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Effect of Fertilizer Application on Maintenance of Replanted Slopes in Reclaimed Land

Chikara OGURA*[1,4], Kiyokazu NEMOTO*[2,6], Yasuo YODEN*[1,6] and Tamotsu FURUYA*[3,5]

*[1] Department of Research Planning and Coordination, Chugoku National Agricultural Experiment Station (Fukuyama, Hiroshima, 721 Japan)
*[2] Department of Plant Protection and Soil Management, Chugoku National Agricultural Experiment Station (Fukuyama, Hiroshima, 721 Japan)
*[3] Department of Agro-Enviroment Management, Chugoku National Agricultural Experiment Station (Fukuyama, Hiroshima, 721 Japan)

Abstract

For the maintenance of replanted slopes in reclaimed land, method of sodding by spraying seeds is widely adopted. However, only sodding is not sufficient for seeds to germinate well. Some plants wither before their transition to local species. Outcome of replanting depends on the state of maintenance. We examined the effect of additional application of fertilizer (topdressing) to develop a relatively convenient method of maintenance. As a result, topdressing applied once in a later period enabled grasses to grow well, and the rate of canopy was improved. The effect of fertilizer persisted even 4 years after sodding. Since other species than the originally sprayed ones were able to grow, the sustained effect of fertilizer enabled the vegetation to succeed to local species.

Discipline: irrigation, drainage and reclamation
Additional key words: sodding

Introduction

Generally the replanting method has been adopted for the preservation of slopes in reclaimed farmland in Japan. Replanting method on slopes has progressed through the construction of highways and residential land development and it led to the improvement of the technology for replanting suited to the soil and climatic conditions. At present, it is technically possible to plant and grow grasses permanently on slopes less than 60° in inclination[1].

It is generally recognized that the success or failure of replanting largely depends on how the slope was managed[5]. Nowadays, as for most of farmland reclamation, field reclamation on improved slopes has been adopted, the area with reclaimed slopes is increasing. However, on reclaimed slopes for agricultural use, it is difficult to achieve precise management due to the complexity of the conditions of the slopes. On the other hand, in some cases, the replanting method did not lead to stable germination, or the original species planted on the slope began to wither before the planted species became established.

It is necessary to develop replanting methods suitable for the actual conditions of each slope in order to prevent such phenomena from occurring. At present, in most of the reclaimed farmlands seed spraying method has been adopted. This report outlines the findings of the effect of fertilizer application on the current methods#.

Present address:
*[4] Department of Regional Resources, National Research Institute of Agricultural Engineering (Tsukuba, Ibaraki, 305 Japan)
*[5] Department of Land Improvement, National Research Institute of Agricultural Engineering (Tsukuba, Ibaraki, 305 Japan)
*[6] Retired.
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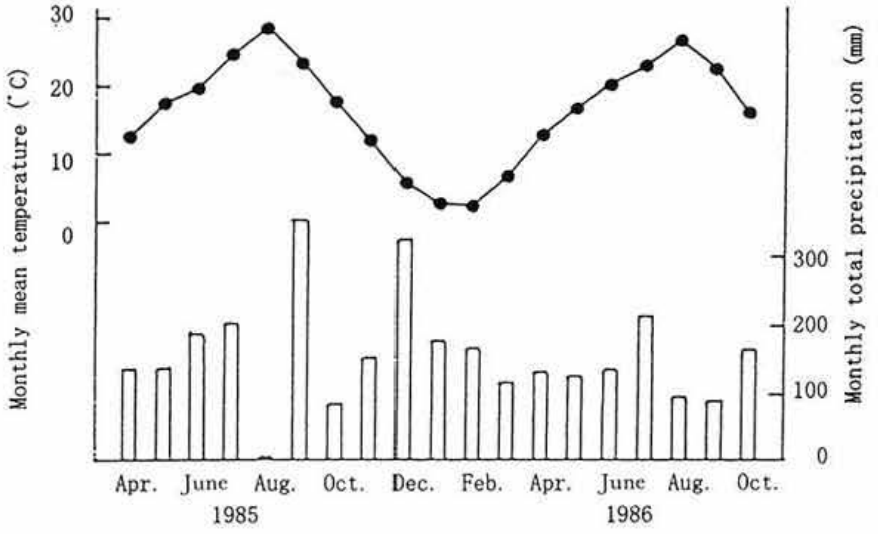

Fig. 1. General weather conditions in the experimental area (observed in Taiza)

Materials and methods

The experiments were carried out by the additional application of fertilizer to the current replanting methods under the project of agricultural land reclamation. The experimental slopes were fertilized once by changing either the time of fertilizer application or the form of fertilizer applied. The experimental slopes were located within the reclaimed slopes developed under the National Project for Farm Land Reclamation in Tango, 30 to 70 m in altitude and 2 km from the coast of Amino-cho, Takeno, Kyoto Prefecture. The experiments started in 1985. As a reference, Fig. 1 shows the average temperature and precipitation observed at Taiza Observatory in Tango about 6 km apart from the site each month, during the experiments (from April 1985 to October 1986). In August 1985, precipitation was 5 mm, which was extremely low.

For the replanting method on the experimental slopes in the region, seeds of 3 species of Gramineae and 1 species of Leguminosae were sprayed along with the application of chemical fertilizer and curing material. Table 1 shows the combination of materials for the planting method.

Table 1. Design of sodding method

Composition	Weight (g/m^2)
Seeds *Festuca rubra* (Creeping redfescue)	10
Agrostis alba (Redtop)	2
Lolium perenne (Perennial ryegrass)	5
Trifolium repens (White clover)	3
Chemical fertilizer ($N:P_2O_5:K_2O = 15:15:15$)	150
Curing material (Woody fiber)	200
Material for prevention of erosion	10
Coloring agent (green)	0.5

1) Outline of the experiments

The experiments on fertilization of the site were carried out by 2 methods: 1) spraying of chemical fertilizer together with bark compost on the slope as topdressing (fertilizer spraying method), and 2) placement of non-woven fabric bags containing slow-release fertilizer on the slope (fertilizer bag method).

The fertilizer spraying method aimed at achieving the effect of fertilization in the form of current topdressing. On the other hand, the fertilizer bag method was used to obtain a long-term effect of organic matter application by putting slow-release fertilizer on the slope. The fertilizer bags, which were set on the slope prepared for replanting as basal fertilizer were more effective as preliminary topdressing. As it was relatively easy to apply fertilizer on a steep slope by using the bag method, other bags were added for the topdressing experiments.

2) Experiments

(1) Fertilizer spraying method

On the slope replanted in April 1985, topdressing was applied in July 1985. The test site consisted of a range of cutting and banking slopes facing south. The experimental plots were set up on the cutting and banking slopes. Each plot was divided into 3 parts: 1) plot with the application of bark compost

(B-plot), 2) plot with the application of a mixture of bark compost and chemical fertilizer (M-plot) and 3) plot with the application of chemical fertilizer (C-plot). Each plot was 2 × 5.5 m in area and 1 : 1.2 in inclination. For topdressing, 20 g/m^2 nitrogen was applied. On the M-plot bark fertilizer was added.

(2) Fertilizer bag method

On the cutting slope replanted in October 1985, the fertilizer bags were set up in September 1985, 1 month before the replanting. Fertilizer bag was made of non-woven fabric, containing slow-release chemical fertilizer and vermiculite. The bags were fixed with nails on the slope.

Table 2 shows the design of fertilizer application for each experiment.

The experiment using fertilizer bags as topdressing was carried out on the cutting slope which would become almost bare 2 years after the replanting.

Table 2. Design of fertilizer application

Experiment	Treatment	Quantity of elements (g/m^2)		
		N	P_2O_5	K_2O
Fertilizer spraying method	B-plot	3.6	1.5	0.9
	M-plot	23.6	21.5	14.2
	C-plot	20.0	20.0	13.3
Fertilizer bag method*		30.0	33.4	25.5

* In addition, vermiculite 292.5 g/m^2

Moreover, in the experiment, the fertilizer bags were tied with nylon ropes with a ladder shape in order to save energy for fertilization before they were brought to the site to be set (Plate 1).

3) Evaluation of the effect

The effects of fertilizer application were evaluated based on the changes of the amount and length of grown-up grasses, physical properties of soil, canopy rate, and growth of other species except for the original species during the 4-year period after replanting. Changes in the amounts of grasses in the area where the spraying method was applied were determined in the year of replanting, the following year, 2 years after and 4 years after replanting, respectively. The amount was measured based on the grasses cut from each site: 20 × 20 cm (from 1985 to 1987) and 50 × 50 cm (in 1989) after they were dried at a temperature of 70°C. The values were considered to be average since the grasses were cut from an area with an average cover of grasses. The average length of grasses was measured using 10 stalks from the surrounding area at random where the volume of grasses was measured. Soil was gathered at 0 to 5 cm depth from the surface using a 100 cc cylinder to determine the void-ratio and saturated hydraulic conductivity.

These measurements had been performed for each treatment plot, at the same time, 1 year after

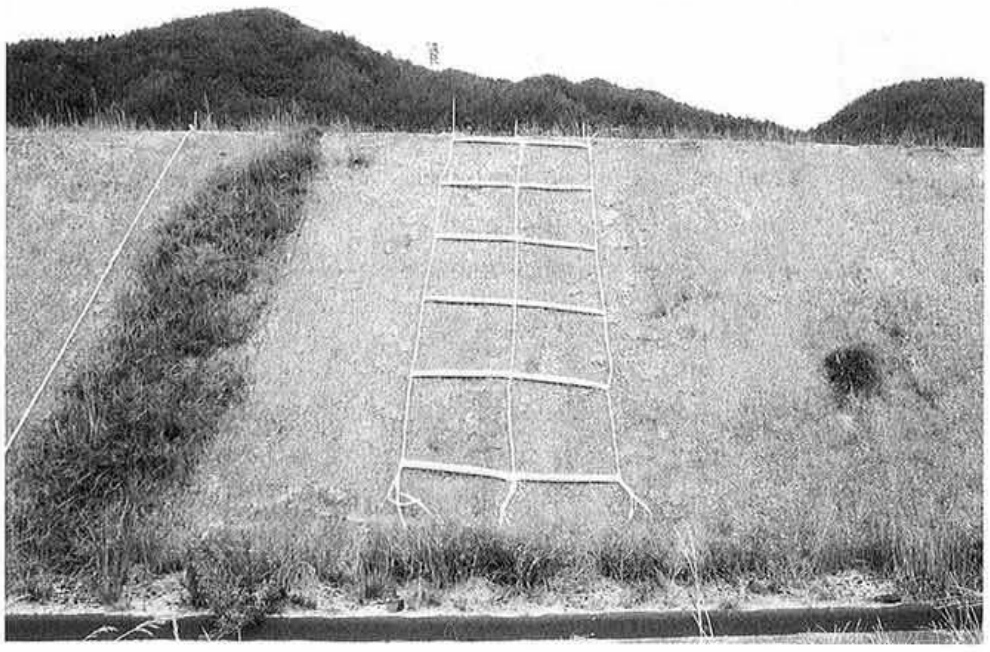

Plate 1. Fertilizer bags put on the slope 2 years after the replanting

replanting. The measurements were also performed in each check plot from the neighboring treatment plot of the slope for reference.

Results and discussion

1) Change of vegetation

(1) Status before the additional application of fertilizer (topdressing)

On the slope where the experimental plots were located, among the original 4 species sprayed at the beginning of the experiment, only *Agrostis alba* dominated 1 year after the replanting, and the other species could not be observed.

On the slope where the fertilizer spraying method was scheduled to be applied, average length of grasses was 6.3 cm on the cutting, and 6.6 cm on the banking slopes, respectively and the density of grasses was 1,600 stalks/m^2 on the cutting slopes, and 2,300 stalks/m^2 on the banking slopes in July 1985, just before the application of fertilizer. These figures exceeded the standard of the Japan Highway Public Corporation under which the number of germinated grasses should reach a volume of 1,000 stalks/m^2 [5] during the 60-day period after seeding. However, 1 seed germinated over a surface of 4.4 cm^2 on the banking slope and 6.1 cm^2 on the cutting slope. The length of the grasses was less than 6 cm and the canopy rate was very low. When replanting is carried out by the application of the spraying seed method, vegetation occasionally begins to deteriorate 2 months after replanting due to the shortage of fertilizer and if no measures are taken, the land may become bare[5]. This phenomenon was probably caused by a shortage of fertilizer in the experimental area. As for the replanted species, *Trifolium repens* could not be observed. Although Gramineae appeared, they could not be clearly identified at that stage.

On the other hand, at the site where fertilizer bags had been applied as basal fertilization, the canopy rate of *Agrostis alba* reached a value of 100% by the next July in the treatment plot and the check plot. The difference in the growth of *Agrostis alba* between the 2 sites was presumably associated with the timing of replanting: when the fertilizer spraying method was used, replanting took place in April 1985, while when the fertilizer bags were used, replanting occurred in October 1985 when *Agrostis alba* grows well. Therefore, for temporary covering of grasses, additional fertilization of the slope was not necessary except for the application of fertilizer with seeds at the time of spraying because the slope was already covered with grasses. However, in the 2-year regeneration trial, *Agrostis alba* could hardly be found in treatment plots and the check plot, as it withers readily when it grows densely.

(2) Status after the additional application of fertilizer (topdressing)

(A) Amount of grasses

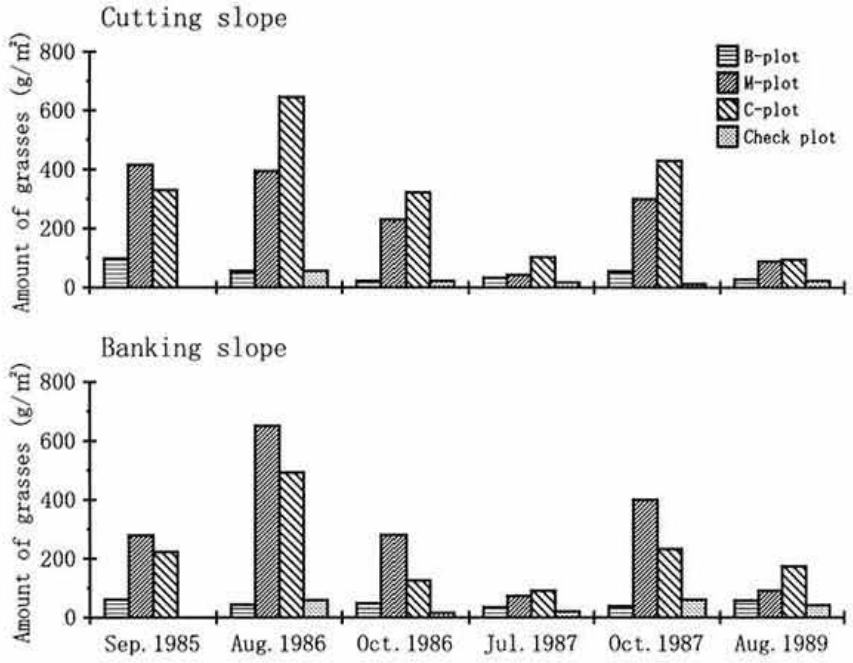

Fig. 2. Change in the amount of grasses (fertilizer spraying method)

Plate 2. Experimental plots 1 year after replanting (July 1986)
B-plot, M-plot, C-plot from the left.

Fertilizer spraying method: Fig. 2 shows the amount of grasses in each plot after topdressing when the fertilizer spraying method was applied. In the beginning of September 1985, 2 months after topdressing, in the M-plot and the C-plot the values both on the cutting and banking slopes were 3 to 4 times higher than those in the B-plot. In the beginning of August 1986 (1 year after topdressing), the volumes in the M-plot and the C-plot were 10 to 20 higher than those in the B-plot and the check plot (Plate 2). As the time of measurement varied each year, the values could not be simply compared year by year. Although the amount generally decreased 2 years after the replanting, there were conspicuous differences, between the M-plot and the C-plot, and the B-plot and the check plot. The effect persisted until 1989, 4 years after the replanting.

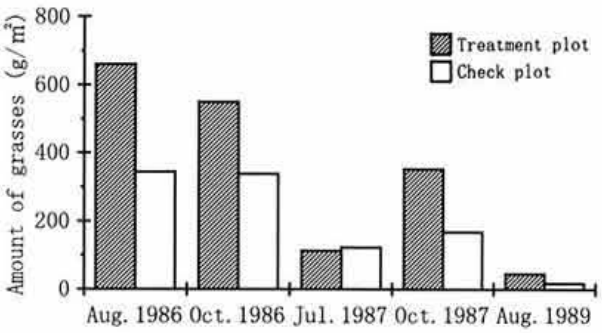

Fig. 3. Change in the amount of grasses (fertilizer bag method)

Fertilizer bag method: Fig. 3 shows the changes

Table 3. Changes in length of grasses

(cm)

Experiment	Treatment		Aug. 1986	Jul. 1987	Aug. 1989
Fertilizer spraying method	Cutting slope	B-plot	12.6	41.2	29.6
		M-plot	43.7	44.0	43.2
		C-plot	58.1	45.6	40.4
		Check plot	7.7	37.0	37.5
	Banking slope	B-plot	20.6	43.6	40.6
		M-plot	40.1	48.0	44.8
		C-plot	63.2	54.8	43.8
		Check plot	15.5	47.2	37.8
Fertilizer bag method		Treatment plot	77.5	54.6	45.7
		Check plot	58.8	46.8	28.7

in the amount of grasses when the fertilizer bag method was applied. From 1986 to 1987, or 1 year and 2 years after the replanting, the amount of grasses in the treatment plots was about twice that in the check plot. However, the values in the treatment plots in October 1987, 2 years after the replanting, decreased by two-thirds compared with the figures in 1985. In August 1989, 4 years after the replanting, the amount of grasses decreased to one-tenth in comparison with the values in 1985. However, the amount of grasses in the treatment plots was 3 times that in the check plot in 1989.

Moreover, on the slope where fertilizer bags had been used as topdressing, the amount, which reached 7.5 g/m^2 2 years after planting, rose to 262.6 g/m^2 2 years after the setting of the bags. This volume corresponds to an amount about 50 times that of 5.4 g/m^2 in the treatment plots.

(B) Length of grasses

Fertilizer spraying method: Table 3 shows the changes in the length of grasses. By August 1986, 1 year after replanting, when the fertilizer spraying method was applied, the length of the grasses reached 40 cm in the treatment plots including both cutting and banking slopes. On the other hand, in the B-plot and the check plot the value was less than 20 cm, which was almost the same as the original length in the year of replanting. However, by 1987, 2 years after the replanting in every plot including the treatment plots, the length of the grasses reached almost 40 cm, and the difference in the length among the 3 plots was no longer observed.

Fertilizer bag method: As mentioned above, on the slope where the fertilizer bag method was applied, *Agrostis alba* grew well even in the check plot. There was no appreciable difference between the treatment plots and the check plot by 1986, the year after replanting.

(C) Vegetation belt

As Plate 3 shows, when the fertilizer bag method was applied for topdressing, *Agrostis alba* formed a vegetation belt along the line of the bags, and *Agrostis alba* spread runner branches by crawling on the ground and had taken root on the slope.

2) State of vegetation 4 years after replanting

Table 4 shows the investigation carried out in August 1989, 4 years after the replanting, on the condition of the canopy and species growing on the slope except for those originally sprayed.

(1) Covering with grasses

Fertilizer spraying method: Among the sites where the fertilizer spraying method was applied, in the M-plot in the treatment plots and the C-plot including both cutting and banking slopes, the rate of covering with grasses reached a value of 80% and the whole slope was almost covered with grasses. On the contrary, the rate was less than 40% on the B-plot

Plate 3. *Agrostis alba* (Redtop) belt formed along the fertilizer bags

Table 4. Status of vegetation 4 years after the replanting (August 1989)

Experiment	Treatment		Height of community (cm)	Rate of canopy (%)	Rate of bare ground (%)	Invading species[a)]
Fertilizer spraying method	Cutting slope	B-plot	51	40	70	*Digitaria adscendens* (5), *Erigeron sumatrensis* (1)
		M-plot	51	80	60	*Kummerowia striata* (20), *Digitaria adscendens* (15)
		C-plot	43	80	55	*Digitaria adscendens* (1)
		Check plot	51	15	85	-
	Banking slope	B-plot	48	40	60	-
		M-plot	49	80	55	*Digitaria adscendens* (1), *Erigeron sumatrensis* (1)
		C-plot	43	95	35	*Kummerowia striata* (20), *Digitaria adscendens* (1), *Bidens frondosa* (1)
		Check plot	47	30	75	-
Fertilizer bag method	Treatment plot		61	55	60	*Gnaphalium japonicum*[b)], *Gnaphalium affine*[b)], *Pinus densiflora*[b)]
	Check plot		57	25	80	-

a): Numbers in parentheses indicate cover degree (%). b): Cover level is less than 1%.

and the check plot.

Fertilizer bag method: When the fertilizer bag method was applied, the rate was around 55% even in the treatment plots, a value lower than the rate in the C-plot when the fertilizer spraying method was used. At that time, as Plate 4 shows, the decline of *Agrostis alba* became remarkable in the plots except for the treatment plots. This phenomenon was attributed to the thick growth of grasses 1 year after the replanting which adversely affected the growth of *Agrostis alba*. On the other hand, when the fertilizer bag method was applied, the canopy rate reached a value of 80 to 85% in the treatment plots, but was less than 5% in the check plot which was almost bare at that time, 2 years after the setting of the bags. Moreover, while the rate of bare ground was high in the check plot in each of the 2 experiments, the density of vegetation was almost the same on each experimental slope regardless of the treatments employed.

(2) Invading species

Fertilizer spraying method: As for the species

Plate 4. Plot with fertilizer bag method, 4 years after the replanting (August 1989)

that invaded the slope, when the method of fertilizer spraying was used, species including *Kummerowia striata* were found in the treatment plots, mainly in the plot where chemical fertilizer compound was sprayed, but not in the check plot. Among all the slopes, including the experimental site, invading species grew well in the experimental areas compared with the other plots.

Fertilizer bag method: When the fertilizer bag method was applied, a few other species invaded the lower part of the treatment plots. Few species other than the original ones invaded the slope, presumably because withered *Agrostis alba*, which had covered the slope had prevented other species from growing.

3) Effect on the soil

The soil of the experimental site was a *Masa* soil (weathered granite soil). The soil texture of the slope where the fertilizer spraying method was used, ranged from sandy loam (SL) to loam (L) and the specific gravity of the soil particles ranged from 2.62 to 2.64 based on the standard of the International Society of Soil Science.

(1) Void ratio

Fertilizer spraying method: As for the changes in the soil properties in each plot when the fertilizer spraying method was used, the void-ratio was 0.95 on the banking and 1.17 on the cutting slopes before topdressing in July 1985. The number on the banking slopes was comparatively smaller than on the cutting slopes, presumably due to the effect of rolling-compaction at the time of the banking construction. Table 5 shows the changes of void-ratio after topdressing was performed in the next year (1986). Void ratio, which tended to decrease in the check plot increased in the treatment plots including the B-plot where the effect on vegetation was not determined. Although the rate varied with the treatment plots, it tended to increase compared with the rate in the year of replanting (1985).

Fertilizer bag method: On the slope where the fertilizer bag method was applied, the rate in the treatment plot was larger than that in the check plot.

(2) Saturated hydraulic conductivity

Fertilizer spraying method: As for the saturated hydraulic conductivity, when the fertilizer spraying method was used, the value was 1.6×10^{-4} cm/s on the cutting slope and 4.4×10^{-5}cm/s on the banking slope in the year of replanting (1985). It had ranged from 6.1×10^{-4}cm/s to 1.4×10^{-3} cm/s in the treatment plots and from 2.3 to 8.3×10^{-4} cm/s in the check plot during the 2-year period after the replanting. It had ranged from 1.8×10^{-4} cm/s to 3.2×10^{-3} cm/s during the 2-year period from the former measurement. The differences in the values did not seem to be affected by the respective treatments.

Fertilizer bag method: On the slope where the fertilizer bag method was employed, the rate ranged from 9.2×10^{-4} cm/s to 1.1×10^{-3} cm/s. Differences in the values among the plots were not conspicuous except for a slight difference between the treatment plot and the check plot 2 years after the replanting.

(3) Effect of soil improvement on the vegetation

When the fertilizer bag method was applied 3 months after the replanting by sodding, *Agrostis alba* formed belts on the soil along the fertilizer bags and was so well established 2 years after the replanting that even moss began to grow. In contrast, the surface of soil was exfoliated except in the treatment plots. The use of fertilizer bags was more effective on the stabilization of the soil surface on almost bare land than on the improvement of the soil physical properties.

Kurata stated that the local species easily spread on the site where grasses had already been replanted

Table 5. Changes in void ratio of surface soil

Experiment	Treatment		Aug. 1986	Oct. 1987	Aug. 1989
Fertilizer spraying method	Cutting slope	B-plot	1.26	1.12	1.25
		M-plot	1.24	0.99	1.34
		C-plot	1.29	1.03	1.15
		Check plot	1.07	0.89	0.81
	Banking slope	B-plot	1.06	1.10	1.44
		M-plot	1.00	1.10	0.88
		C-plot	1.22	1.11	1.21
		Check plot	0.83	0.87	0.87
Fertilizer bag method		Treatment plot	1.14	1.16	1.38
		Check plot	1.05	1.05	1.10

compared with bare land, based on the findings of an investigation carried out on the replanted site along the Shiga-Kusatsu route. This is because the soil surface was stabilized by the invading grasses and the physical properties of soil were so much improved that small seedlings were protected from freezing and snow melting[3]. The experiment demonstrated the beneficial effect of fertilizer application after the replanting on the growth of local species.

Conclusion

We examined the effect of additional fertilizer application to conventional methods of preservation compared with the widely used seed sprayer method (sodding) for the maintenance of replanted slopes.

The experiment was carried out by applying the fertilizer spraying method and the fertilizer bag method with packed slow-release fertilizer. When the fertilizer spraying method was applied, the effect of topdressing was examined and when the fertilizer bag method was used, the effect of basal fertilizer and topdressing was examined alternately. Topdressing was applied on a slope almost bare with a low rate of vegetation.

(1) In the experiment of topdressing by using the fertilizer spraying method, vigorous growth of grasses and a high rate of vegetation could be observed with chemical fertilizer as topdressing, and various species except for the planted ones could be recognized.

(2) On the slope where fertilizer bags were mainly used as basal fertilizer, 100% rate of canopy could be attained including the surroundings of the experimental site 1 year after replanting in 1986. It was not necessary to apply fertilizer except for the combined fertilizer that was sprayed at the time when the seeds were sprayed. However, 4 years after the replanting, the treatment plots showed a higher rate of canopy than other sites.

(3) In the experiment of topdressing using the fertilizer bags, *Agrostis alba* grew better and thicker and formed a belt-shaped vegetation along the bags set at the site. The presence of the *Agrostis alba* belt promoted growth of grasses and stabilized the surface of soil. As a result, the conditions for the invasion of other species became favorable.

The effect of fertilizer usually lasts 2 or 3 months. However, based on the experiments, the effect of the fertilizer applied indirectly persisted due to the improvement of the conditions of the vegetation and physical properties of soil even after the direct effect of the fertilizer was lost. The indirect effect lasted for 4 years after the replanting and additional fertilizer application. This phenomenon contributed to the transition from the original replanted species to the local species.

The effectiveness of the replanting method depends on the technology for conservation. The results of the current experiments showed that the effective application of fertilizer once is sufficient for the vegetation on the slope to grow well if careful management is implemented. However, topdressing was useful when the amount of vegetation was insufficient.

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