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Treading Resistance and Breeding of Guineagrass Suitable for Rollbale

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Abstract

The decrease in dry matter production in guineagrass by the use of a mechanical harvesting system was investigated in terms of treading resistance. It was revealed that treading treatment of stubbles led to a serious decrease in dry matter production while shading of stubbles by foliage did not result in an appreciable decrease in dry matter production. A cultivar resistant to treading was found to show more stems at the time of cutting and better tiller regeneration after harvest. Most of the tillers trodden using a tractor regenerated from the nodes near the ground level, whereas cultivars with a low treading resistance regenerated new tillers from the higher nodes, suggesting the presence of a strong apical dominance. Analysis of varietal differences in the treading resistance indicated that the tiller number and apical dominance could become morphological and physiological selection criteria for the treading resistance, respectively. Based on this assumption, 3,541 plants consisting of 318 accessions of genetic resources were evaluated for their morphological traits and apical dominance over a period of 7 years. Several candidate strains were then investigated for their treading resistance, and one strain with a strong treading resistance and suitability for rollbale harvest was eventually selected, and released as a new cultivar named Natsukomaki in 1999. Natsukomaki belongs to the slender guinea grass group characterized by fine stems, small leaves and a short plant height. Drying rate and flexibility of stems and leaves were outstanding in Natsukomaki. Hay from Natsukomaki contained a higher TDN content, and showed a good digestibility and high palatability.

Discipline: Plant breeding
Additional key words: Natsukomaki, tiller number, apical dominance, drying rate, palatability

Introduction

Guineagrass, *Panicum maximum* Jacq., was introduced as a summer annual forage grass into Japan[4] in the 1960s and its agricultural performance was evaluated, but it was not disseminated throughout Japan until 1970[6]. Greenpanic, *P. maximum* var. *trichoglume*, was grown for hay production in the southern part of Kyushu island. Guineagrass was not disseminated to Honshu island as a summer annual forage grass due to the low germination rate, poor early growth after germination and low production of dry matter[2].

In 1985, the first Japanese cultivar Natsukaze was released at the Kyushu National Agricultural Experiment Station[6]. It showed a superior agricultural performance as a summer annual soiling crop. As Natsukaze displayed a vigorous early growth and high dry matter production, farmers expected to grow Natsukaze to produce hay and silage using a mechanical harvesting system. Unfortunately, Natsukaze regrowth was not successful and the cultivar did not produce hay from the 2nd harvest because of the low resistance of the stubbles to treading. It was not easy to make hay from Natsukaze because of

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the thick culm that was responsible for the slow drying rate[1]. The second cultivar Natsuyutaka was released in 1988, and was characterized by a persistency in a perennial grassland in the subtropical area of Okinawa, and a high treading resistance[5].

Treading resistance and suitability for rollbale hay and wrapped rollbale silage were the new requirements for the breeding of a guineagrass cultivar other than Natsukaze. These became the objectives for the breeding of a new cultivar[2]. The other important objectives included digestibility and palatability, which suggested the existence of varietal differences and the possibility of selection of orchard grass[3]. First, the breeding strategy involved the evaluation and selection of the genetic resources with a wide morphological diversity collected from around the world.

Decrease in dry matter production and changes in tiller number due to treading pressure

When 3 guineagrass cultivars, Natsukaze, Natsuyutaka and Greenpanic were used in the treading trials, Natsukaze showed the highest productive performance at the 1st cutting and Natsuyutaka showed the lowest dry matter production that was well reflected in the early growth after seed germination (Fig. 1).

After the 1st cutting, guineagrass stubbles were trodden using a tractor with or without shading by foliage to analyze the effect on the regrowth. A small tractor (13 HP, 800 kg) was used to tread stubbles 4 times for 3 days after harvest. Dry matter production decreased in the treading treatment (T) and treading with shading treatment (TS). When stubbles were trodden for 3 days, tiller regeneration and regrowth were delayed by about 7–10 days compared to the control. Because of this delayed regrowth associated with the treading pressure, harvest was performed 3 times for Natsukaze and Greenpanic compared to 4 times for the control. The total dry matter production without treading (C) in Natsukaze was 172 kg/a, but it decreased to 114 kg/a in the treading treatment (T) and 97 kg/a in the treading with shading treatment (TS). When the treading resistance was estimated based on the total dry matter production after the 2nd cutting, it corresponded to ca. 60% dry matter for Natsukaze, Natsuyutaka and Greenpanic in the treading treatment (T), and ca. 50% dry matter in the treading with shading treatment (TS). The effect of shading on dry matter production was not as conspicuous as that of treading. Although the treading pressure led to a decrease in dry matter production, varietal differences in the treading resistance were not evident based on this experiment. This might be the reason why the small tractor did not damage the stubbles so severely as to affect the regrowth.

Stem number increased rapidly at the 2nd and 3rd cuttings without treading (C), and then decreased at the 4th cutting (Fig. 2). But, in both treading treatment (T) and treading with shading treatment (TS), the number of

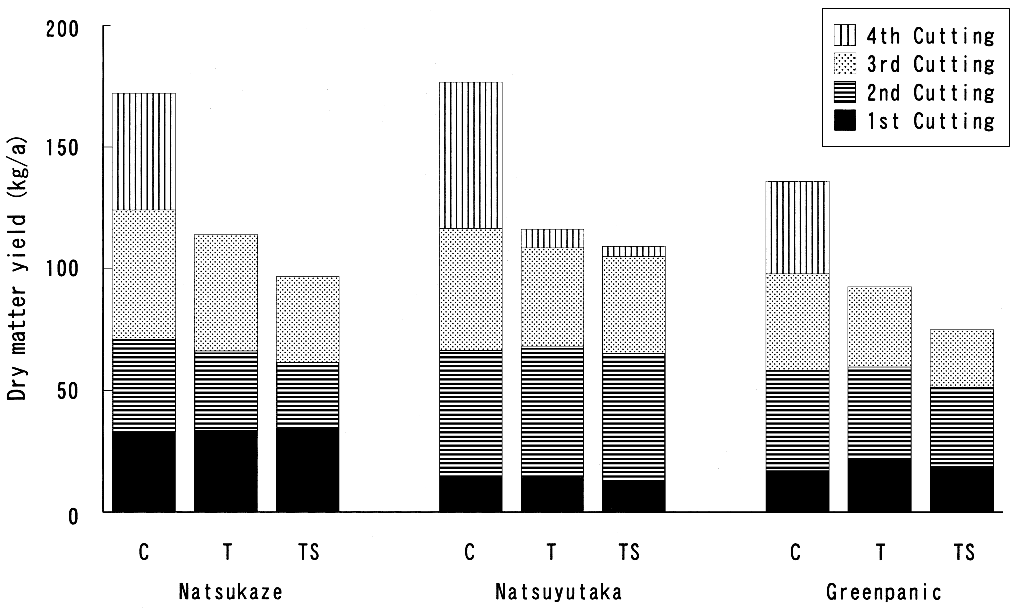

Fig. 1. Decrease of dry matter production by treading pressure

Guineagrass stubbles were trodden 4 times for 3 days using a small tractor (800 kg) with or without shading treatment.
C: Control, T: Treading treatment, TS: Treading with shading treatment.

stems at the 2nd, 3rd and 4th cuttings tended to decrease gradually. Although most of the stubbles were crushed and destroyed by the treading pressure (T and TS), new tillers regenerated from the lateral buds near the ground and grew to new stems which contributed to dry matter production at the next cutting. Natsuyutaka had many stems at each cutting and showed almost the same stem number with or without treading treatment, except for the 3rd cutting in the control. Although Natsukaze stubbles experienced the most serious damage by the treading pressure, the number of regenerated tillers increased gradually and finally reached almost the same value as that of the control at the next cutting. The density of 300 stems/m^2 might be sufficient to produce dry matter at the time of cutting in Natsukaze. On the other hand, a relative decrease in dry matter production was observed at the 2nd and 3rd cuttings in Greenpanic, suggesting that 300 stems/m^2 might not be sufficient in slender guineagrass.

Apical dominance

When stubbles were trodden using a medium-scale tractor (33 Hp, 1.8 t), the treading damage in Natsukaze and Greenpanic was more serious than that with a small tractor. The regrowth of Natsuyutaka and Gatton was satisfactory and they produced the 2nd yield. Although almost twice the number of tillers was regenerated from the lateral buds except for Natsukaze where the number of regenerated tillers was less than that at the time of cutting, half of the tillers did not contribute to dry matter production at the next cutting (Table 1). Most of the tillers after cutting were regenerated from the ground level in the treading treatment (T). There were obvious varietal differences in the percentage and the position of the regenerating tillers from the lateral bud after cutting without treading (C). In Natsukaze, in the absence of treading, tillers regenerated from the upper node on the stubble. The percentage of tillers from the ground level was 33% and the regeneration height was 5.5 cm. In Natsuyutaka and Gatton, more than 50% of the tillers regenerated from the ground level and the regeneration height was relatively low.

Varietal differences in the percentage and the position of the nodes from the ground level which regenerated new tillers in the control treatment (C) suggested that apical dominance could become a selection criterion for the treading resistance. The number of regenerated tillers played an important role in dry matter production at the next cutting.

Breeding strategy for a new cultivar suitable for rollbale in a mechanical harvesting system

It was suggested that the morphological traits, the number of tillers regenerated and the apical dominance of lateral buds could become selection criteria for the treading resistance at the time of cutting. As it is generally recognized that the number of tillers or stems per plant shows a negative relationship with the size of the culm,

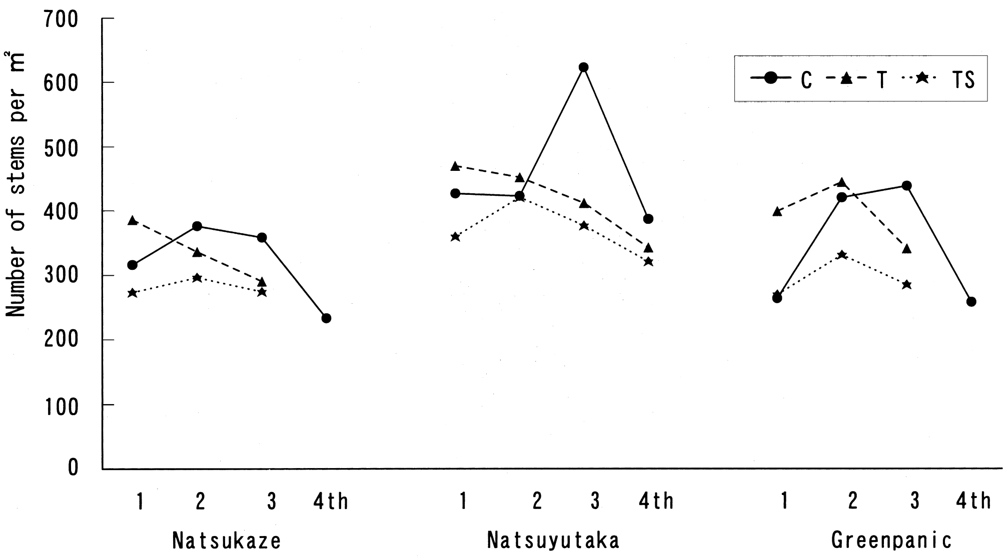

Fig. 2. Changes in stem number associated with treading pressure
Treading treatment is the same as that in Fig. 1.
C: Control, T: Treading treatment, TS: Treading with shading treatment.

Table 1. Effect of treading treatment on tiller regeneration after cutting

Cultivar	Treatment[a)]	Stem cutting (/m^2)	Tiller regeneration (/m^2)	Percentage of tillers[b)] from ground (%)	Regeneration height[c)] (cm)
Natsukaze	C	349	650	33	5.5
	T	233	195	96	0.7
Natsuyutaka	C	412	794	57	3.4
	T	358	742	94	0.5
Gatton	C	374	1,014	58	3.6
	T	377	656	89	1.2
Greenpanic	C	357	636	41	5.0
	T	239	425	87	1.2

a): C,Control; T,Treading treatment using a medium-scale tractor (1.8 t).
b): Percentage of tillers regenerated from the ground level.
c): Height from the ground level.

accessions with many fine stems could be primarily selected from genetic resources in the morphological evaluation trials. These candidates could then be evaluated based on the apical dominance and the regeneration of trodden stubbles by a tractor after harvest. By this breeding strategy, actual treading-resistant strains could be selected. Strains with fine stems and small leaves also are likely to dry faster than those with thick stems and large leaves and to be flexible for making hay or making rollbale wrapped silage.

A new cultivar "Natsukomaki"

Treading resistance and dry matter production

According to the breeding strategy outlined above, 3,541 plants consisting of 318 accessions of genetic resources were investigated in terms of morphological traits and apical dominance over a period of 7 years, and then the treading resistance was evaluated. Natsukomaki was released as a treading-resistant cultivar at the Kyushu National Agricultural Experiment Station in 1999 (Fig. 3). When the treading resistance was estimated from the 2nd yield, Natsuyutaka that produced 71.9 kg/a of dry matter, 5 times the amount of Natsukaze, showed the strongest resistance. Gatton and Natsukomaki produced 63.7 and 55.9 kg/a of dry matter, respectively (Table 2). Natsukaze and Natsukomaki showed the highest dry matter production of 51.5 kg/a at the 1st cutting, reflecting the vigorous seedling growth of these cultivars at the early stage after seed germination. Other cultivars such

Fig. 3. Varietal differences in treading resistance in guineagrass
The 1st cutting of guineagrass was harvested for hay using a 90 Hp tractor (4.5 t) and the regrowth of Natsukomaki (left) and Natsukaze (right) is shown 3 weeks affer the cutting.

Table 2. Treading resistance of Natsukomaki guineagrass

Cultivar	Dry matter yield (kg/a)			Ratio	Treading resistance[a)]
	1st	2nd	Total		
Natsukomaki	51.5	55.9	107.3	162	383
Natsukaze	51.5	14.6	66.1	100	100
Natsuyutaka	30.1	71.9	102.0	154	492
Gatton	29.6	63.7	93.3	141	436
Greenpanic	32.7	16.7	49.3	74	114

a): Treading resistance was estimated by the ratio of the 2nd yield to that of Natsukaze.

as Natsuyutaka, Gatton and Greenpanic showed a low dry matter production at the 1st cutting.

Although Natsukomaki did not display the strongest treading resistance, total dry matter production in a mechanical harvesting system was the highest because of the strong treading resistance and the high dry matter production at the 1st cutting.

Drying rate of foliage

Rapid drying enables the foliage to produce readily hay or wrapped rollbale silage. When the foliage was harvested at the head emergence stage, the highest water content was 83.8% in Natsukaze and the lowest was 79.0% in Natsuyutaka while in Natsukomaki the water content was 81.5%. There were few varietal differences in the water content at the head emergence stage (Fig. 4). One kg of fresh materials was put into a drying cabinet and weighed every 12 h to investigate the drying rate. Although in Natsukomaki and Natsuyutaka drying occurred rapidly (40% water content after 24 h and 20% after 48 h), in Natsukaze drying was slow (50% water content after 24 h). This tendency was almost the same 36 and 48 h later. Drying in Gatton and Greenpanic was slow as in the case of Natsukaze. Rapid drying in Natsukomaki was also observed at the 2nd cutting.

Flexibility of culms

Elongated fresh internodes from the 1st and 2nd cuttings at the head emergence stage were collected from near the ground and the diameter was measured to calculate the sectional dimensions. The internodes were then pressed by the Force Gage, Imada DPRS-50T, to measure the flexibility of the culm that was expressed as the breaking strength of an internode.

There was an obvious positive relationship between the sectional dimensions and the strength of the culm (Fig. 5). Slender types of guineagrass such as Natsukomaki, Gatton and Greenpanic showed small sectional dimensions and their internodes were easily broken by a weak pressure. The internodes of Natsuyutaka were hard to break, and required 3 kg pressure corresponding to twice the pressure recorded in slender guineagrass. Although Natsukaze showed large sectional dimensions, the breaking strength of the internodes was almost similar to that of Natsuyutaka for which the sectional dimensions were smaller. This finding may be attributed to the abundant pith inside of the culm in Natsukaze which may have decreased the breaking strength.

The fine stem of Natsukomaki did not require a strong pressure to break the internodes, suggesting the flexibility of the Natsukomaki culm.

Feed composition and palatability

The contents of CP and EE in the hay from Natsukomaki were almost the same as those in the hay from

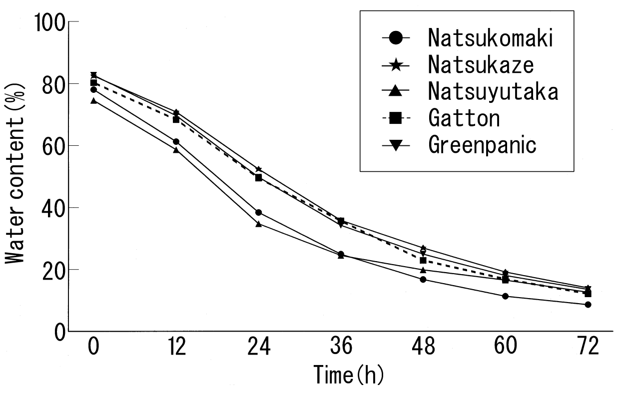

Fig. 4. Drying process of foliage harvested at the head emergence stage of guineagrass
One kg of fresh stems and leaves was put into a drying cabinet to determine the drying rate.

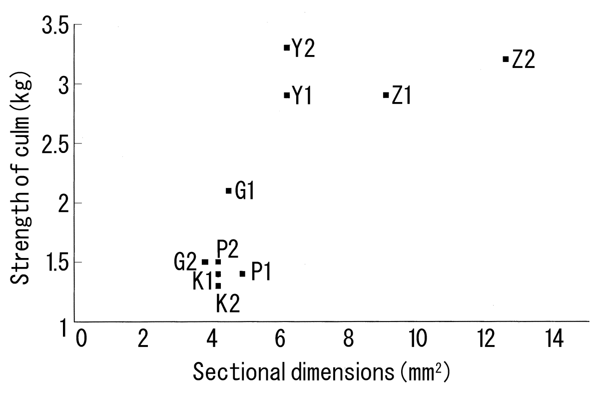

Fig. 5. Flexibility of guineagrass culms near ground
Flexibility was expressed by the breaking strength of internodes. 1: 1st cutting, 2: 2nd cutting. K: Natsukomaki, Z: Natsukaze, Y: Natsuyutaka, G: Gatton, P: Greenpanic.

Table 3. Feed composition and palatability of hay at the head emergence stage of guineagrass

Cultivar	Cutting date	CP[a] (%)	EE[b] (%)	NFE[c] (%)	CF[d] (%)	TDN[e] (%)	Palatability[f] (%)
Natsukomaki	7/31	12.1	1.9	40.3	34.5	53.6	66.1
Natsukaze	8/ 9	12.0	2.0	37.7	36.6	45.2	24.0
Natsuyutaka	8/22	11.2	1.6	38.6	36.4	45.9	23.7
Gatton	8/ 5	12.1	1.9	38.6	35.7	49.8	22.9
Greenpanic	8/ 2	12.4	1.7	39.9	34.3	48.8	25.3

a): Crude protein, b): Crude fat, c): Nitrogen-free extract, d): Crude fiber,
e): Total digestive nutrients; TDN was evaluated by using goats,
f): Palatability was estimated after 30 min of free cafeteria feeding by goats.

other cultivars, but Natsukomaki hay showed a slightly higher content in NFE and a lower content in CF (Table 3). Natsukomaki hay showed a higher TDN content than that of the hay from other cultivars (53.6% in Natsukomaki hay and 45.2% in Natsukaze hay). Dry matter digestibility was also higher in Natsukomaki hay. There was a distinct varietal difference in palatability. The intake of hay from Natsukomaki was 66.1% at 30 min after the start of free cafeteria feeding, and it was 24.0% in Natsukaze and 22.9% in Gatton. The superior palatability of Natsukomaki hay may be attributed to the high TDN content and digestibility.

Conclusion

At the start of breeding activities, it is necessary to set up a field for selection using cross breeding materials. The old cultivar Natsukaze had been derived from the hybrid progeny of a strain with sexual reproduction crossed with an apomictic strain. However, as the major reproductive type of guineagrass is apomixis, which is not suitable for obtaining real hybrid progenies, the breeding activities began with the investigation and evaluation of the introduced apomictic genetic resources. Fortunately, there were wide morphological, physiological and genetic variations. Selection criteria are particularly important in apomictic species. The second cultivar Natsuyutaka was evaluated for persistency in Okinawa, a subtropical area in Japan. In the new cultivar Natsukomaki, treading resistance, drying rate and flexibility of culms were the major selection criteria that would be suitable for the use of a mechanical harvesting system as well as for rollbale. Morphological selection for the treading resistance was primarily based on the number of tillers and physiological selection was then based on apical dominance.

Although Natsukomaki showed a strong treading resistance, the strongest treading resistance was observed in Natsuyutaka and Gatton. Natsukomaki showed a combination of superior traits including vigorous early growth after seed germination, rapid drying of foliage and flexible fine stems. Moreover, Natsukomaki hay showed a high TDN content and a good digestibility resulting in its superior palatability. The use of Natsukomaki should enable to obtain good hay and wrapped rollbale silage, and morphological traits such as short plant height, fine culm and spreading plant type suggest that it will be easy to harvest Natsukomaki with a small tractor and use it for grazing. Although regional adaptability tests of Natsukomaki did not include the agricultural performance for soiling crop in the subtropical area, through the application of appropriate growing methods, Natsukomaki could become suitable for perennial grasslands.

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