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SAFETY AND EFFICIENCY FOR WEEDING WORK AND LEVEE SLOPE'S FORM REQUIRED FOR MOWING MACHINES ON PADDY FIELDS IN STEEP SLOPING AREAS IN JAPAN

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ABSTRACT: In Japan, land readjustment projects have standardized and expanded the design and size of rice paddy fields. These projects have simultaneously promoted the conversion of levee slopes into stable inclines by expanding the difference in levels between paddy fields, which has expanded levee slopes, i.e. the weeding area. Continuous weeding work is required to prevent erosion and the collapse of steep levee slopes, and serious accidents sometimes occur in the weeding work using brush cutters on such slopes. Brush cutters have been popular for weeding work, but mowing machines are increasingly popular for reasons of safety and work efficiency. However, the levee form was designed based on the assumption of using brush cutters, which recommends small horizontal standing places both at the middle and the bottom of the slope. Therefore, it is necessary to examine whether the form of the levee slope is suitable for mowing machines. We conducted weeding work experiments in two types of levee slopes (with and without standing places) using two types of weeding equipment (mowing machines and brush cutters), and the flora of the levee slopes and the working stress on operators were investigated. Our conclusions are that (1) mowing machines are safer and more efficient than brush cutters and (2) the conventional levee form with standing places will also be effective for mowing machines.

Keywords: Steep Sloping Areas, Paddy Fields, Levee Slope Form, Weeding Work, Mowing Machines

1. INTRODUCTION

Japan is mountainous and not blessed with sufficient flat land – 47% of the country has slopes of 15° or more. Because of typhoons, paddy fields are considered the best available form of cultivation and occupy 50% of cultivated land in Japan. All paddy fields in steep sloping areas have levee slopes. When these paddy fields were developed, they were small-sized rice terraces. However, with recent rapid development of mechanized farming technology, land readjustment of the farmland was required. Land readjustment projects not only standardized and expanded plot design and size but also provided stable inclines for levee slopes, which resulted in expansion of the levee weeding area. Levee slopes are occupied by various plants. Because growth of plants in Japan is excellent due to the climate, if weeding is not carried out in a timely manner, plant succession will continue unchecked.

Many farmers use brush cutters to remove weeds from the slope of these levees (Fig. 1). Brush cutters are useful for irregular slopes, but the incidence of machinery accidents is high. The injuries caused by brush cutter accidents and are often serious and are of several types: those from contact with the edge (e.g. cutting off a leg and cuts to a leg); those caused by breakage of the edge; injuries to eyes from broken pieces of stone; and those occurring while removing entangled weeds. Many victims have mentioned "poor footing", such as on steep slope surfaces, as the cause of accidents. This problem has been previously examined [1].

The cause of machine work accidents can be categorized into three types: (1) "human factors" (e.g. erroneous operation, poor skills, and failure to check safety); (2) "mechanical factors" (e.g. defects and damage to parts, and abnormal working); and (3) "environmental factors" (e.g. steep slopes and defective safety facilities) [2]. These factors often compound and lead to accidents. For "human factors", every year the Japanese Government carries out a campaign and training sessions for brush cutters' work security to prevent accidents. In addressing "mechanical factors", mowing machines have recently become more popular for reasons of safety and work efficiency. Concerning "environmental factors", the levee form has been redesigned to have small horizontal standing places (small berms) both at the middle and the bottom of the slope (Fig. 2) [3]. This design was developed about 20 years ago and was based on the assumption of using brush cutters.

Therefore, it is necessary to examine the form

of the levee slope that is suitable for mowing machines. In this study, we conducted weeding work experiments on two types of levee slopes (with and without small berms) using two types of weeding equipment (mowing machines and brush cutters). We investigated the flora of levee slopes and the working stress on operators.

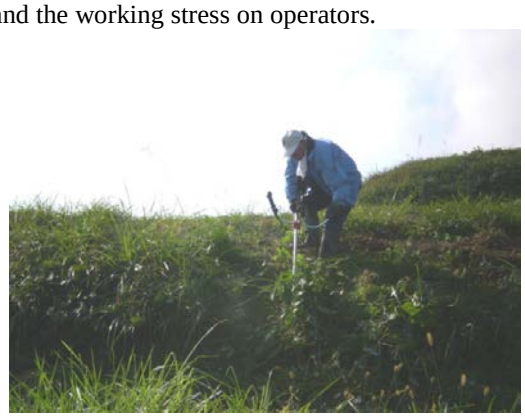

Fig.1 Weeding work using a brush cutter

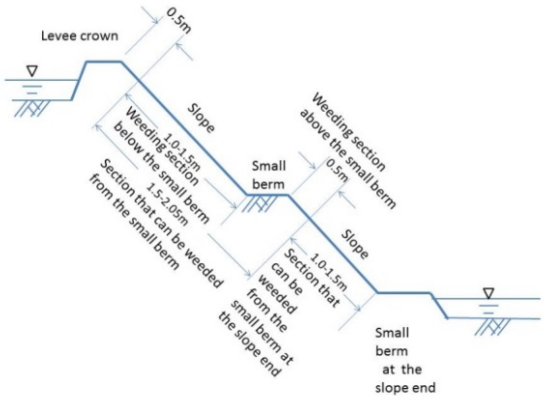

Fig. 2 Levee slope surfaces with appropriate weeding work areas

2. METHODS

In August 2014, we studied vegetation and conducted weeding work experiments at Obasute District, Chikuma City, Nagano Prefecture, Japan [4]. The conditions and the methods follow.

2.1 Working Environment

The four experimental plots had levee slopes with small berms both at the middle and the bottom (Fig. 3). The angle of inclination was 36.3°, the overall slope was 4 m in width by 15 m in length, and the small berms were 60 cm in width.

2.2 Working Machines

The brush cutter was a carried-type model equipped with a steel rotary edge on the end of its rod, with a chip saw attached (230 mm in diameter) (STIHL FS23P, engine output 0.75 kW, mass 3.9 kg, and 1780mm in total length) (Fig. 4). The mowing machine was a self-propelled-type (OREC SP850B, engine output 2.43 kW, mass 49 kg, 1700 mm in total length, overall width 550 mm, overall height 1100 mm (Fig. 5).

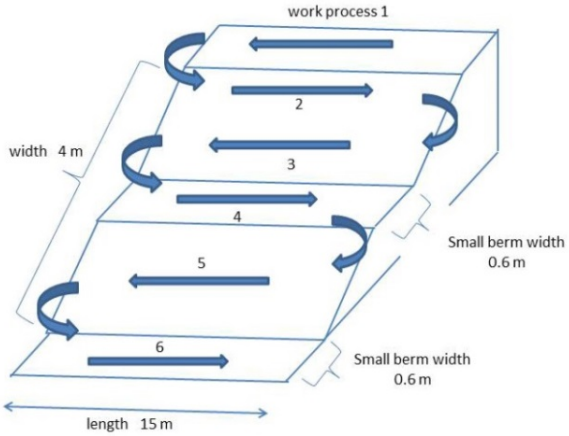

Fig. 3 Plot shape and methods of weeding work used for the experiment

Fig. 4 A brush cutter

2.3 The Test Subject

The subject was a healthy man (178 cm tall, 78 kg in weight, and aged 41 years) who was an expert with these kinds of machines.

2.4 Methods of Weeding Work

Weeding work according to the methods is shown in Fig. 3. The direction of the arrow shows the walking direction of the subject. The work process is 1–6, proceeding from the levee crown, to the upper slope and then to the lower part. When using the brush cutter, the slope surface was entirely cut by the downward weeding method; at the slope end, the upward weeding method was used, so that no grass fell to the plot below.

Fig. 5 A mowing machine

2.5 Methods of Measuring Physical Burden

The physical influence of weeding work appears congruent to the shape of the levee slope surface (the working environment), work method, performance of the machine, and the physical condition and skill of the worker. We measured a surface electrode on both deltoid muscles of the shoulder, between the hand and the elbow on the back of the forearm, and the muscle between the knee and the hip on the front of the leg (femur). In addition, we measured the time required for work, and recorded the work using a stationary video camera from two viewpoints.

3. RESULTS

3.1 Vegetation Survey

Table 1 shows the representative common plant species and coverage at the experimental plots.

We employed the following six classes of plant coverage in each plot for the field survey, with the plant species covering: (+) < 1% of the plot area; (1) 1–9%; (2) 10–24%; (3) 25–49%; (4) 50–74%; and (5) 75–100%.

3.2 Work Area and Weeding Time

Table 1 Plant species and coverage.

	No.	1	2	3	4
	small berm	yes	yes	no	no
species	machine	B	M	B	M
Festuca arundinacea		1	1	1	2
Trifolium repens		1	1	+	1
Equisetum arvense		1	1	1	2
Miscanthus sinensis		3	2	3	3
Erigeron annuus		1	1	1	1
Trifolium pratense		1	1	1	2

B: brush cutter M: mowing machine

Table 2 shows the results for the actual working area and time. We calculated the work area per working hour based on this result (Fig. 6). The results clearly showed that the mowing machine had more workload than a brush cutter.

Table 2 Area and work time for each plot

Plot no.	Small berm	Area [m^2]	Work time [s]
1	Yes	105.0	1194
2	Yes	112.5	999
3	No	79.5	794
4	No	82.5	757

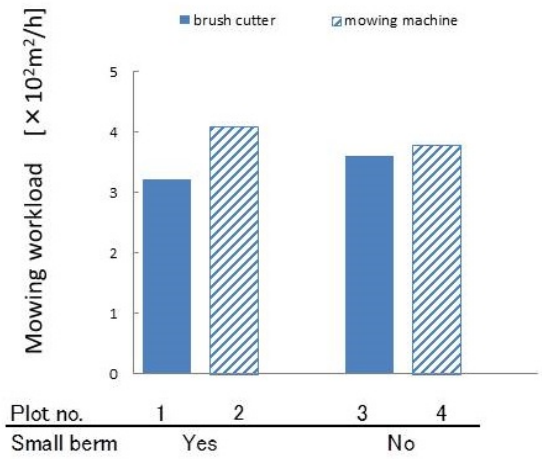

Fig. 6 Mowing workload

3.3 Work Strain Imposed by Machines and Slopes

The work strain results are shown in Fig. 7. During cutting, the work strain imposed by using the mowing machine was 30, 56, and 50% less than the brush cutter for the shoulders, forearms, and thighs, respectively. Notably, the brush cutter imposed a large strain on the forearms compared with other body parts.

The surface electrode on each muscle does not clearly show according to the availability of footing.

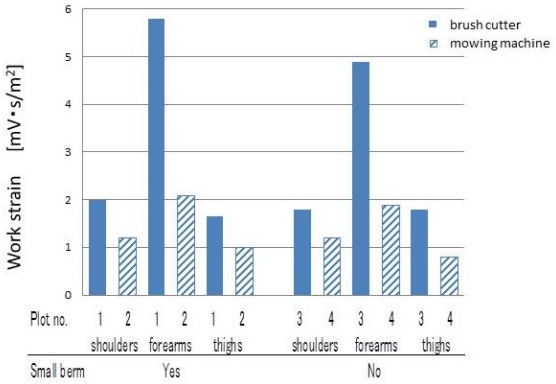

Fig. 7 Work strain on three body parts from using each machine during cutting

3.4 Density of Litter and Work Strain

Table 3 shows the density of cut material (litter) about each plot and work strain on the shoulders and forearms. Regardless of the litter density, the work strain imposed by the mowing machine was less than for the brush cutter.

Table 3 Work area and weeding hours of each plot

plot no.		1	2	3	4
small berm		yes	yes	no	no
machine		B	M	B	M
density of litter[kg/m^2]		0.27	0.19	0.18	0.14
work strain	S	1.98	0.87	1.67	0.96
[mV・s/m2]	F	5.55	1.53	4.72	1.32

B: brush cutter M: mowing machine
S: shoulders F: forearms

4. DISCUSSION

The experimental results showed that the physical burden from the mowing machine was less than from the brush cutter, and the work efficiency was superior. It is self-evident that the mowing machine is safer than the brush cutter, because the cutting edges are not exposed.

Small berms of levee slopes have been provided as a means to secure footing on the slope for safe and efficient weeding work and also as safety zones (stoppers) in the event of slips by brush cutters [1]. On the other hand, from this study, the stability of footing was not necessarily shown to be effective in the work by the mowing machine either. From the walking working conditions in the levee slope, it is expected that the burden would be greater on the lower than the upper thigh. It was thought that the judgment by such a measurement was necessary in future. In addition, it was confirmed that the arm length of the mowing machine suited the position of the small berm according to the current design standard.

5. CONCLUSIONS

The results led to the following conclusions: (1) mowing machines are safer and more effective than brush cutters, since the former had more workload, and less physical burden than the latter; (2) the conventional levee form with standing places did not clearly proved to be effective for mowing machines in the viewpoint of workload and physical stress. However, the mowing machines were confirmed applicable sufficiently to the conventional levee with standing places in this study: the existence of standing places will enable the operators to move safely, with low risk to slide down.

6. REFERENCES

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