造林場面における除草剤の利用に関する研究

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https://doi.org/10.15017/14780

出版情報：九州大学農学部演習林報告. 42, pp.99-233, 1968-01-31. 九州大学農学部附属演習林
バージョン：
権利関係：

Résumé

Introduction

The growing field of our object trees is also a field in which the weeds grow. In these fields there are our severe fightings against weeds, which have been successive from older times, and will be far into the future.

As WILLIS pointed out, weeds cause damage to cultivated trees in three important ways——nitrogen and water capture and light interception, so that, under the competition of weeds, we can not except the normal growth of trees without the aid of human hands, as shown by the author in Fig. 1-1. And the excluding of these competitions is called "Weed Control."

Weed control, at least in forestry, means the promoting the growth of planted trees by the excluding or reducing the competition between weeds and trees by physical and chemical means, and never means the complete removal of weeds.

In this paper, it is defined that a weed is a plant which is not useful, and therefore undesirable, in the forest and the nursery. Such as annual or perennial plants in nursery, annual or perennial weeds, ferns, shrubs, trees, vines and mistletoes in forest stand, the all plants which exist in the same place and at the same time with our useful object trees, and give, more or less, some damages to cultivated trees, are weeds.

Chapter 1. Influences of Weeds upon Forest Trees

1. Interception of Light by Weeds

Reduction of light intensity caused by weeds: Weeds grow with trees in the forest and for 6 or 7 years they damage our objective crops—trees by interception. The degree of interception is due to the amount and the kinds of weeds.

Two surveys were done under various herbage on the foot of Mt. Aso in Kumamoto Pref., to know the interception as to vertical and horizontal extents. Fig. 1-3 shows the vertical decrease of light in 4 differnt herbal plots in which grow Susuki (*Miscanthus sinensis* ANDERSS.) and Yomogi (*Artemisia princeps* PAMPANINI).

Each curve in 4 plots which have different weed height and amount are similar, and it can be said that the light under weeds decreases suddenly. 50% relative intensity is certain at a 30 cm. from the weed top.

The horizontal distributions of light under weeds at 10 cm. from the ground are shown in Fig. 1-4. In the plot-1, in which relatively low weeds grow, it's not so dark, average intensity is 17.5% ±16.3, and 21% of plot area is more dark than 3000 Lux, while in another plot-2, growing high weeds, average intensity is 3.5±3.9, 75% of area is more dark than 3000 Lux.

Reduction of photosynthesis activity with light intensity reduction: It is clear that the photosynthesis of trees is proportional with light intensity to some extent—about 20 or 30 K Lux, and the less light, the less assimilation of carbon dioxide.

A experiment of the uptake of isotope labeled carbon dioxide is done under various light intensity. Labeled CO_2 made of labeled $BaCO_3$ (37.8 μc/ 37.8 mg. $BaCO_3$) was filled in the assimilation chamber shown in Fig. 1-5, in which 3 kinds of Sugi (*Cryptomeria japonica* D. DON) branch were set and forced to assimilate for 3 hours under 7, 4, 3 K Lux light, at 25° C temperature. According to Fig. 1-6 shown as the result of this experiment, it was clear that the photosynthesis of Sugi was reduced because of light reduction.

Interception of light by planted trees: Also planted trees intercept light to the ground like weed, and at last, planted trees expell weeds from the forest-stand by shading.

Now, 2 examples, diurnal change of light under young Sugi tree and variation of light intensity under old Sugi forest, are shown in Fig. 1-7, 1-8 and 1-9 as follows: 6-year-old Sugi intercepts 20 % of light to same area as its shadow through out a day, and also intercepts 80 % of light to only 20 % area of north side in its projection, But in older forests, the light intensities at 30-50 cm. from the ground are influenced by tree number per unit area, and most of ground surfaces are intercepted 80-99 % of light by trees.

Discussion: As mentioned above, in the extent of light intensity from 2 to 30 K Lux, any interception is unfavourable on CO_2 assimilation connected with tree growth. And besides, the compensation point of young seedling to plant is comperatively high. They need at least 50 % of the sun's light.

On the other hand, in the surveyed field, like most Japanese forest, there are a lot of high——about 150 cm.——weeds, and have intercepted sun light severely during growing season of tree. Without any weed control, planted trees cannot develop or will die.

But this survey indicates that concerning light, it is not necessary to completely destroy the weeds, but to control only its height to less 1/2 length. It is enough for tree growth to reach 50 % of the light.

2. Nutrient capture by weeds

It can be said the most damaging influence of weeds on trees or seedlings is the capture of nutrient, especially added nutrient. When fertilizers are applied to a forest, it is often disturbed in its uptake by trees or seized by weeds.

In this section, how weeds disturb the uptake or capture of soil and added nutrient, and how weeds suppress the tree growth are discussed from the experiments used pots, lysimeters and field, and also is described the amount and shapes of weed and tree roots connected with nutrient absorption.

1) Influence of nutrient capture upon Sugi (*Cryptomeria japonica*) growth.

Generally speaking, fertilizer application is most important factor to tree growth. It is, however, obserbed very often that when fertilizer is applied, not only the growth of trees but also that of weeds are promoted in forest. And even if fertilizer is not added weeds grow vigorously, while tree among weeds cannot grow normally. It is certain that there is nutrient capture by weeds. Sugi growth at 4 months after fertilizer (N 5.0 or 10.0, P_2O_5 2.5 or 5.0 K_2O 2.5 or 5.0 g/m^2) was added to tree planted in concrete pot sowed Italian rye grass seeds shown in Fig. 1-10, are shown in Tab. 1-2. According to this table, weeds suppressed growth in elongation of tree to less 1/3 in comparison with nonherbal pot. Lower nutrient contents in tree leaves (Tab. 1-3) and absorption rates (Tab. 1-4) indicate it was caused by nutrient capture by weeds. It is noticeable that weeds uptook 30 % of added fertilizer, while Sugi tree only 4 or 9 %.

The same results were obtained in 2nd experiment. Two disadvantageous plantings (Refer to Tab. 1-6) carried out in next year used same pots and fertilizer, especially remarkable reduction of nitrogen absorbed under the herbage (less 1/2 mg. N/ tree than without weeds).

In 1966, using lysimeter (1.5 m.×1.8 m. area, 0.8 m. depth, shown in Fig. 1-12) with autoirrigation and protecting rainfall, the nutrient capture was studied between Sugi and Kentucky blue grass under high density of Sugi (12 trees/2.7m^2). This experiment, which applied fertilizer, N (Urea and Ammonium phosphate) 5.0, P_2O_5 (Ammonium phosphate) 15.0 and K_2O (Potassium chloride) 2.5 g/tree, resulted in a not so remarkable reduction of elongation as shown Fig. 1-13, but caused a conspicuous reduction of the tree weight. Also in this experiment the loss with drain water from lysimeter was measured, but there are no significant differences between the plots with and without grass (Tab. 1-11, Fig. 1-14, 1-15, 1-16, 1-17.).

On the other hand, it is well known that water soluble phosphate is fixed by soil easily and it is to hard to be avairable for plant. In forest, the absorption rate of phosphate by trees is low, and there is a much ability to seize phosphate by weeds.

For this reason a experiment was done with Sugi trees using ^{32}P-labelled superphosphate (294.6 μc/g P_2O_5) for a month at Kyusyu University Experimental Forest in Fukuoka Pref.. The experimental area was divided in two, one was with herbs and another without herbs. At 15 days and 35 days after an application of 2.5 g. as P_2O_5 of labelled superphosphate, the sample trees were uprooted and measured for radio-actiyity. The amount of absorption of added phosphate by trees and herbs calculated from their activity were, as shown in Fig. 1-18, 9 mg. after 15 days, 25 mg. after 35 days for Sugi, and no difference was found with and without herbs, but 2.7 mg. after 15 days and 7.9 mg. after 35 days were absorbed by woody plants existed in 60 cm. diameter circle around the sample tree, and besides 20 and 288 of added phosphate were seized by herbs in the same circle. Even if absorption rate had no significant differences between with and without herbs, the average rate of the herbs amounted to 12 %, while that of trees is 1 %. It is very noticeable fact that herbs captured 86 % of added phosphate which was available by all plants in the applicated area.

2) Root weight of weeds in young forests.

Weed roots grown in the young forest located at the foot of Mt. Aso in middle Kyushu and dominated by Susuki (*Miscanthus sinensis*), were dug up and measured. The weights per m^2. were shown in Fig. 1-19, 1-20. It was found that more than 90 % of root weight was Susuki and they were distributed to the extent of 20 cm., almost 10 cm. depth from the surface. The fact that Susuki root consist of net-like subterranean stems give a suggestion of its nutrient and water capture.

3) Roots of young Sugi trees.

Sugi has deeper roots than some other conifers such as Hinoki (*Chamaecyparis obtusa* SIEB. et ZUCC.), and the root of old Sugi reaches to 250 cm. or so. Its root are so loose in comparison with that of herbs that Sugi is placed at a disadvantage on nutrient uptake. The results of root system study are shown as follows: 5-year-old Sugi root in cultivated farm in Fig. 1-21, 1-22, 1-23, 1-24, 1-year-old Sugi root treated by fertilizer in Fig. 1-25～1-43.

3. Water capture by weeds

Whether the weeds capture nutrient or water, this capture or competition takes place in some extent. If there are sufficient nutrient or water to be consumed by tree and weeds, there would be no competition. Generally it would be true for forest soil to have enough moisture content for the survival of trees. So the reduction of tree growth caused by water capture appears only in dry condition of soil, especially that which has been dry for long time. More or less, however, the water capture occurs in any forest with herbs.

By using lysimeters in which Sugi and Kentucky blue grass were growing together shown in Fig. 1-12, a experiment concerning this problem was done by means of measuring the soil moisture at 3 and 20 cm. depth. The gypsum block method (Fig. 1-44) was used for successive measurement of soil moisture. Fig. 1-45 shows the changes of soil moisture of each depth as electric-resistance value of gypsum block. According to this figure, soil surface at 3 cm. depth begin to lose its moisture 2 days after saturation, and this drying up in herbal plot is more conspicuous than non-herbal one, while the moisture at 20 cm. depth never changes at least for 7 days, in spite of drying completely at nearly ground level.

From this experiment it is considered that water capture by weeds does not have much influence upon Sugi growth, because a lot of Sugi root is distributed in a lower depth than 20 cm. and when water deficiency reaches to lower part of ground, it is sure, weeds distributed in upper part will already be dead. and will never seize water in the soil.

Chapter 2. Influences of Herbicides upon Forest Trees

When herbicides are applied in the forest or nursery to control weeds, not only weeds but also planted trees or seedlings are injured more or less at the same time. In this chapter, some physiological influences of herbicides upon trees are discussed.

1. Influence upon transpiration of trees

When trees are treated with chemicals, they decrease their transpiration through the stomatal closure caused by chemicals, or destruction or death of conductive tissue.

In this experiment the decreasing of the amount of water absorption of Hinoki (*Chamaecyparis obtusa*) seedlings treated with 5 % of water solution of sodium chlorate, 0.05 % of 2,4-D-Na salt, 2 % of dalapon and water as control, and treated to leaves or roots, was observed for 8 days in September by using potometers shown in Fig. 2-1.

The results are shown in Fig. 2-2, 2-3, 2-4, as total amount of water absorption and the amount per unit time and tree weight. Visible damage such as becoming yellow or pale could be found at 2—5 days after treatment, while a decreasing of water absorption could be observed at 2 days after. When treatment was done to leaves, sodium chlorate controled water absorption severely. No suppression was found in treatment of roots, and was most in 2,4-D.

In this experiment also the influence of ammonium sulfate was surveyed. Water absorption by Hinoki seedlings treated with 5 % as sodium chlorate and 0.2 % as ammonium sulfate solution, 0.05 % as 2,4-D and 0.2 % as ammonium sulfate, and 0.2 % of ammonium sulfate solution to roots, are shown in Fig. 2-5.

Treatment with 2,4-D solution mixed ammonium sulfate, sodium chlorate mixed that and sodium chlorate only brought to a stop of water absorption of trees at 5 days after treatment, but ammonium sulfate treatment promoted the absorption of water much more than control (Fig. 2-6).

Some investigators dicussed the herbicides as antitranspirants, and it is found that 2,4-D and dalapon close stomata of trees by their chemical actions.

It is, however, in this experiment considered that death of conductive tissue was more effective to stop water absorption, and reducing absorption by stomatal closure was not so noticeable. These results might be due to too high concentration of herbicides.

2. Influence upon respiration of trees

Respiration is a kind of chemical change of substance and is influenced by many factors such as temperature, inhibiting of action of respiratory enzymes, decreasing of respiratory substance, closure of stomata and so on. Many investigator reported the actions of herbicides to respiration of plants.

In this section, the actions to respiration of Hinoki seedlings of 1 and 2 % solution of sodium chlorate, 1 % sodium chlorate and 0.2 % ammonium sulfate mixed solution, 1 and 2 % of dalapon, 250 and 500 ppm of 2,4-D and water as control, were investigated and discussed.

The concentration of carbon dioxide in the air through closed bags in which 1-year-old Hinoki seedlings were set was measured by using the device including infrared gas analizer shown in Fig. 2-7.

The results were shown in Fig. 2-8, 2-9 which were ploted as carbon dioxide amount of exhaust by seedlings. Untreated sample tree exhausted 0.465 mg/g per hour, while all treated samples except dalapon treated took out much more carbon dioxide, especially that of 2,4-D (250 ppm) treated one reached to 3.2 times as untreated one.

It was found in this experiment that generally after 72 hours the respiration was reduced gradually, but most trees treated with herbicides were forced to respire intensively in first stage after treatment.

3. Influence upon photosynthesis

Many herbicides interfere with photosynthesis by various way of chemical actions.

In addition to the stomatal closure, some herbicides such as triazines or urea-compounds inhibit the process of photosynthesis.

ATA destroys chlorophyll in leaves and causes chlorosis, and this reduction of chlorophyll decrease the carbon dioxide assimilation. Furthermore, other actions caused by herbicides such as oxidation of protoplasm, inhibition of absorbing water or decomposition of protein included in plant, are all connected with photosynthesis reduction.

In this experiment, the reductions or interferences of carbon dioxide fixation of Hinoki seedlings which were treated with some herbicides were investigated. The method was almost the same as mentioned in Chapter 1 (Fig. 1-5), and

^{14}C-labeled CO_2 assimilation was carried out under 7000 Lux of light for 3 hours. Then the photosynthesis activities in proportion to radioactivity were compared with each other. When 2,4-D 500 ppm, sodium chlorate 3 %, sodium chlorate 3 % mixed ammonium sulfate and dalapon 2 % were treated to leaves, interference of CO_2 fixation was not so severe (Fig. 2-10, 2-11), while intensive effects were found when treated to root by means of culture in herbicide solution. In the root treatment, all treated trees fixed CO_2 only 40 % of that which was fixed by untreated tree after 24 hours and less 20 % after 72 hours (Fig. 2-12, 2-13).

And in this experiment the effect to promote the fixation of CO_2 by mixing ammonium sulfate was expected, but it hindered rather than helped photosynthesis because of much higher concentration of mixed solution than that of single solution.

Some herbicides disturb the functions of photosynthesis and for this effect treated plants are driven away to death.

It is, however, considered that the reduction of CO_2 fixation in these experiments was due to the death of some tissue, such as conductive tissues, roots or root apex cells, and death of tree or tissues caused by herbicides disturbed carbon dioxide assimilation.

4. Translocation of 2,4-D in plants

When some herbicides called translocating type are treated to plants, they move through conductive tissue, then display their actions to kill plants. The translocating ability of herbicides has large connection with their killing effect for weeds besides the penetration through epidermis on bark and the recovering function against confusion caused by chemicals.

In this section is reported the results of prelimirary translocating study of 2,4-D treated to Sugi (*Cryptomeria japonica*), Susuki (*Miscanthus sinensis*), Hime-mukashiyomogi (*Erigeron canadensis L.*), and Yabutsubaki (*Cameria japonica L.*). Labeled 2,4-D which was 12.1 mc/mM, that is, 54.7 μc/mg 2,4-D of specific activity, and 300 ppm solution of Na-salt was used.

As shown in Tab. 2-1, when 2,4-D was treated to terminal part of Sugi, it scarecely moved, and it was estimated the amount of residue in treated part was 84.8 % of 2,4-D absorbed, while in lateral branch treatment it showed a little more movement than in the terminal, and residue was 72.4 % at 27 days after treatment. On the other hand, when 2,4-D treated to soil in the pot planted Sugi, it was found 20.8 % of absorped 2,4-D in top, 79.2 % in root.

It was also difficult to move in Yabutsubaki treated with labeled 2,4-D to terminal branch, and almost all 2,4-D penetrated through leaf epidermis did not move and remained in the treated part after 27 days (Tab. 2-2). The most radio activity originated in translocated 2,4-D was detected in the bark, vascular system.

Translosating in Susuki, one of most troublesome plants belong to Family Poaceae, was shown in Tab. 2-3. At 27 days after treatment to young leaf, 27.1 % of absorbed 2,4-D was detected in treated part, and another 72.9 % in untreated part as translocated 2,4-D, while, when it was treated to older leaves, it never moved.

Moving in Hime-mukashiyomogi, typical broad-leaved weed found at road side, was easier (Tab. 2-4), and only 27.5 % was remained in middle part treated with 2,4-D on leaves and stem. Half amount of absorbed 2,4-D was detected in the lower part, especially in leaves and stem.

5. Sodium chlorate uptake and run-off from soil

It is said that sodium chlorate, the intensive herbicide used most often in our country, is easily soluble in water and tend to run off with water from soil. The tendency to run-off was surveyed as the change of Na concentration in drain water from 0.3 m^3. capacity pots planted Sugi tree and Kentucky blue grass, and applied 33 g. of sodium chlorate or 33 g. of it and 72 g. of ammonium sulfate together. Unfortunately the amounts of drain water for 27 days were not equal among the various treatments so it was impossible to discuss the absolute amount of Na run-off which was proportional to drain water. In spite of this fact, the changes of concentration of Na each day were detectable as shown in Fig. 2-17, 2-18, 2-19, 2-20. From these changes of Na concentration, it can be said that the run-off of sodium chlorate (powder) starts from 10 days after soil surface application and comes to an end after 2 months, and is ammonium surlfate was mixed into sodium chlorate, the end of run-off of sodium chlorate is compeled to come a little later and to run off much more amount. Much more sodium chlorate ran off from herbal pot than non-herbal pot, and the difference between single and mixed use of sodium chlorate and ammonium sulfate was not distinct.

It is considered that trees can absorb a large amount of herbicide if it is easily soluble in water like sodium chlorate. When Hinoki seedlings cultured in 3 % water solution of sodium chlorate for 10 days, as shown in Tab. 2-5, a considerable amount of sodium were found in Hinoki. As 10-20 times sodium of that in normal Hinoki was detected by flame photometer, and its absorption was promoted by addition of ammonium sulfate to sodium chlorate solution (Tab. 2-5). The fatal dose of sodium chlorate for Hinoki seedling, which was calculated from absorption amount of Na, were 27.7 mg/g dry weight in single solution of sodium chlorate and 44.8 mg. in mixed solution of ammonium sulfate on assumption that ClO_3^- was absorbed as equivalent amount as Na^+ by seedling. This fact indicates that ammonium sulfate helps trees to absorb nearly 2 times more sodium chlorate, that is, lessens the damage caused by sodium chlorate when it is used in forests.

6. Influence upon seed germination

The influence upon germinations of Sugi seeds treated with 4 herbicides by means of pre-emergence application was observed and the number of germinated seedlings 4 months after treatment is given in Tab. 2-6. The germination in plot treated with herbicides was a little less than untreated, especially more remarkable with simazine (CAT), there are, however, no significant differences between each plot. And the same results were obtained at the experiments for Hinoki (*Chamecyparis obtusa*) and Kuromatsu (*Pinus Thunbergii* PARL.) (Tab. 2-7) seeds.

Even soaking in herbicidal solution for 15 or 24 hours, seeds did not suffer from herbicidal toxicity for germination. Two examples of the weeping grass seeds are shown in Fig. 2-21, 2-22.

7. Influence upon growth

In the forest or nursery considerably severe influences of herbicide on tree growth are frequently found. Most intensive damage was observed on young Sugi seedlings at 2 or 3 months after germination caused by treatment with CMU, CAT and C1-IPC (Tab. 2-8, Fig. 2-23), while little damage was found on Kuromatsu and Hinoki (Tab. 2-9, 2-10, 2-11) when 0.1 or 0.2 g/m^2 or sesone (SES), or 0.1 or 0.2 g/m of simazine (CAT) were used by means of preemergence application to seed beds.

When the herbicidal application tests using the treatment methods shown in Tab. 2-12, no damage was found to 1-year-old transplanted Kuromatsu (*Pinus Thunbergii*) as shown in Tab. 2-13, and also the same results at Hinoki (*Chamecyparis obtusa*) as shown Fig. 2-24, 2-25.

As indicated by these results, usual doses or treatments do not give any damages to seedlings cultivated in the nursery. In the forests of our country, we should control weeds for 6 or 7 years after planting trees. Without weed control, it can not be expected that objective trees would grow normally. For this reason, many herbicidal application tests at young forests were carried out by many investigators, yet unfortunately no flawless method or herbicide has been found until now.

The author carried out many application tests during the past several years, which included spot spray application method and combination method of herbicide and fertilizer.

If the spot spray which is a method to spray powdered or water soluble herbicide in a circle around the planted tree is used, no remarkable damage ever appears, as shown in Tab. 2-16, 2-17, as results for Sugi and in Tab. 2-18, 2-19 for Hinoki. The influences upon forest trees of herbicides are surely due to the application method and herbicidal dose, and the more use of herbicide, the more suppression of growth. The less use maybe does not have any influence, but no weed control is expected.

Chapter 3. Influence of herbicide upon weeds and undesirable trees and shrubs

Chapter 4. The effects of herbicidal application and mixture use of fertilizer and herbicide

In this two chapters many investigations connected with the practical uses of herbicides are reported and also discussed about effective and economical application methods of herbicides. They are summurized as follows:

After the investigations of flora in forest nurseries and forest in Kyushu, south-western part of Japan, it became clear that in nurseries the main weed vegetation was Mehishiba (*Digitaria adscendens* HENRARD) and most cultivating beds were covered with it (Tab. 3-1, 3-2, 3-3, 3-4), while in forests, especially young forests, Susuki was overwhelmingly dominant in many forests (Tab. 3-5, 3-6).

These weed vegetation under trees forced a change and weeds would have been expelled by the gradual reduction of light caused by growth of trees (Tab. 3-7 (1), (2), (3), (4), (5), Fig. 3-1, 3-2, 3-3).

Dalapon was most effective for preparing beforehand grassy plain to plant trees, and the overall spray of 60 kg/ha of dalapon over the grasses as powder destroyed almost entirely the dominant weed, Susuki, then the plain changed its flora into that which Yomogi (*Artemisia princeps* PAMPANINI), the Carduaceae plant with broad leaves, was dominant (Fig. 3-4, 3-5) after 3 years.

For both purposes, killing useless broad-leaved trees and shrubs for preparation of reforestation and sprout control from stumps, soluble treatment to trunk wound made by axing or cut surface spray of phenoxy compound herbicides such as 2,4-D or 2,4,5-T were considereably useful (Tab. 3-8, 3-9, 3-10, 3-11, 3-12, 3-13, 3-14, 3-15).

After the investigations carried out in several forest nurseries in Kyushu, simazine was selected as most effective herbicide for weed control in nursery, especially more effective and even economical when used as mixture with fertilizer (Tab. 3-16, 3-17, 3-18, 3-19, 3-20).

On the other hand, it was found that sodium chlorate and dalapon were avairable for weed suppression in young forest if the spot or belt spray was introduced (Fig. 3-11, 3-12, 3-13 (1), (2)).

Ammonium sulfamate was the recommendable herbicide for fern control, and the use of 6 kg/a to fern vegetation, Urajiro (*Diploterygium glaucum* NAKAI) and Koshida (*Dicranopteris dichotoma* BERNHARDI) were dominant, destroyed intensively and suppressed sufficiently its resprouting (Tap. 3-21, 3-22, Fig. 3-14, 3-15, 3-16)

Silvicultural use of herbicides means physiologically effective and economical use. It is certain the foresters expect the inexpensive, harmless, both for objective trees and for workers, and easy method of herbicidal use. From this point of view, the author proposed in practice to introduce the pre-emergence and pre-planting method and co-use of fertilizer in forest nursery, and spot or belt spray method and also co-use of herbicide and fertilizer in forests (Fig. 4-2, Tab. 4-4). And for this introduction there is needed, by all means, the establishment of systematic silvicultural opperation combined with the use of herbicide.