林地における施用肥料の効率に関する研究

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Summary

Forest fertilization has three main objects. The first is accelating the tree crown closure by means of stimulating the growth of young plantation and this shortens the period of weeding and decreases the necessary laborers to establish the forest plantation. It is considered that the second object of forest fertilization is to increase the growth of middle-aged stand. It namely means the increment of stand volume and the market price at the time of thinning or clear-cutting. It is thought as third object to improve and increase the growth of planted trees in low-productive or infertile forest land.

For these reasons, nowadays, fertilization on plantation has been adopted to a great extent. The area of fertilized forest was about 17 % of the whole planted area in Japan in 1970. However, it is more difficult to investigate the effects of fertilization on middle-aged forest than on nursery or young plantation, because the size of these planted trees is very large and require a long time to culture the tree, from planting to cutting. And moreover, large area is needed for plantation. Concerning the effects of forest fertilization, therefore, many workers have been chiefly studied on tree height and diameter in young plantation or nursery at the view point of a morphological phase. Especially, study on the uptake rate of applied fertilizer by planted forest tree is very difficult and troublesome. That is why the reports about these researches are few. Moreover, in forest land, there exist competition among forest trees and between undergrowths and planted trees concerning the uptake of applied fertilizer, and organic matters return to the forest soil system through the defoliation of planted trees. It is, therefore, necessary to investigate the cycle of nutrient in middle-aged forest stands.

On the other hand, forest laborers have been decreased year by year in our country. It is necessary to consider how to save the laborers in forest fertilization.

From these points of view, this study has been carried out to establish methods to raise the uptake rate of applied fertilizer by forest trees anywhere.

This report consists of two parts. In the first part, the uptake rates of applied three macro nutrients by forest tree were studied as the basic work.

The contents of the first parts are as follows;

1. Incomings and outgoings of applied nutients in the model HINOKI (*Chamaecyparis obtusa*) seedling stands, where the stand densities were different.
2. Influences of various fertilizer levels on the uptake rate of applied nutrients by HINOKI seedling.
3. The uptake rates of applied nutrients by HINOKI seedling by using of pots without leaching of the applied nutrient.

4. Relationship between the uptake rate of applied fertilizer and different soil mediums.

5. Effects of planting densities and fertilization on the photosynthetic ability (labelled CO_2 fixation by needles) in the model HINOKI seedling stands.

Besides the above contents, stem volume growth, uptake rate of applied fertilizer, changes of soil chemical properties, photosynthetic ability of needles, and chlorophyll contents in leaves were studied in roughly closed HINOKI stand.

In the second part, the field experiments were carried out as the applied work. In the first chapter, the possibilities of sand-culture at practical nursery and the growth of the seedlings produced by sand-culture in forest land were investigated, while in the second chapter, the applicative research of fertilization by helicopter broadcast was carried out.

The following results were obtained in these studies.

1) The uptake rates of three macro nutrients depended upon the dry weight increment by fertilization and the nutrients contents of trees. With respect to planting density, the uptake rates of nitrogen, phosphorus and potassium were improved by increasing the planting densities (Fig. 1-5, Fig. 1-7, Fig. 1-8).

The dry weight increments of fertilized plots increased rapidly with increasing the planting density, while that of unfertilized plots increased gradually (Fig. 1-3). It was, therefore, recognized that the dry weight products per unit area in fertilized and dense stand was more than in the unfertilized and sparse stand at the model HINOKI seedling stand.

On the other hand, in 11-year-old HINOKI stand which was at the beginning of crown closure, the uptake rate of applied nutrients was highest in the 5000 trees per hectare plot. It is considered that effect and uptake rate of applied fertilizer might be highest at the optimum stand density.

2) It seems that the application of fertilizer to the sparse stand speeded up the time to reach the optimum density, and fertilizer application changed the trend that stand yield per unit area was kept constantly. However, growth of the stem weight was accelated by fertilization in considerably dense stand (10000 trees per hectare, 10-year-old plantation) (Fig. 1-38).

3) Furthermore, nutrient uptake rate of applied fertilizer was affected by the fertilizer levels. When the great amount of fertilizer was applied to the model stand, the culculated nutrient uptake rate of applied fertilizer showed the negative value by increasing the number of dead seedling per unit area. In this model experiment, plots applied a little amount of fertilizer showed the high values of nitrogen, phosphorus and potassium uptake rates (Fig. 1-14, Fig. 1-17, Fig. 1-18). It is found that the essential condition to raise the nutrient uptake rate is to

obtain the significant growth response by means of applying the lowest level of fertilizer. Because this uptake rate is calculated as the amount of nutrients devided by the applied fertilizer.

4) Judging from the difference of nutrient elements, phosphorus uptake rate showed a lower tendency comparing to nitrogen and potassium in all cases.

5) Loss of fertilizer by leaching varied with the planting densities and precipitation (Fig. 1-6). When the constant amount of fertilizer was applied to stand regardless to seedling density, a great amount of nitrogen loss occured after the heavy rain fall, especially in the sparse density stands. It was observed that there was the trend of reverse correlation between the nurient uptake rate by seedling and leaching rate (Tab. 1-5).

6) When the leaching of applied nutrients from the soil was stopped by the rubber stopper attached to pot bottom, the concentration of nitrogen, phosphorus and potassium were remarkably high (Fig. 1-21, Fig. 1-22, Fig. 1-23), but air contents in the soil (sandy loam soil) were very low. This caused the abnormal growth of seedlings and low uptake rate of applied fertilizer (Fig. 1-24). It was clarified to be necessary to maintain the moderate air contents of soil for raising the uptake rate of applied fertilizer.

7) It can be said that the change of uptake rate of applied fertilizer depended upon the condition of soil moisture according to the experiment using various kinds of soil. Nutrient uptake rate were highest in the heavy clayey soil (Fig. 1-26), and reached to 58-67 % in nitrogen and 66-74 % in potassium. It is recognized that the recovery of applied fertilizer could be raised on account of frequent application of small amount of fertilizer. Thus, even in the volcanic ash soil, phosphorus uptake rate showed the high value of 16-30 %.

8) The uptake rate of applied fertilizer by planted trees in forest land is different from that of agricultural crops. Some nutrients will be returned to the forest land every year by the defoliation and branch shedding. This means the uptake rate of applied fertilizer by planted trees become higher and higher as the time proceeds. In young stand where crown were closed, the recovery of applied nutrients was high at the moderate stand density (Fig. 1-46, Fig. 1-47, Fig. 1-48).

9) There was a competition of nutrients between the planted trees and undergrowths especially in young forest stands. To raise the amount of nutrient absorbed by the planted tree, it is important to control the undergrowths by weeding and to return the large amount of nutrient absorbed by the undergrowths to the forest floor.

10) From the observation of the photosynthetic ability of leaves which are assimilating organs, it was found that the leaves of fertilized stand had high ability of CO_2 fixation (Fig. 1-27, Fig. 1-28, Fig. 1-29) and moreover the positive corre-

lation between the concentration of nutrient in leaves and photosynthetic ability was observed (Fig. 1-31, Fig. 1-50). As the closer spacing and fertilized stand had a large amount of shady leaves and quick transformation from sunny leaves to shady leaves must occur, the photosynthetic ability per unit area of fertilized leaves was high. Consequently, a high productivity of organic matter and a high uptake rate of applied fertilizer were observed in dense and fertilized plots.

11) Concerning a chlorophyll contents in leaves, no significant difference between the fertilized and the unfertilized stand in middle-aged forest was found (Tab. 1-24). The only differences between the leaves position of tree crown were significant. It seems that there is no effect of fertilization on chlorophyll contents of leaves in the middle-aged plantation, except on the nutrient content in leaves.

12) After fertilization during 3 years, chemical properties of soil on fertilized plots were almost same as unfertilized plots on middle-aged HINOKI stands (Tab. 1-22). In young SUGI (*Cryptomeria japonica*) stands grown on volcanic ash soil, only porosity of soil was improved by fertilization (Tab. 2-20).

13) An applicable experiment of nursery work with sand-culture was carried out in practical nursery. The results of seedlings cultured for 2 years by sand medium was shown in Tab. 2-1. T/R ratio of sand cultured seedling was higher than on usual soil culture, but the fresh weight was heavier in spite of high density. And these seedlings cultured in sand bed were fairly resistant to any damages. Especially 1-year-old seedling cultured on sand bed was excellent, comparing to soil cultured seedling (Tab. 2-2). Besides, the sand-culture had the great advantage in survival rate.

14) When the sand cultured seedlings were planted in the forest land, these seedlings showed rather good results than seedlings on usual soil medium as regards both the survival rate and 6 months growth after planting (Fig. 2-1, Fig. 2-2). Particularly the survival rate in forest land of the sand cultured 2-year-old seedling was approximately 99 % and about 84.5 % for 1-year-old seedling. It is considered, from these results, that the 1-year-old seedling cultured on sand medium is capable to use for forestation without transplanting in nursery and it is beneficial to save the time of nursery practice, laborers and costs.

15) According to the test of fertilization to the wide area of forest land by helicopter broadcast, the following results were obtained.

Concerning the uptake of applied fertilizer by undergrowths, it was more uptaken by broad-leaved undergrowths, especially CARDUACEAE plants. It is necessary that these nutrients must be returned to forest floor by increasing the times of weeding. On the other hand, height, diameter at ground level and dry weight growth of planted trees were promoted by applying the commercial fertilizer once a year during 3 years. In both 250 kg/ha and 400 kg/ha fertilized plots,

nitrogen and phosphorus uptake rates by planted trees were about 18 % and 8 % respectively after 3 year fertilization (Fig. 2-10). It is generally recognized that nutrients uptake rate by planted trees is very low in this area covered with Aso volcanic ash soil. However, it was found that the nutrient uptake rate could be raised by means of applying the adequate amount of fertilizer every year.

In this test the deviation from planned amount of broadcast fertilizer were practically surveyed, and it was nearly 10 % in 250 kg/ha fertilized plots. By means of cross flight fertilization by helicopter, the distribution of applied fertilizer per unit area was approximately uniform. It could be found that the fertilizer coated with paraffin somewhat adhered to the leaves and the braches, but it fell easily to the ground by wind, and paraffin coat was useful to prevent the fertilizer from its hydroscopicity and decomposition.

16) The fertilizer broadcast by helicopter has the merits that it can quickly broadcast in rocky and remoted area where it is difficult to apply with man hand, and is beneficial to labor saving. As the results of this experiment, fertilization could be carried out by about one-twentieth laborers of usual fertilization by helicopter in this area.

It can be said that the fertilizer application by helicopter should be positively adopted for labor saving in case of a wide spreading plantation in the future.