Sod-pulling by Beef Cattle Grazing Bahiagrass (*Paspalum notatum* Flügge) Pasture on Sandy Soil

Masahiko Hirata, Masashi Kikuchi and Masakazu HigashiYama

**Synopsis**


This study investigated sod-pulling by beef cattle grazing two paddocks of a bahiagrass pasture on sandy soil. The sod-pulling was often observed during the grazing season.

The number of sod materials pulled per day was in the ranges of 0.54-9.23 materials/m² and 181-1961 materials/head. Bahiagrass accounted for 13.3-96.8% of the number.

The weight per sod-pulled material was in the ranges of 159-493 mg DM in bahiagrass and 53-248 mg DM in other species. The aboveground parts accounted for 52.9-68.1% and 63.6-91.7% of the weight per material in bahiagrass and other species, respectively. There were positive linear relationships between the weights of the plant parts in bahiagrass.

The weight of sod materials pulled per day was in the ranges of 0.06-1.40 g DM/m² and 22-298 g DM/head for the aboveground parts, 0.02-0.88 g DM/m² and 4-188 g DM/head for the belowground parts, and 0.08-2.29 g DM/m² and 29-485 g DM/head for the total plant parts. Bahiagrass accounted for 11.9-99.2%, 33.3-99.4% and 15.3-99.2% of the weights of aboveground parts, belowground parts and total plant parts, respectively. In bahiagrass, the aboveground weight pulled per m² per day was positively and linearly related to the herbage mass above the ground level. The slope of the line was greater in the smaller paddock.

Based on the data obtained, the factors affecting the sod-pulling were discussed, and the plant losses due to the pulling were estimated.

**Key words** : Bahiagrass pasture, Sandy soil, Sod-pulling.

**Introduction**

A grazed pasture is characterized by dynamic interactions between the pasture plants and the grazing animals. Animals give impacts to the plants by selective grazing, pulling, treading, defecation, urination, etc. Among these impacts, the information on pulling is scarce. Pulling is distinguished into sod-pulling and tiller-pulling. In sod-pulling, plants are pulled out of the ground with some roots still attached to them. In tiller-pulling,
unrooted aerial tillers are pulled off the plants.

Bahiagrass, which forms a dense sod with stout stolons, is regarded as resistant to pulling. However, in the authors' grazing trial with beef cattle on a bahiagrass pasture on sandy soil\(^2\), a number of sod-pulled materials were seen on the sward surface. Taking this fact into account, we investigated the number and the amount of sod materials pulled by animals, and estimated the plant losses due to the pulling.

**Materials and Methods**

The investigation was conducted from May to October 1992 in a Pensacola bahiagrass (*Paspalum notatum* FLüGGE) pasture in the Sumiyoshi Livestock Farm (31°59' N, 131°27' E), Faculty of Agriculture, Miyazaki University. The Farm is located on a dune area facing the Pacific Ocean (about 2 km from the coastline). The soil type is the Sand–dune Regosols. Physical and chemical characteristics of the soil have been shown by MiAKI *et al.*\(^3\).

1. **Pasture and animals**

Three paddocks in the pasture were rotationally grazed by a herd of 17 Japanese Black Cattle consisting of 11 heifers and 6 steers. The areas of the paddocks 1, 2 and 3 were 0.37, 0.36 and 0.61 ha, respectively. The paddock 3 was oversown with Italian ryegrass (*Lolium multiflorum* LAM.) in the autumn of 1991.

The animals grazed one paddock for 3–10 days under a daytime grazing system before being rotated to the next paddock. Total days for which the animals grazed the paddocks 1, 2 and 3 were 51, 50 and 80 days, respectively. The animals were introduced to the paddocks at about 9 a.m. and returned to the barn at 4 p.m. every day. The animals were supplemented

<table>
<thead>
<tr>
<th>Paddock</th>
<th>Investigation period (Date)</th>
<th>Mean air temperature (°C)</th>
<th>Herbage mass (g DM/m(^2))(^{,})</th>
<th>Mean liveweight (kg LW/head)(^{,})</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>12~14 May</td>
<td>19.9</td>
<td>193.4 (73.8)</td>
<td>283.2</td>
</tr>
<tr>
<td></td>
<td>7~ 9 Jun.</td>
<td>21.0</td>
<td>218.2 (91.3)</td>
<td>307.2</td>
</tr>
<tr>
<td></td>
<td>14~20 Jul.</td>
<td>26.4</td>
<td>469.9 (92.8)</td>
<td>324.6</td>
</tr>
<tr>
<td></td>
<td>7~13 Aug.(^{b})</td>
<td>26.1</td>
<td>503.7 (97.4)</td>
<td>330.3</td>
</tr>
<tr>
<td></td>
<td>24~30 Sep.</td>
<td>21.5</td>
<td>330.2 (92.8)</td>
<td>342.7</td>
</tr>
<tr>
<td></td>
<td>9~11 Oct.</td>
<td>17.6</td>
<td>285.4 (97.0)</td>
<td>347.7</td>
</tr>
<tr>
<td>3</td>
<td>15~21 May</td>
<td>19.4</td>
<td>198.6 (73.7)</td>
<td>288.5</td>
</tr>
<tr>
<td></td>
<td>10~17 Jun.</td>
<td>21.2</td>
<td>299.9 (97.2)</td>
<td>310.4</td>
</tr>
<tr>
<td></td>
<td>21~25 Jul.</td>
<td>27.7</td>
<td>567.3 (91.3)</td>
<td>326.1</td>
</tr>
<tr>
<td></td>
<td>14~17 Aug.</td>
<td>26.7</td>
<td>421.1 (91.7)</td>
<td>331.4</td>
</tr>
<tr>
<td></td>
<td>12~16 Sep.</td>
<td>23.6</td>
<td>515.2 (96.2)</td>
<td>338.6</td>
</tr>
<tr>
<td></td>
<td>23~27 Oct.</td>
<td>16.4</td>
<td>424.0 (97.3)</td>
<td>354.1</td>
</tr>
</tbody>
</table>

a) Areas of paddocks 2 and 3 were 0.36 and 0.61 ha, respectively.
b) The paddock was not grazed on 8 Aug. due to a typhoon.
c) Mean values during the respective investigation periods.
d) Herbage mass above the ground level. Figures in the parentheses show the percentage (%) of bahiagrass.
e) Number of animals was 17.
Photo 1. Sod-pulling observed in paddock 2 in mid-June. The sod-pulled material is relatively small in size (cf. Photo 2).

Photo 2. Sod-pulling observed in paddock 3 in late July. The sod-pulled materials are relatively big in size (cf. Photo 1).

Photo 3. Sod-pulled materials lying on the sward surface of paddock 3 in late July. A number of pulled materials are seen on a well-grazed short-sward area of the paddock.

Photo 4. Sod-pulled materials lying on the sward surface of paddock 2 in late October. A number of dying or dead materials are scattered on the sward.
in the barn after the everyday grazing with wheat bran plus corn silage or plus rhodesgrass hay (mean intake over the grazing season = 10.9 g DM/kg LW/day).

The paddocks, in addition to the grazing, were mown in May or June and in August. The paddocks were fertilized with 10 t/ha of poultry manure and chemical fertilizer equivalent to 38 kg N/ha, 38 kg P₂O₅/ha and 38 kg K₂O/ha in February–March, and with 110 kg urea/ha in May or June.

Some information on the air temperature, herbage mass and animal liveweight is shown in Table I. Detailed information of the air temperature, pasture conditions, intake of supplementary feed and grazing behavior of animals during the grazing season has been presented by Higashiyama et al.³)

2. Sampling method

Investigation of the sod-pulling was made once a month in paddocks 2 and 3 (Table 1). The animals grazed the respective paddocks during the investigation periods. Immediately before the investigation periods, twenty 1 m × 1 m fixed-quadrats were randomly set in the paddocks, and the sod-pulled materials lying in and around the quadrats were removed. Then, immediately after the investigation periods, the sod-pulled materials lying in the quadrats were collected.

The number of the materials collected from each quadrat was recorded with species names. The bahiagrass materials were separated into aboveground parts (leaf + stem + standing dead materials), stolon and root, and the materials of other species were separated into aboveground parts (leaf + stem + standing dead materials + runners) and belowground parts (rhizome + root). The dry weight of the separated samples was determined after oven-drying at 85°C for 72 hours.

The sod-pulled material in this study usually had one to three tillers on a piece of stolon. Therefore, in this study, the number of sod-pulled materials does not equal the number of tillers of pulled materials.

Results

1. Occurrence of sod-pulling

The sod-pulling often occurred during the grazing season (Photos 1 and 2), and the number of the sod-pulled materials lying on the sward surface increased as the grazing season proceeded (Photos 3 and 4). In contrast, the tiller-pulling was seldom observed during the grazing season.

2. Number of sod materials pulled per day

The number of sod materials (total plant species) pulled per m² per day was in the range of 0.54–9.23 materials (Fig. 1). The number tended to increase from May to October in both the paddocks. Paddock 2 usually gave higher numbers than paddock 3.

The number of sod materials (total plant species) pulled per animal per day was in the range of 181–1961 materials (Fig. 2). The number tended to increase from May to October in both the paddocks.

Bahiagrass accounted for 13.3–96.8% of the number of the sod-pulled materials (Table 2). The percentage of bahiagrass was lowest in May in both the paddocks. As for the composi-
tion of the species other than bahiagrass, in paddock 2, the dicots were major in May–June, after which the Gramineae with the Cyperaceae took over (Table 3). In paddock 3, the Gramineae was always major in the species other than bahiagrass. The major grasses were *Poa annua* L. and *Lolium multiflorum* LAM. (only in paddock 3) in May–June, and *Digitaria adscendens* (H.B.K.) HENRY and *Eleusine indica* (L.) GAERTN. thereafter. In the Cyperaceae, *Cyperus rotundus* L. and *C. brevifolius* HASSK. were the major species. The major dicots were *Veronica arvensis* L., *Gnaphalium affine* D. DON and *Geranium thunbergii* SieB. et Zucc. in

![Fig. 1. Number of sod materials pulled per m² per day. Symbols indicate bahiagrass (■) and other species (□). Vertical bars indicate the SE of the mean of the number of total species.](image1)

![Fig. 2. Number of sod materials pulled per animal per day. For the symbols and the vertical bars, refer to Fig. 1.](image2)

![Table 2. Percentage (%) of bahiagrass in the number of sod-pulled materials*).](table2)

<table>
<thead>
<tr>
<th>Month</th>
<th>Paddock 2</th>
<th>Paddock 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>15.7</td>
<td>13.3</td>
</tr>
<tr>
<td>6</td>
<td>61.9</td>
<td>50.6</td>
</tr>
<tr>
<td>7</td>
<td>93.5</td>
<td>92.9</td>
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<tr>
<td>8</td>
<td>96.8</td>
<td>89.4</td>
</tr>
<tr>
<td>9</td>
<td>88.9</td>
<td>56.2</td>
</tr>
<tr>
<td>10</td>
<td>91.3</td>
<td>63.9</td>
</tr>
</tbody>
</table>

a) Calculated from Figs. 1 and 2.
Table 3. Percentage composition (%) of other species than bahiagrass in the number of sod-pulled materials.

<table>
<thead>
<tr>
<th>Month</th>
<th>Paddock 2</th>
<th></th>
<th></th>
<th>Paddock 3</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gramineae</td>
<td>Cyperaceae</td>
<td>Dicots</td>
<td>Gramineae</td>
<td>Cyperaceae</td>
<td>Dicots</td>
</tr>
<tr>
<td>5</td>
<td>27.9</td>
<td>2.3</td>
<td>69.8</td>
<td>84.6</td>
<td>1.0</td>
<td>14.4</td>
</tr>
<tr>
<td>6</td>
<td>33.3</td>
<td>0.0</td>
<td>66.7</td>
<td>93.0</td>
<td>2.3</td>
<td>4.7</td>
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<td>7</td>
<td>55.0</td>
<td>20.0</td>
<td>25.0</td>
<td>100.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>8</td>
<td>40.0</td>
<td>40.0</td>
<td>20.0</td>
<td>84.2</td>
<td>15.8</td>
<td>0.0</td>
</tr>
<tr>
<td>9</td>
<td>67.5</td>
<td>28.0</td>
<td>6.5</td>
<td>86.1</td>
<td>12.7</td>
<td>1.2</td>
</tr>
<tr>
<td>10</td>
<td>79.1</td>
<td>16.7</td>
<td>4.2</td>
<td>88.8</td>
<td>10.3</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Fig. 3. Weight per sod-pulled material.
Symbols indicate the aboveground parts of bahiagrass or other species (■), stolon (□) and root (■) of bahiagrass, and belowground parts of other species (■). Vertical bars indicate the SE of the mean of the weight of total plant parts.

May–June, and Oxalis corniculata L. and Erigeron bonariensis L. thereafter.

3. Weight per sod-pulled material

The weight per sod-pulled material (total plant parts) of bahiagrass, which was in the range of 159–493 mg DM, increased from May to July or August and decreased thereafter (Fig. 3). The aboveground parts, stolon and root accounted for 52.9–68.1%, 27.6–40.8% and 3.0–6.5% of the total weight, respectively. The weight per sod-pulled material (total plant parts) of the other species was in the range of 53–248 mg DM. The aboveground parts accounted for 63.6–91.7% of the total weight.

There were positive linear relationships between the weights of the plant parts per sod-pulled material in bahiagrass (Fig. 4). The following equations through the origin were obtained:

\[ W_S = 0.557 W_A \] \[ (R^2 = 0.976, P < 0.001) \] \[ (1) \]

\[ W_R = 0.153 W_S \] \[ (R^2 = 0.983, P < 0.001) \] \[ (2) \]

where \( W_A \), \( W_S \) and \( W_R \) are the weights (mg DM/material) of the aboveground parts, stolon and
root, respectively.

4. Weight of sod materials pulled per day

The weight of sod materials (total plant species) pulled per m² per day was in the ranges of 0.06–1.40 g DM for the aboveground parts, 0.02–0.88 g DM for the belowground parts and 0.08–2.29 g DM for the total plant parts (Fig. 5). The weight of the three parts increased from May to August or September, and decreased or leveled off thereafter. Paddock 2 tended to give greater weights than paddock 3.
Fig. 6. Weight of sod materials pulled per animal per day.
For the symbols and the vertical bars, refer to Fig. 5.
Belowground parts of bahiagrass consist of stolon and root.

Table 4. Percentage (%) of bahiagrass in the weight of sod-pulled materials(a).

<table>
<thead>
<tr>
<th>Plant part</th>
<th>Month</th>
<th>Paddock 2</th>
<th>Paddock 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aboveground parts</td>
<td>5</td>
<td>11.9</td>
<td>18.8</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>83.0</td>
<td>78.0</td>
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<td></td>
<td>7</td>
<td>96.1</td>
<td>99.2</td>
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<td></td>
<td>8</td>
<td>98.6</td>
<td>94.9</td>
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<td>9</td>
<td>91.3</td>
<td>53.3</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>92.2</td>
<td>69.8</td>
</tr>
<tr>
<td>Belowground parts</td>
<td>5</td>
<td>38.3</td>
<td>33.3</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>93.4</td>
<td>86.9</td>
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<td>7</td>
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<td>99.2</td>
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<td>8</td>
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<td>98.3</td>
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<td>97.4</td>
<td>88.9</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>96.6</td>
<td>92.2</td>
</tr>
<tr>
<td>Total plant parts</td>
<td>5</td>
<td>15.3</td>
<td>22.3</td>
</tr>
<tr>
<td></td>
<td>6</td>
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<td>63.1</td>
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<tr>
<td></td>
<td>10</td>
<td>94.2</td>
<td>78.7</td>
</tr>
</tbody>
</table>

a) Calculated from Figs. 5 and 6.
b) Belowground parts of bahiagrass consist of stolon and root.
The weight of sod materials (total plant species) pulled per animal per day was in the ranges of 22–298 g DM for the aboveground parts, 4–188 g DM for the belowground parts and 29–485 g DM for the total plant parts (Fig. 6). The weight of the three parts increased from May to August or September, and decreased or leveled off thereafter.

The percentage of bahiagrass in the weight of sod-pulled materials was 11.9–99.2% for the aboveground parts, 33.3–99.4% for the belowground parts and 15.3–99.2% for the total plant parts (Table 4). The percentage of bahiagrass was lowest in May in both the paddocks.

In bahiagrass, there were positive linear relationships between the aboveground weight of sod materials pulled per m² per day and the herbage mass (Fig. 7). The following equations were obtained in paddocks 2 and 3, respectively:

\[ U = 0.00302(M - 120.2) \quad (R^2 = 0.655, P < 0.1) \]  \hspace{1cm} (3),

\[ U = 0.00119(M - 157.1) \quad (R^2 = 0.813, P < 0.05) \]  \hspace{1cm} (4),

where \( U \) is the aboveground weight pulled (g DM/m²/day) and \( M \) is the herbage mass above the ground level (g DM/m²).

**Discussion**

1. **Factors affecting the sod-pulling**

Sod-pulling can occur when grazing animals bite pasture plants to ingest herbage. Therefore, in each plant species of a pasture, the weight of sod materials pulled per m² per day is determined principally by three factors; (1) the herbage mass of the species per m², (2) the number of bites imposed on the species per m² per day, and (3) the resistance of the species to the pulling.

1. **Herbage mass**

In bahiagrass, the aboveground weight of sod materials pulled per m² per day was positively and linearly related to the herbage mass above the ground level (Fig. 7 and Eqns 3 and 4). The \( x \)-intercepts of the equations indicate that no sod-pulling occurred when the herbage mass was less than or equal to 120.2 and 157.1 g DM/m² in paddocks 2 and 3, respectively. The slopes of the equations indicate that, when the herbage mass exceeded the critical values, 0.302 and 0.119% of the exceeded aboveground biomass were pulled per day.
paddocks 2 and 3, respectively. Thus the two paddocks differed greatly in the slopes, and little in the x–intercepts. This difference in the slopes, as discussed below, is considered to be caused mainly by the difference in the number of bites imposed on the bahiagrass under different stocking densities.

2) **Number of bites imposed**

The number of bites imposed on the plant species per m² per day is determined by the stocking density (head/m²), the number of bites per animal per day (bites/head/day) and the preference by animals for the species. The number of bites per animal per day is expressed as a product of the biting rate (bites per unit time) and the grazing time per day.

There was a great difference in the stocking density between paddocks 2 and 3. Paddock 3 was 1.69 times as large as paddock 2. This means that paddock 2 was 1.69 times as high in stocking density as paddock 3, since the number of the animals was always constant. On the other hand, according to HIGASHIYAMA et al. 3, the two paddocks were usually similar in the biting rate and the grazing time. Furthermore, the two paddocks were highly dominated by bahiagrass during the grazing season except for May (Table 1), which indicates that the animals usually had little chance for species selection when they bit the plants. Thus, it is considered that the number of bites imposed on the bahiagrass plants differed largely between the two paddocks mainly due to the difference in the stocking density.

3) **Resistance to pulling**

The resistance of the species to pulling is considered to be affected by such factors as the sward height, the development of stolons, rhizomes and roots, the soil conditions, etc. TALLOWIN 9, in perennial ryegrass swards of three different heights, found greater amount of pulled tillers by cattle in taller swards. In this study, there were positive linear relationships between the weights of the three plant parts of bahiagrass sod material (Fig. 4 and Eqns 1 and 2). The sward was tall when the aboveground weight per pulled material was heavy (HIGASHIYAMA et al. 9 and Fig. 3). Thus, this study confirmed that taller sward is less resistant to pulling with more stolons and roots attached to the pulled aboveground parts (Figs. 5 and 6). TALLOWIN et al. 10, in perennial ryegrass swards maintained at a constant height, observed that the amount of sod–pulled materials increased with increasing rate of nitrogen fertilization. This indicates that the factors such as the development of roots and the soil conditions are responsible for the resistance to pulling. Sandy soil like in this study is considered to favor the sod–pulling.

The bahiagrass plants in paddocks 2 and 3 are not regarded as different in any of the above factors concerning the resistance to pulling. The heights of bahiagrass in the two paddocks, as shown by HIGASHIYAMA et al. 3, were usually similar during the grazing season. There were no large differences between the two paddocks in the weights of plant parts per pulled material (Fig. 3). Furthermore, the two paddocks were similar in the soil condition and the fertilization rates. Therefore, in due consideration of what we have seen in the preceding two factors, the great difference in the slopes between the two paddocks (Fig. 7 and Eqns 3 and 4) is considered to be caused mainly by the difference in the number of bites imposed on the species under different stocking densities.

This study also showed a difference in the pulling between bahiagrass and other species.
In May, the percentage of bahiagrass in pulled materials was less than 19% for the above-ground parts (Table 4), though the percentage in the herbage mass was about 74% (Table 1). This indicates that bahiagrass had higher resistance to pulling and/or lower preference than other species.

2. Plant losses due to the sod-pulling

There is scarce information on the plant losses due to pulling in grazed pastures. Therefore, in this section, we made some estimation of the losses using the present data. The number and the weight of sod materials pulled in paddock 1 were assumed to be the same as those in paddock 2, since the two paddocks were similar in area and the total days of grazing (see Materials and Methods). The word “losses” was used here, though some of the minerals in pulled materials will be uptaken by the plants after the decomposition of the materials. The number of sod materials (total plant species) pulled per m² per day, when averaged over the six months, was 3.90 and 1.94 materials in paddocks 2 and 3, respectively (Fig. 1). From these values, the number of sod materials pulled over the grazing season was estimated at 195 materials/m² in paddock 2 (50 days of grazing) and 155 materials/m² in paddock 3 (80 days of grazing).

The number of sod materials (total plant species) pulled per animal per day, when averaged over the six months, was 829 and 696 materials in paddocks 2 and 3, respectively (Fig. 2). Accordingly, the number of sod materials pulled over the grazing season (51, 50 and 80 days of grazing in paddocks 1, 2 and 3, respectively) was calculated at about 140,000 materials/head.

2) Losses in the weight over the grazing season

When averaged over the six months, the weights of aboveground parts, belowground parts and total plant parts of sod materials (total plant species) pulled per m² per day were respectively 0.62, 0.43 and 1.05 g DM in paddock 2, and 0.36, 0.19 and 0.54 g DM in paddock 3 (Fig. 5). From these values, the weights of sod materials pulled per m² over the grazing season in paddocks 2 and 3 were respectively estimated at 31 and 28 g DM for the aboveground parts, 21 and 15 g DM for the belowground parts, and 52 and 43 g DM for the total plant parts. According to Hirata et al., the net primary production of a bahiagrass pasture grazed by dairy heifers was about 1400 g DM/m² during May–October. Thus, the percentage losses to the net primary production were considered to be as low as 2.0–2.2% for the aboveground parts, 1.1–1.5% for the belowground parts, and 3.1–3.7% for the total plant parts.

When averaged over the six months, the weights of aboveground parts, belowground parts and total plant parts of sod materials (total plant species) pulled per animal per day were respectively 131, 91 and 223 g DM in paddock 2, and 127, 66 and 194 g DM in paddock 3 (Fig. 6). These values resulted in the estimation that the weights of sod materials pulled per animal over the grazing season were 23.5 kg DM for the aboveground parts, 14.5 kg DM for the belowground parts and 38.0 kg DM for the total plant parts.

3) Daily percentage losses to the plant biomass

The weight of aboveground materials (total plant species) pulled per m² per day ranged between 0.06 and 1.40 g DM (Fig. 5). The aboveground biomass ranged between 193.4 and 567.3
g DM/m² (Table 1). From these values, the percentage losses of the aboveground parts to their biomass were estimated at 0.020–0.297% per day. In this connection, as already discussed, when a linear regression was employed for the aboveground parts of bahiagrass, the percentage losses were shown to be 0.302 and 0.119% per day in paddocks 2 and 3, respectively (Fig. 7 and Eqns 3 and 4). Thus the percentage of the aboveground weight pulled per day was not more than 0.302% of the aboveground biomass.

The weight of belowground materials (total plant species) pulled per m² per day ranged between 0.02 and 0.88 g DM (Fig. 5). According to Hirata et al.⁴, the belowground biomass of a bahiagrass pasture grazed by dairy heifers was about 1100 g DM/m² during the grazing season. From these values, the percentage losses of the belowground parts to their biomass were considered to be as small as 0.002–0.080% per day.

In this study, the animals grazed a bahiagrass pasture on sandy soil at a high stocking rate (17 animals in 1.34 ha). Such a stocking rate and a soil condition were considered to stimulate the sod-pulling, in spite of the daytime grazing and the supplementary feeding. In fact, the sod-pulling was often observed during the grazing season (Photos 1 and 2), and the number of the sod-pulled materials lying on the sward surface increased as the grazing season proceeded (Photos 3 and 4). However, as indicated in the above estimation of the percentage losses to the net primary production and to the plant biomass, the plant losses due to the sod-pulling were considered to be still small. This conclusion accords with those by Tallowin⁹ and Tallowin et al.⁴⁰ in perennial ryegrass swards grazed by cattle. Such a small impact of the pulling on the pasture plants is a clear contrast to the impact of defecation⁹.

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肉牛が放牧される砂質土壌上のパヒアグラス（Paspalum notatum Flügge）草地における植生の引き抜き

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要　約

肉牛が放牧される砂質土壌上のパヒアグラス草地における植生の引き抜きについて、面積の異なる2つのパドックで5～10月の放牧期間中に調査した（表1）。引き抜きは放牧期間中にしばしば観察された（写真1～4）。1日・1m²当りの引き抜き個数は0.54～9.23個であり（図1）、1日・1頭当りの引き抜き個数は181～1961個であった（図2）。パヒアグラスの割合は13.3～96.8％となった（表2）。

引き抜き1個当りの重量は、パヒアグラスで159～493mgDM、他草種で53～248mgDMの範囲にあった（図3）。パヒアグラスの引き抜き1個当りの重量に占める各部位の割合は、地上部で52.9～68.1％、はふく茎で27.6～40.8％、根で3.0～6.5％であった。また、他草種の引き抜き1個当りの重量においては地上部が63.6～91.7％を占めた。パヒアグラスの引き抜き1個当りの各部位の重量の間には正の直線関係が成立った（図4および式1と2）。

1日・1m²当りの引き抜き重量は、地上部で0.06～1.40gDM、地下部で0.02～0.88gDM、全植物体で0.08～2.29gDMであった（図5）。1日・1頭当りの引き抜き重量は、地上部で22～298gDM、地下部で4～188gDM、全植物体で29～485gDMであった（図6）。パヒアグラスの割合は、地上部で11.9～99.2％、地下部で33.3～99.4％、全植物体で15.3～99.2％となった（表4）。パヒアグラスにおける1日・1m²当りの地上部引き抜き重量は、1m²当りの地際からの草量と正の直線関係にあり（図7）、直線の勾配は面積の小さなパドックで大きくかつた（式3と4）。

以上のようなデータに基づき、引き抜きに影響を与えられる要因について考察し、引き抜きによる植物体の損失について評価した。

キーワード：砂質土壌、パヒアグラス草地、引き抜き。