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[Short Report]

Effects of Cutting Height and Trampling over Stubbles of the First Crop on Dry Matter Yield in Twice Harvesting of Forage Rice

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Abstract : We examined the effects of cutting height and trampling over stubbles of the first crop on dry matter yield in twice harvesting of forage rice *Oryza sativa* L., Tachiaoba and Taporuri. Dry matter yield of the second crop, after the first harvest at the full-heading stage, increased with increasing cutting height. However, the dry matter yield of the first crop decreased with increasing cutting height. Overall, total dry matter yield did not vary with the cutting height. Dry matter yield and its components of the second crop were not greatly affected by the trampling treatment. At cutting heights of 15 and 5 cm from the base, the number of tillers developed from unelongated nodes was increased by the trampling treatment. Thus, although the number of tillers developed from the elongated nodes was decreased after the trampling treatment, the decrease is compensated for by the increased number of tillers from unelongated nodes.

Key words : Cutting height, Dry matter yield, Forage rice, Tachiaoba, Taporuri, Trampling, Twice harvesting.

The production of forage rice (*Oryza sativa* L.) is increasing in Japan because of improved control of rice grain production and increasing demand for domestic forage (Sakai et al., 2003). In 2006, forage rice was grown on 5000 ha, and half of which was in southwestern Japan, where there is a prosperous livestock industry.

There are four main cropping systems used for forage rice in southwestern Japan : single-cropping, with very early planting, which is performed mainly in the southern part of southwestern Japan; cropping together with Italian ryegrass (*Lolium multiflorum* Lam.), with early planting, which is performed in most of southwestern Japan; cropping with wheat (*Triticum aestivum* L.) or barley (*Hordeum vulgare* L.), with normal planting, which is performed mainly in the northern part of southwestern Japan; and cropping with tobacco (*Nicotiana tabacum* L.), with late planting, which is performed mainly in the central part of southwestern Japan. We previously reported a fifth system, twice harvesting (i.e., ratoon cropping) of the rice cultivar Taporuri, with very early planting (Nakano and Morita, 2007; 2008). The best time for the first harvest was the full heading stage. The best form of nitrogen management was to provide a large amount of nitrogen, 2/3 in the first crop and 1/3 in the second crop.

We previously examined the effects of planting time (i.e., early versus normal planting) and cultivar (i.e., Tachiaoba, Nishiaoba, and Hinohikari) on dry matter yield in once harvesting and found that early planting

of Tachiaoba gives a high dry matter yield (Nakano et al., 2008a). However, dry matter yield was much higher in twice harvesting of Taporuri than in once harvesting of Tachiaoba. High dry matter yield is essential in forage rice production because forage rice must have low production costs, and therefore we expect twice harvesting of Taporuri to be effective in the southern part of southwestern Japan. It is thus necessary to develop an efficient twice-harvesting method for the production of forage rice using Taporuri to spread this harvest system in rice-producing areas.

The cutting height of the first crop determines the number of buds for regrowth (Chauhan et al., 1985). Although there are reports on the effects of cutting height at the first harvest (at the full-ripe stage) on grain yield of the second crop (Saran and Prasad, 1952; Evatt and Beachell, 1960; Ishikawa, 1964; Grist, 1965; Hsieh et al., 1968; Balasubramanian et al., 1970; Prashar, 1970; Bahar and De Datta, 1977; Reddy et al., 1979), the effects of cutting height at the full-heading stage on total dry matter yield of the first and second crops have not been examined. In the twice-harvesting system, about half of the stubbles of the first crop were trampled over by a forage harvester, and farmers are afraid of the effects of trampling over stubbles on the dry matter yield of the second crop. Although Kobayashi et al. (2007) examined the effects of trampling on dry weight per hill and its components in the second crop in 1/5000 a Wagner pots, there are no studies on the effects of trampling on the dry

Table 1. Effects of cultivar, cutting height, and trampling treatment at the first harvest on dry matter yield and growth of tillers of the second crop.

		Dry matter yield (g m ⁻²)			Growth of tillers of the second crop			
		Total	First crop	Second crop	Tillers per square meter (tillers m ⁻²)	Tillers from unelongated nodes (%)	Dry weight per tiller (g tiller ⁻¹)	
Cultivar (A)								
	Taporuri	2321	1157 b	1163 a	384 b	82 a	3.03 a	
	Tachiaoba	2249	1350 a	899 b	498 a	72 b	1.82 b	
Cutting height (cm) (B)								
	15	2240	1081 c	1159 a	483 a	56 c	2.50 a	
	5	2325	1258 b	1067 b	442 b	78 b	2.48 a	
	0	2289	1422 a	867 c	396 c	100 a	2.27 b	
Trampling treatment (C)								
	Trampling	2272		1018	449 a	85 a	2.36 b	
	Not trampling	2298		1044	431 b	71 b	2.48 a	
A×B								
	Taporuri	15	2296	1036	1260	405	61	3.11
		5	2368	1165	1203	391	87 a	3.07
		0	2298	1271	1026	355	100	2.90
	Tachiaoba	15	2184	1126	1058	560 a	51	1.89
		5	2282	1351	932	493 b	69 b	1.89
		0	2280	1572	707	436 c	100	1.64
A×C								
	Taporuri	Trampling	2314		1157	383	91	3.02
		Not trampling	2327		1169	384	74	3.03
	Tachiaoba	Trampling	2229		879	514 a	78	1.69 b
		Not trampling	2269		919	479 b	68	1.92 a
B×C								
	15	Trampling	2234		1153	487	70 a	2.49
		Not trampling	2295		1037	479	41 b	2.52
	5	Trampling	2285		864	449	83 a	2.39
		Not trampling	2246		1165	435	73 b	2.58
	0	Trampling	2355		1098	410	100	2.20
		Not trampling	2292		870	381	100	2.34
ANOVA								
	Cultivar (A)	NS	*	**	*	*	**	
	Cutting height (B)	NS	**	*	*	**	*	
	Trampling treatment (C)	NS		NS	*	**	**	
	A×B	NS	NS	NS	*	*	NS	
	A×C	NS		NS	*	NS	*	
	B×C	NS		NS	NS	**	NS	
	A×B×C	**		**	NS	NS	*	

Values represent the means of the sub-plots.

A, B, and C represent 'Cultivar', 'Cutting height', and 'Trampling treatment', respectively.

Means within a treatment that are followed by the same letters do not differ significantly ($P < 0.05$, LSD).

** and *, significant at $P < 0.01$ and $P < 0.05$, respectively.

matter yield and its components of the second crop in the field.

The objective of the present study was to determine the effects of cutting height and trampling over stubbles of the first crop on dry matter yield in twice harvesting of the forage rice cultivars Taporuri and Tachiaoba in southwestern Japan.

Materials and Methods

The study was conducted on a Grey Lowland soil at the National Agricultural Research Center for Kyushu Okinawa Region (33°12'N lat., 130°30'E long., 10 m a.s.l.), Chikugo, Fukuoka, Japan, in 2006. The mean temperature during late April in 2006 was 2.5°C lower than normal, but that during mid- and late October in 2006 was 2.4°C and 3.0°C, respectively, higher than normal. The previous crop grown in the field was rice. The experiment had a 2 (cultivar) × 3 (cutting height at the first harvest) × 2 (trampling over stubbles of the first crop) factorial design, arranged in a randomized complete block split-split-plot design with three replicates. The main plot, subplot, and sub-subplot factors were cultivar, cutting height at the first harvest, and trampling over stubbles of the first crop, respectively. The two cultivars were Taporuri, which is currently being tested as a forage rice for twice harvesting, and Tachiaoba, which is normally used as a forage rice. Taporuri and Tachiaoba were developed by the Chia-Yi Agricultural Experiment Station in Taiwan and the National Agricultural Research Center for Kyushu Okinawa Region in southwestern Japan, respectively (Sakai et al., 2007).

Germinated seeds were sown in nursery boxes in late March and grown in a greenhouse. Seedlings were transplanted by hand in the paddy field in mid-April. The mean number of fully expanded leaves on the main culm at transplanting was 4.2. The field received 7 g N, 7 g P₂O₅, and 7 g K₂O m⁻² in the form of chemical fertilizer broadcast by hand 3 days before transplanting, and the fertilizer was incorporated into the soil in such a way as to allow puddling. Plants received 7 g N m⁻² in the form of ammonium sulfate at the active tillering stage of the first crop (early June) and at both 7 and 21 days after the first harvest. After trimming, each plot was 2.1 × 1.8 m, with a mean density of 22.2 hills m⁻² (3 seedlings per hill, 30 × 15 cm). Forty eight hills (2.16 m⁻²) (forty two hills for determination of dry matter yield and six hills for determination of position where the ratoon appears) in the first crop were cut by hand to a stubble height of 15, 5, or 0 cm from the base at the full-heading stage (early August for Taporuri, mid-August for Tachiaoba). Then, half of these hills were left untouched or were trampled over crawlers of a combine harvester (R9511G, Kubota, Ltd., Osaka, Japan) that produces an average ground contact pressure of 19.7 kPa and is 2800 kg in weight. Water in each plot was completely

drained during the trampling treatment. Twenty one hills (0.95 m⁻²) for determination of dry matter yield in each treatment were cut by hand from the base at the yellow-ripe stage (late November for Taporuri, mid-November for Tachiaoba). For each sample, the number of tillers per square meter and dry weight were determined as described by Nakano and Morita (2007). Three hills (0.14 m⁻²) for determination of position where the ratoon appears in each treatment were uprooted by hand at the yellow-ripe stage. For each sample, the number of tillers per square meter developed from elongated and unelongated nodes was determined.

We tested for differences among treatments by means of analysis of variance (ANOVA). When an *F*-test gave *P* < 0.05, we compared the treatment effects using the least-significant difference (LSD) test.

Results and Discussion

We examined the effects of cultivar, cutting height, and trampling treatment of the first crop on dry matter yield in twice harvesting of forage rice to develop a method of cultivating Taporuri in areas that produce forage rice. Nakano and Morita (2007) reported that dry matter yield of the first crop and total dry matter yield were higher in Taporuri than in Tachiaoba in southwestern Japan. In the present study, dry matter yield of the second crop was higher in Taporuri than in Tachiaoba (Table 1). Among the dry matter yield components, the number of tillers per square meter was smaller in Taporuri than in Tachiaoba, but dry weight per tiller was much higher in Taporuri than in Tachiaoba. However, dry matter yield of the first crop was lower in Taporuri than in Tachiaoba. Overall, total dry matter yield did not differ between cultivars. Taporuri and Tachiaoba were developed in Taiwan and southwestern Japan, respectively (Sakai et al., 2007). The mean temperature during late April, just after transplanting, in 2006 was 2.5°C lower than normal. In Taporuri but not in Tachiaoba, delayed rooting after transplanting was observed. Therefore, dry matter yield of the first crop in Taporuri might have been affected by the cold temperature just after transplanting.

Dry matter and grain yields of the second crop, after the first harvest at the full-ripe stage, generally increase with increasing cutting height of the first crop (Evatt and Beachell, 1960; Grist, 1965; Hsieh et al., 1968; Mochizuki et al., 2000). Similarly, in the present study, dry matter yield of the second crop, after the first harvest at the full-heading stage, increased with increasing cutting height (Table 1). Among the dry matter yield components, the number of tillers per square meter and dry weight per tiller increased with increasing cutting height. However, dry matter yield of the first crop decreased with increasing cutting height. Overall, total dry matter yield was not affected by the cutting height.

In Japan, forage rice is mainly used as fodder after fermentation. In a previous study, the water content of the whole plant was higher in the first crop harvested at the full-heading stage than in the second crop harvested at the yellow-ripe stage (Nakano et al., 2008b). The difference is significant, because high water content causes defective fermentation of silage (Hattori et al., 2006). Furthermore, previous research revealed that the total digestible nutrient (TDN) content was higher in the second crop harvested at the yellow-ripe stage than in the first crop harvested at the full-heading stage (Nakano et al., 2008b). These results and the present study suggest that cutting the first crop at 15 cm from the base is most effective to obtain high-quality fodder.

Kobayashi et al. (2007) examined the effects of trampling over stubbles (with strong or slight trampling) on dry weight per hill, its components, and the position where tillers appear in 1/5000 a Wagner pots and reported that none of these factors were influenced by the trampling intensity. In the present study, dry matter yield of the second crop was not influenced by the trampling treatment (Table 1). There was a significant ($P < 0.05$) cultivar \times trampling treatment interaction in the number of tillers per square meter and dry weight per tiller. In Taporuri, the dry yield components were not affected by the trampling treatment, but in Tachiaoba, the number of tillers per square meter was slightly increased and dry weight per tiller was slightly decreased by the trampling treatment. There was a significant ($P < 0.05$) cutting height \times trampling treatment interaction in the proportion of tillers from unelongated nodes. At cutting heights of 15 and 5 cm from the base, the number of tillers from unelongated nodes was increased by the trampling treatment. The difference between the present results and those of Kobayashi et al. (2007) may be due to difference in the method of trampling treatment. These results suggest that the number of tillers per square meter is not greatly influenced by trampling over stubbles. Although the number of tillers developed from elongated nodes decreased by trampling, the decrease is compensated

for by the increased number of tillers from unelongated nodes.

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* In Japanese with English summary.

** In Japanese with English synopsis.

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**** In Chinese with English summary.