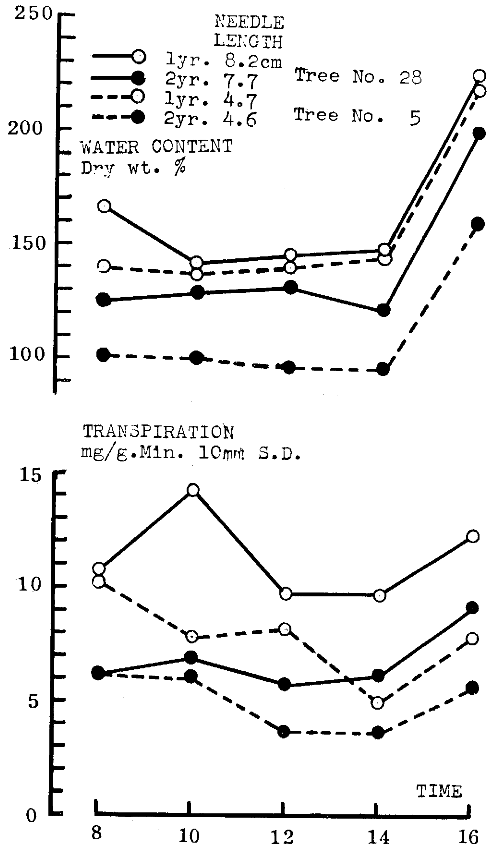

Fig. 7. Transpiration rate at 10 mmHg of saturation deficit and water content of *Pinus densiflora* of different needle length.
Mean of each six determinations.

ations and natural forests reported by TSUTSUMI (1962). As shown by Fig. 6, a close connection was recognized between the nitrogen concentration and the length of needles. Correlation coefficient was 0.67* for trees on eroded land and 0.80** for the whole samples including samples from the plantation. Nitrogen concentration was higher in longer needles. Similar trend was reported on a forest of Scots pine in Germany where litter was collected for long years, though the nitrogen concentration itself was much higher than the present case (FIEDLER *et al,* 1962). Similar trend between nitrogen concentration and dry weight of needles of Sitka spruce was found when fertilizer was not given (LEYTON 1958). It is reported that longer needles of *P. densiflora* (KAWANA 1960) and larger leaves of apple trees (RUCK and BOLAS 1956) were produced by fertilization. It is also reported that in a plantation of Scots pine nitrogen concentration of needles and tree height were closely related (LEYTON and ARMON 1955), but, in this case, there was not such a trend, as the age of trees is not uniform. Needles from the plantation, except one sample, had very narrow range of nitrogen concentration (0.45~0.5%). When needles of similar nitrogen concentration were compared, the needles from the eroded land were much shorter than those from the plantation. The length of needles having nitrogen concentration ranging from 0.45 to 0.5 percent averaged 6.5 cm for the plantation and 3.2 cm for the eroded land. The longer needle of the trees of the plantation at the same nitrogen level in needle seems to be caused by more favorable growing conditions of the plantation such as phsical properties of the soil improved by the hillside works and deeper root systems. The same trend was reported by LEYTON (1958) that needles of Sitka spruce of stands given with phosphorus fertilizer were heavier than the needles of the same nitrogen concentration of stands without fertilization.

6. Needle length and the water relations of needles.

As rain water is very hard to infiltrate into the soils of this area and the soils are very dry even after a heavy rain (SATOO and NAMURA 1955), it is very probable that water relations of needles were different among trees of different needle length. Diurnal change of transpiration rate and water content of needles of *P. densiflora* of different length were compared in August. Transpiration rate was determined by weighing rapidly a pair of needles with a torsion balance immediately after picking them and then again 4 minutes later, in situ, and water content was determined by oven-drying the same pairs of needles. Transpiration rate was converted into the value at a vapor pressure deficit of 10 mmHg. Fig. 7 shows one of the determinations. Needles of the current year had higher rate of transpiration and higher water content for both longer and shorter needles. For leaves of both ages, longer needles had higher rate of transpiration and higher water content, and water relations seemed to be more favorable in longer needles.

9. Summary.

As there was a large variation in the length of needles among trees of *Pinus densiflora* and *P. thunbergii* growing on a small area of badly eroded land, studies were made on some of their natures. There was a close correlation between the length of needles of the current and the previous years and the difference of needle length seemed to reflect conditions of their growth. A topographical map was made in detail and each tree was located on it with symbols showing the length of needles. There was a trend that trees of similar needle length grow together; trees with longer needles were found mostly on the "bottomland" and those with shorter needles were found on "ridges" and "hillsides". Trees with exceptionally longer needles were found in the center of a group of trees growing closely together. There was no significant difference in soil texture except one spot and soil texture seemed not to affect the length of needles so much. Nitrogen content of the soil was far below the one in the normal forest soils, but relatively higher content of nitrogen was found in spots where trees grew closely together. Nitrogen concentration of needles of *P. thunbergii* was far below the normal levels and had close relation with the length of needles, nitrogen concentration was higher in longer needles. Among needles of similar nitrogen concentration, needles from a nearby plantation were longer than those from the eroded land, though the length and nitrogen concentration of the needles from the plantation were also far below the values of those of normal plantations and natural forests. Transpiration rate and water content were higher in longer needles than in shorter ones of *P. densiflora*,

water relations seemed to be more favorable in longer needles. These results suggest that the length of needles of pine trees on the badly eroded land reflects the internal and external conditions of growth of trees.

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*in Japanese with English summary.
**only in Japanese.

ハゲヤマ の マツ の 葉 の ナガサ に ついて

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あ ら ま し

ハゲヤマ に はえている アカマツ と クロマツ の 葉 の ナガサ が, ごく せまい ばしょ の なか でも, じつに さまざま なので, それ に ついて いささか しらべて みた。

アカマツ でも クロマツ でも, まえのとし の 葉 と そのとし の 葉 の ナガサ の あいだ には たかい 相関 が みられ, なんらかの 生育条件 の チガイ をうつして いる と おもわれる。

ヒロサ 560 m² の 調査地 の こまかい 地形図 を つくって, それに 葉 の ナガサ を おとして みると, ながい 葉 を もった 木 も, みじかい 葉 を もった 木 も, それぞれ, かたまって はえて いる 傾向 が あり, 葉 の ながい もの は 「谷」 の 下 の ほうに, 葉 の みじかい もの は 「尾根すじ」 と 斜面 に おおい 傾向 が みられた。例外的に ながい 葉 を もった 木 は, やや 密に はえて いる 群 の まんなか の あたり に みられた。土 の 粒径組成 は, 1カ所 を のぞいて, チガイ は なかった。土 の N の 含量 は きわめて ひくかった が, 木 が いくらか こんで いる ところ の ほう が, ちいさな 木 が まばらに はえて いる ところ よりも たかかった。

クロマツ の 葉 の N の 濃度 は，普通の 林 に くらべて，かなり 低く，葉 の ナガサ と たかい 相関 が みられ，ながい 葉 ほど N の 濃度 が たかかった。ちかくの 造林地 の クロマツ と くらべると，N の 濃度 が おなじくらい ならば，造林地 の もの の ほうが 葉 が ながかった。造林地 の 木 の 葉 の ナガサ も N の 濃度 も 普通の 林 の もの に くらべると はるかに すくなかった。

アカマツ に ついて しらべた ところ では，葉 の ながい もの は，みじかい もの よりも，蒸散 は おおく，葉 の 含水率 は たかく，水分関係 も めぐまれて いる ようだった。

これらの こと から 葉 の ナガサ は 生育条件 を あらわして いる と おもわれる。