Emergence and Growth of Temperate Forage Plants Surface-seeded on Litter Layers and Cattle Dung on the Forest Floor

Emergence and Growth of Temperate Forage Plants Surface-seeded on Litter Layers and Cattle Dung on the Forest Floor

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Key words: cut-over area, germination strategy, grazing cattle dung, litter layer, moisture content, safe site, seedling establishment, surface-sowing

Contents

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Ⅰ Introduction

Recently in Japan, to prevent desolation of unused or underused agricultural lands and use them for the livestock industry, they have been increasingly used as cattle pasture, providing significant public and social-economic benefits[22]. However, a problem that has been faced is the plants on such land, which are primarily native plants and shrubs and have poor regrowth rate after being grazed, while those that are not eaten by cattle are overgrowing[21]. In particular, in areas that have been used continuously for grazing, a significant problem is the gradual decline in mass of edible plants, along with the decreasing number of wild plant species. The most pressing issue for the long-term use of these underused agricultural lands as pasture is the stable supply of edible plants for livestock. Therefore, introducing perennial forage plants, which have a better regrowth rate and better nutritional properties than wild plants, into these areas is thought to be an effective means to increase the carrying capacity and prolong the period these pasturelands can be used.

A thick layer of leaves and organic debris often covers the surface of agricultural and forestry lands that have been abandoned for a long time[18,19]. This litter layer prevents the germination of plants with small seeds, such as forage plants[10], and inhibits the seedlings' roots from reaching the soil surface[19,20,26]. Therefore, dealing with this litter layer has become a significant technical issue in the establishment and renovation of grasslands[9,14]. Most physical methods used to modify this litter layer during grassland establishment are not technically practical under the unfavorable conditions of former agricultural land in mountainous regions, because of the topography, the amount of labor required, and the financial burden[13,15,27].

However, an intriguing phenomenon is often noted in pastures: many seedlings of forage plants and weeds emerge from cattle dung[2,6,7,17]. Yet no studies have investigated the use of cattle dung as germination sites and nursery beds for surface-sown forage plants or the germination and survival of forage plants on cattle dung pats in which those seeds are mixed.

In this study, I attempted to develop a forage plant introduction method using dung from grazing cattle under the condition with accumulated litter layers. I examined the difference in germination and growth of three temperate forage plants surface-sown on a litter layer and on cattle dung scattered on the floors of a secondary forest and a deforested area used as grazing land, which are common underused lands in Japan. In addition, I investigated whether cattle dung acted as a safe site[5,11] for forage plants that were surface-sown.

Ⅱ Materials and Methods

1 Study site

The study site was situated on a grazing pasture at the Ohda Campus of the National Agricultural Research Center for the Western Region (132°30′4″E, 35°10′20″N; average annual temperature and precipitation 15.4 ℃ and 1759 mm) in Ohda city, Shimane Prefecture, Japan. The pasture (4.9 ha) was grazed by a breeding herd of Japanese Black cattle in rotation with other pastures and had been extensively managed without fertilization since 1994. In addition, because the pasture was infrequently used (i.e., low grazing pressure) until 2003, there were few introduced forage plants except a little tall fescue (*Festuca arundinacea* Schreb.) and redtop (*Agrostis alba* L.) in the open area and were a significant number of shrubs and wild plants, such as *Rhus javanica* L., *Rosa multiflora* Thunb., *Miscanthus sinensis* Anderss., and *Pteridium aquilinum* Kuhn. The pasture consisted of two paddocks, one of which was used as the test paddock (2.5 ha, elevation of 110-130 m) and had a secondary deciduous broad-leaved forest with a litter layer.

2 Grazing management

In 2004 and 2005, six Japanese Black cattle steers were introduced to the test paddock and were rotated to the other paddock every 2 weeks. The steers were grazed from 1 June to 21 October 2004 and from 26 May to 19 October 2005. The average weight of the steers at the start of grazing was 414 kg/head in 2004 and 374 kg/head in 2005.

3 Seeding area

The site used for seeding in the test paddock was composed of two areas: (1) a rectangular area of 7 ares in the center of a secondary forest of 60 ares primarily composed of deciduous trees, including 22-to 26-year-old *Quercus serrata* Thunb., 24-to 29-year-old *Platycarya strobilacea* Sieb. et Zucc., and *Styrax japonica* Sieb. et Zucc. (hereafter referred to as the "secondary forest area"); and (2) a felled area of 28 ares in which 19 ares was clear-cut and 9 ares was thinned, both of which were cut in March 2005 (hereafter referred to as the "felled area"). The stand density of trees with a breast-height diameter greater than 15 cm was 10.6 trees/are in the secondary forest area and 5.1 trees/are in the thinned area. Both seeding areas were covered with a litter layer having a dry matter weight (measured as the average value of 15 locations) of 1021.3 ± 388.2 g/m^2 (SD). Randomly distributed dung pats were deposited by grazing cattle from June to September on the litter layer in both seeding areas. Forage plant species introduced in the past (i.e., *F. arundinacea* and *A. alba*) were not distributed in these areas. The relative photosynthetic photon flux densities on the surface of the litter layer in the cut-over, thinned, and secondary forest areas are shown in Figure 1.

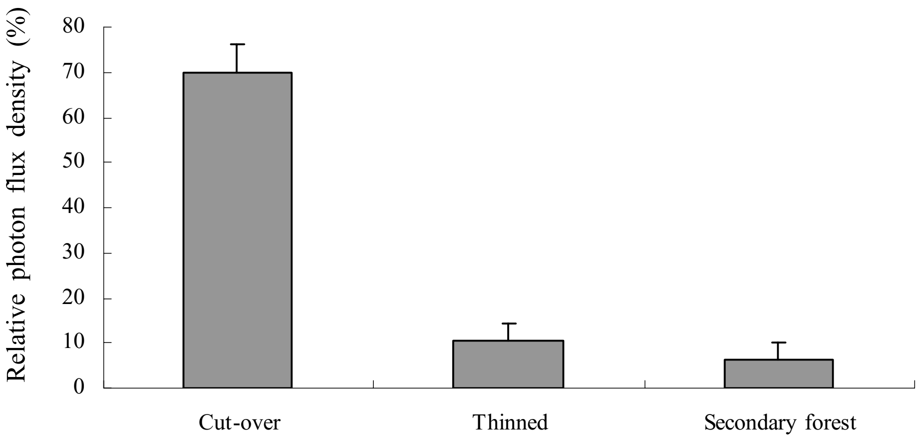

Figure 1 Relative photosynthetic photon flux density (%) on the surface of the litter layer in the cut-over area, thinned area, and secondary forest area.
Measurements were conducted around 14 : 00 on 20 June 2006 (n = 15 in each area).

4 Seeding method

The three forage plant species tested were tall fescue (*F. arundinacea* cv. Fawn, hereafter "Tf"), white clover (*Trifolium repens* L. cv. Huia, hereafter "Wc"), and orchardgrass (*Dactylis glomerata* L. cv. Akimidori, hereafter "Og"). The germination rates of these three plant species were over 80% in a preliminary germination test. In the felled area, where the canopy density was low, Tf and Wc were mixed-seeded on the surface on 21 September 2005. The seeding rates for each plant species were 4 and 1 g/m^2, respectively. In the secondary forest area, where the canopy density was high, the shade-tolerant Og[12)] was seeded on 6 October 2005 at 4 g/m^2. Fertilizer was not applied. The daily average air temperature and precipitation in Ohda city from 21 September to 31 October 2005, which influenced the emergence and growth of the forage plants, are shown in Figure 2.

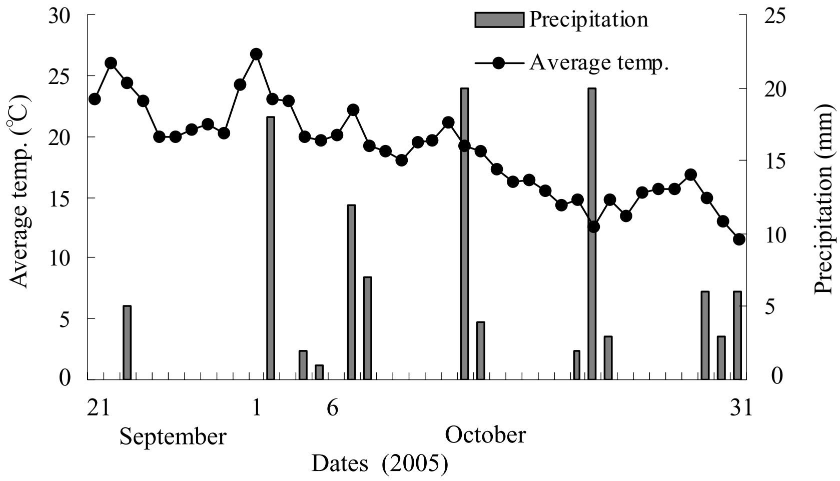

Figure 2 Daily average air temperature and precipitation in Ohda city (elevation 15 m) from 21 September to 31 October 2005.
The seeding date was 21 September for tall fescue and white clover and 6 October for orchardgrass.

5 Survey method

1) Survey locations

Cattle dung locations were randomly selected in both areas, excluding the peripheries. A 10-cm × 10-cm square surrounding the center of the selected dung pat and a square of the same size 1 m due south of the dung pat were used as the survey locations. Most of the latter locations were covered by a litter layer and were assumed to have the same topographic conditions and light environment as the corresponding dung pat. Data were collected from 40 of these paired survey locations in the felled area and 20 in the secondary forest area.

2) Survey period

Tf, Og, and Wc seedlings were counted from 17 to 18 November 2005. Numbers of individuals were counted again and plant lengths were measured from 26 to 29 May 2006, just before the cattle were let into the paddock.

6 Statistical analysis

All statistical analyses were performed using SPSS 13.0J software. Student's *t*-test was used to determine significant differences in mean seedling numbers per 100-cm^2 area and in plant length between the dung pat and litter layer locations.

Ⅲ Results

1 Number of emerged seedlings and individual tall fescue and orchardgrass plants in the following year

The numbers of seedlings emerged in November and individual plants in the following year were greater in the cattle dung locations than in the litter layer locations for Tf in the felled area and Og in the secondary forest area (Figs. 3 and 4). The average number of Tf seedlings per 100-cm^2 cattle dung location was 2.3 times that in the litter layer locations (P < 0.01), and the average number of Tf plants in the cattle dung locations in the following year was 1.8 times that in the litter layer locations (P < 0.05). The average number of Og seedlings per 100-cm^2 cattle dung location was 2.8 times that in the litter layer locations (P < 0.001), and the average number of Og plants in the following year was 1.4 times that in the litter layer locations. In winter, 4 of the 20 test cattle dung pats in the secondary forest area were scattered by wild boars. Therefore, when the survey was conducted in May, the number of Og plants on these 4 dung sites was markedly decreased.

2 Number of emerged seedlings and individual white clover plants in the following year

In the felled area, the number of Wc seedlings emerged in November and the number of individual plants in the following year tended to be greater in the cattle dung locations than in the litter layer locations, although the differences were not statistically significant (Fig. 5). The average number of Wc seedlings per 100-cm^2 cattle dung location was 1.7 times that in the litter layer locations. The number of individual plants in the following year was 1.1 times that in the litter layer locations.

3 Plant length of tall fescue, orchardgrass, and white clover in the following year

Plant lengths of Tf and Og were longer in the cattle dung locations than in the litter layer locations (Fig. 6). The average plant length of Tf in the cattle dung locations was 1.6 times that in the litter layer locations (P < 0.05). The average plant length of Og in the cattle dung locations was 2.9 times that in the litter layer locations (P < 0.01).

Plant length of Wc was longer in the cattle dung locations than that in the litter layer locations (Fig. 6).

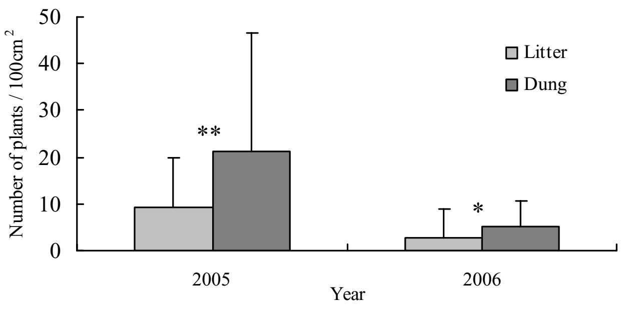

Figure 3 Number of tall fescue seedlings on the litter layer and cattle dung locations in a felled area in November 2005 and May 2006.
Seeds were sown on 21 September 2005 at 4 g/m^2.
Measurements were conducted on 17-18 November 2005, and 26-29 May 2006.
Vertical lines indicate 1 standard deviation.
* P < 0.05, ** P < 0.01 (n = 40).

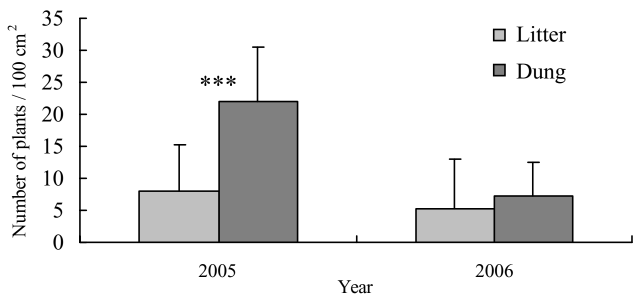

Figure 4 Number of orchardgrass seedlings on the litter layer and cattle dung locations in a secondary deciduous forest in November 2005 and May 2006.
Seeds were sown on 6 October 2005 at 4 g/m^2.
Measurements were conducted on 17-18 November 2005, and 26-29 May 2006.
Vertical lines indicate 1 standard deviation.
*** P < 0.001 (n = 20).

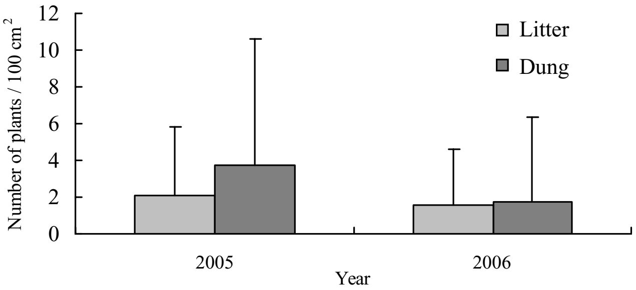

Figure 5 Number of white clover seedlings on the litter layer and cattle dung locations in a felled area in November 2005 and May 2006.
Seeds were sown on 21 September 2005 at 1 g/m^2.
Measurements were conducted on 17-18 November 2005, and 26-29 May 2006.
Vertical lines indicate 1 standard deviation (n = 40).

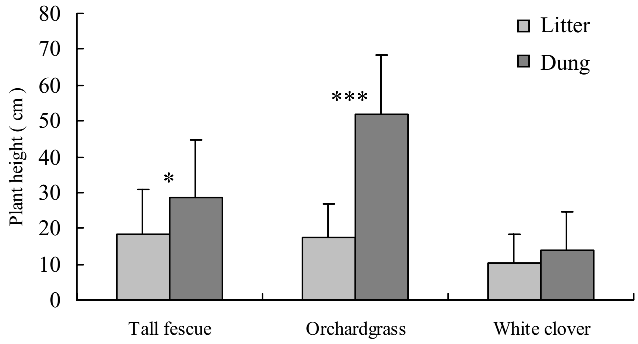

Figure 6 Plant length of tall fescue, orchardgrass, and white clover on the litter layer and cattle dung locations in May 2006.
Tall fescue and white clover were seeded in a felled area on 21 September 2005 at 4 and 1 g/m^2, respectively, and orchardgrass in a secondary deciduous forest on 6 October 2005 at 4 g/m^2.
Measurements were conducted on 26-29 May 2006.
Vertical lines indicate 1 standard deviation.
* $P < 0.05$, *** $P < 0.001$ (n = 40 for tall fescue and white clover, n = 20 for orchardgrass).

The average plant length of Wc in the cattle dung locations was 1.3 times that in the litter layer locations, but there was no significant difference.

Ⅳ Discussion

1 Difference between seedling growth on cattle dung and that on the litter layer

The temperate forage grasses Tf and Og emerged better in the cattle dung locations than in the litter layer locations on the floor of the secondary forest and in felled areas used as cattle pasture (Figs. 3 and 4). In addition, the growth of each seedling was also superior in cattle dung locations (Fig. 6). Thus, the difference in medium conditions between the cattle dung and litter layer locations influenced the germination and subsequent growth of Tf and Og. Thus, cattle dung is a suitable environment for germination and growth of these forage grasses. Although Wc showed a greater number of seedlings and plants the following year and greater plant length at the cattle dung locations than in the litter layer locations, a clearly significant difference between the locations was not found (Figs. 5 and 6). These findings indicate that on a forest floor covered by a litter layer, cattle dung functions as a safe site for surface-seeded temperate forage grasses, but not to the legume Wc as a suitable germination and nursery bed.

2 Factors contributing to the difference in emergence and growth between cattle dung and litter layer locations

Several factors likely contributed to the larger number of forage grass seedlings in the cattle dung location. Cattle dung maintains a higher moisture content for longer than the litter layer[7,24] by absorbing water from sources such as precipitation, thereby promoting the germination of the seeds within. As a result, cattle dung fosters the emergence and growth of forage grasses, resulting in a high survival rate of the seedlings[7]. In addition, large cattle dung masses on top of the litter layer compress the litter, reducing the air-filled spaces and leading to greater cohesion between the surface soil, litter layer, and cattle dung, and so promoting moisture flow from the surface soil to the dung. Therefore, water absorption and germination of seeds on top of or within the dung is promoted. Finally, the nutrients within the cattle dung enhance plant growth[1,23,25].

By contrast, the litter layer surface is generally made up of large leaves and branches that are not well decomposed, and the surface is more prone to dry conditions than the deeper layers. Therefore, seeds that fall on the top of the litter layer during surface-seeding face poor moisture conditions[16]. If a seed does begin to germinate, it is difficult for the root to reach the soil surface. The deeper layers of the litter layer have a much higher moisture content[16], and seeds that reach these deeper layers have an environment conducive to germination. However, it is difficult for the germinated seedlings to penetrate the thick litter layer and reach the surface. Consequently, the germination rate and emergence rate of seeds that fall on the litter layer during surface-seeding appear to be low[19,20,26].

The germination characteristics of Wc may have contributed to the lack of differences in germination and growth between the cattle dung and litter layer locations. In general, Wc germinates better than forage grasses. If sufficient moisture is maintained, Wc seeds can absorb water immediately and germinate quickly[3,8]. Therefore, even those seeds on the litter layer would have been able to absorb water from the precipitation (Fig. 2) and germinate quickly, meaning that the moisture-retaining characteristics of cattle dung pats would not have provided a significant benefit to Wc so much as the grasses.

3 Potential problems in the introduction of forage plants using cattle dung

Most of the abandoned agricultural lands or cut-over areas planned for the introduction of forage plants are in mountainous regions. These sites are covered with a thick litter layer that is not easily managed on account of the unfavorable topography and the amount of labor required. The findings of this study indicate that an effective method for the introduction of forage grasses into abandoned lands with litter layers would be to seed on dung from grazing cattle. The success or failure of introducing forage plants in this way depends on the density of dung pats over a site. Where cattle dung density is low, repeated interannual seeding would likely be important for the gradual expansion of the area covered by forage plants. Further study is required to determine which forage plant species would respond well to the random-point distribution of cattle dung. Short grasses with creeping stems would be promising candidates because they gradually expand their growth area via their creeping stems, which begin from source points[4]. Thus, cattle dung has the potential to be a significant component of an environmental conservation technique for introducing forage plants into areas covered by a litter layer without disturbing existing soil and vegetation.

To further develop this simple technique for introducing forage plants by seeding on cattle dung, the following preliminary work must be completed:

(1) Select promising forage plant species appropriate for seeding on cattle dung.
(2) Using these species, clarify the influence of various characteristics of cattle dung (e.g., size, thickness, moisture content, number of days from the elimination date) on the germination and growth behavior on dung.
(3) Identify the factors that are responsible for differences in the germination and growth of forage grasses and Wc on cattle dung.
(4) Formulate the appropriate seeding rate per unit of cattle dung surface area for each forage plant.

(5) Clarify the influence of cattle dung pat density at the planned site on the rate at which forage plants cover the site.
(6) Identify the water retention characteristics and mechanism of cattle dung.

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Summary

The objective of this study was to evaluate whether dung of grazing cattle could serve as safe sites for forage plants seeded on the surface litter layer of a forest floor. Three temperate forage plants (*Festuca arundinacea* Schreb., *Trifolium repens* L., and *Dactylis glomerata* L.) were surface-seeded in early autumn on litter layers or cattle dung on the floors of a deciduous broad-leaved secondary forest and a felled area in a grazing land. In late autumn, the number of seedlings that emerged on cattle dung was compared with that on the litter layer. The following May, the number and length of individuals that survived were measured. More individuals emerged and survived on cattle dung than on litter. The average number of seedlings of *F. arundinacea, D. glomerata*, and *T. repens* per 100 cm^2 of the cattle dung sites were 21.2, 22.0, and 3.7, which were 2.3, 2.8, and 1.7 times those on the corresponding litter layer sites. The following May, the average number of plants of the same species per 100 cm^2 of the cattle dung sites were 5.0, 7.2, and 1.7, which were 1.8, 1.4, and 1.1 times those on the litter layer sites. The plant lengths of each on the cattle dung sites were 28.4, 51.6, and 13.8 cm, which were 1.6, 2.9, and 1.3 times those on the litter layer sites. All characteristics of the forage grass species, except the plant number of *D. glomerata* in the following May, were significantly different between the two sites, but *T. repens* showed no significant differences. These findings indicate that cattle dung could function as a safe site for surface-seeded forage grasses, providing an environment suitable for their emergence and growth on secondary and clearcut forest floors with litter layers.

林床に分布する落葉層と牛ふんの上に表面播種された牧草の出芽と生育

福田栄紀*

摘　　要

放牧地内の落葉層が堆積する二次林林床において，放牧牛の排糞が，表面播種された寒地型牧草３種のセイフサイトとなりうるかどうかを検証した．５月から10月まで牛群が放牧される草地内の落葉広葉樹二次林において，３月に伐採し，一部間伐区域を含む伐採跡地の林床に９月下旬トールフェスクとシロクローバを，伐採しなかった二次林の林床に10月上旬オーチャードグラスを表面播種した．播種後，両林床において，牛ふん上とその南１ｍの落葉層上に各々10㎝四方の定置調査区を設け，11月中旬に出芽数を，翌年５月末に生残個体数と草高を測定し，それらを牛ふん上と落葉層上とで比較した．両イネ科草種とも，出芽数，翌年の個体数と草高の平均値は，牛ふん上の方が落葉層上より高かった．即ち，牛ふん上のほうが出芽数は約2.5倍，生残個体数は約1.5倍，草高は1.6～2.9倍，落葉層上より高い値を示した．イネ科草種に関するこれら特性値の平均値の差は，オーチャードグラスの生残個体数を除き，いずれも有意であった．一方，シロクローバについても各特性値は牛ふん上のほうが落葉層上より高かったが，いずれも有意な差ではなかった．落葉層で被われた二次林や伐採跡地の林床において，牛ふんは表面播種された寒地型イネ科牧草にとって出芽，生育するのに好適な環境と考えられ，セイフサイトとして機能すると結論づけられた．

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