バヒアグラス(Paspalum notatum Flugge)放牧草地におけるエネルギーと物質の流れにおよぼす家畜の排糞の影響(4)

誌名	日本草地学会誌
ISSN	04475933
著者	平田, 昌彦 杉本, 安寛 上野, 昌彦
巻/号	35巻2号
掲載ページ	p. 93-99
発行年月	1989年7月

J. Japan. Grassl. Sci., 35 (2) : 93-99 (1989)

Effects of Cattle Dung Deposition on Energy and Matter Flows in Bahiagrass (*Paspalum notatum* Flügge) Pasture

IV. Energy flow through the producer

Masahiko HIRATA, Yasuhiro SUGIMOTO and Masahiko UENO

Synopsis

HIRATA, M., Y. SUGIMOTO and M. UENO (1989) : Effects of cattle dung deposition on energy and matter flows in bahiagrass (*Paspalum notatum* Flügge) pasture. IV. Energy flow through the producer. *J. Japan. Grassl. Sci.*, **35**, 93-99.

Dung pats were artificially deposited in a bahiagrass pasture rotationally grazed by Holstein heifers in June (JD sward) and in August (AD sward). The dung-deposited and surrounding places of JD and AD swards gave different energy flow through the producer from the dung-free place (ND sward) as follows. (1) The dung-deposited places of both JD and AD swards took larger litter production (LP) than ND sward in the first periods after the dung deposition, which indicated some plant killing by the dung pat cover. However, bahiagrass was found to be considerably tolerant to the dung pat cover since the net primary production (NPP) in those places was not reduced. (2) The dung-deposited and surrounding places of AD sward in the first period after the dung deposition showed a tendency of higher NPP than ND sward mainly because of the higher storage in plant (ST). This was considered to be primarily caused by the increment in the leaf area index rather than the increment in the leaf nitrogen percentage. (3) Then, in the next year over winter, both JD and AD swards tended to be lower than ND sward in NPP chiefly because of the lower ST and LP. In case of AD sward, the reduction in photosynthesis due to the shading by large standing dead and the rise in respiration due to the large non-photosynthetic organs are regarded as the main reasons. However, in case of JD sward, no reason was found for the smaller NPP.

Key words : Bahiagrass pasture, Cattle dung, Energy flow, Net primary production, Producer.

Introduction

Measurements of energy flow through the producer have been made in several grazed pastures[1,4,5,7,16]. Energy flow in these studies represents the average for the whole pasture. However, grazed pasture is generally considered to be uneven in its various characteristics of soil-plant-animal system[6,8,15], some of which have been investigated in previous papers[9-12]. We in this paper compare the energy flow through the producer in the cattle dung-deposited and surrounding places with that in the dung-free place.

Faculty of Agriculture, Miyazaki University, Miyazaki, 889-21 Japan

Materials and Methods

Bahiagrass (*Paspalum notatum* Flügge) pasture at the Miyazaki Prefectural Animal Industry Experiment Station was grazed by Holstein heifers under a rotational system. Plant and litter samples with three repetitions were taken in the three kinds of swards ; ND (no dung was deposited), JD (a dung pat was artificially deposited on 1 June 1984) and AD (a dung pat was artificially deposited on 28 August 1984) swards. Samples in JD and AD swards were taken in the concentric-like places of three different distances from the dung (0–10 cm, 10–30 cm and 30–50 cm). Here, the 0–10 cm place practically corresponded to the dung-deposited place, and the 10–30 cm and 30–50 cm places did to the surrounding places. Detailed description of the experimental conditions and sampling method was already published[9,10)].

Energy flow through the producer was estimated for the five seasonal periods in Table 1 using the same calculation as before[7)]. Heat of combustion of the plant and litter samples was measured with an oxygen bomb calorimeter. Rate of litter disappearance was estimated by the litter bag method. Litter bags were placed on 1 June in ND and JD swards, and on 23 August in AD sward. In case of JD and AD swards, litter bags were placed in the three places of different distances from the dung, and the litter bags in the 0–10 cm place were beneath the dung pats when the dung pats were deposited. Collection of the bags was done on the last day of each seasonal period (Table 1) with three repetitions.

Results

Seasonal changes in the daily energy flow in ND, JD and AD swards are shown in Table 2. The three places of JD sward took similar net primary production (NPP) to ND sward in period 1, though the grazed herbage (GH) in the three places and the litter production (LP) in the 0–10 cm place were greater than those in ND sward. The JD sward also kept similar NPP to ND sward in periods 2 and 3 in spite of the tendency of higher LP in period 3. Then in period 4 the three places of JD sward were lower than ND sward in NPP mainly owing to the lower storage in plant (ST) and LP. The three places of AD sward in period 2 tended to give higher NPP than ND sward chiefly because of the higher ST. In this period, compared with

Table 1. Outline of the seasonal periods of the experiment.

Period No.	Date (year/month/day)		Season	Duration (day)	TSSR (MJ/m² /day)[d)]	Air temperature(℃)[e)]		
	Start	End				Mean	Min.	Max.
1[a)]	1984/ 6/ 1	1984/ 8/22	summer	83	18.6	22.1	17.0	29.8
2[b)]	1984/ 8/23	1984/11/13	autumn	83	14.5	17.2	11.2	24.7
3[c)]	1984/11/14	1985/ 4/12	winter	150	10.7	6.8	1.4	12.3
4	1985/ 4/13	1985/ 5/30	spring	48	18.1	15.7	9.6	23.4
5	1985/ 5/31	1985/ 8/21	summer	83	17.2	21.3	16.4	28.9

a) First period after the dung deposition for JD sward.
b) First period after the dung deposition for AD sward.
c) No grazing was held.
d) Mean of daily TSSR (total short-wave solar radiation).
e) Mean of daily mean, daily minimum or daily maximum air temperature.

Table 2. Daily energy flow in ND, JD and AD swards in different seasonal periods.

Period No.[a]	Energy flow (kJ/m^2/day)[b]	Sward and place[c]						
		ND	JD			AD		
			0–10	10–30	30–50	0–10	10–30	30–50
1	TSSR	18605	18605	18605	18605	—	—	—
	NPP	315	383	306	320	—	—	—
	GH	97	131^{+}	130^{+}	127^{+}	—	—	—
	LP	98	162^{***}	81	73	—	—	—
	ST	120	89	95	120	—	—	—
2	TSSR	14496	14496	14496	14496	14496	14496	14496
	NPP	74	98	69	83	185^{+}	122	184^{+}
	GH	77	81	69	95	17^{**}	48^{+}	88
	LP	28	48	16	34	64^{*}	14	49
	ST	−32	−30	−16	−46	105^{**}	60^{+}	47
3	TSSR	10671	10671	10671	10671	10671	10671	10671
	NPP	−15	47	58	55	25	79	−2
	GH	—	—	—	—	—	—	—
	LP	7	24	52^{**}	36^{+}	62^{**}	65^{***}	17
	ST	−23	23	6	19	−36	14	−19
4	TSSR	18075	18075	18075	18075	18075	18075	18075
	NPP	176	-3^{**}	9^{**}	-42^{***}	98	0^{**}	26^{*}
	GH	136	134	109	103^{+}	129	129	107^{+}
	LP	50	25	21^{+}	11^{*}	41	42	-1^{**}
	ST	−10	-162^{**}	-121^{*}	-155^{**}	−72	-171^{**}	−79
5	TSSR	17169	—	—	—	17169	17169	17169
	NPP	227	—	—	—	105^{*}	211	208
	GH	119	—	—	—	156^{*}	153^{*}	153^{+}
	LP	80	—	—	—	0^{***}	57	87
	ST	28	—	—	—	−51	0	−31

a) For seasonal periods, see Table 1.
b) TSSR (total short-wave solar radiation), NPP (net primary production), GH (grazed herbage), LP (litter production), ST (storage in plant).
c) For sward and place, see the text.
d) Values in JD and AD swards with $^{+}$, *, ** and *** differ significantly from those in ND sward at 10, 5, 1 and 0.1% levels, respectively.

ND sward, the 0–10 cm place took low GH and high LP, and the 10–30 cm place took low GH. Then AD sward did not differ from ND sward in NPP in period 3 despite of the tendency of higher LP. Thereafter, in period 4, the three places of AD sward tended to take smaller NPP than ND sward mainly because of the smaller ST or of the smaller LP and ST. The 0–10 cm place of AD sward, further in period 5, maintained lower NPP than ND sward with lower LP and ST.

Annual energy flow in ND, JD and AD swards is presented in Table 3. Annual NPP, GH, LP and ST in the three places of both JD and AD swards were not different from those in the corresponding ND sward with three exceptions : The 0–10 cm place in JD sward and the

Table 3. Annual energy flow in ND, JD and AD swards.

Period Nos.	Energy flow (MJ/m^2/year)[a]	Sward and place[c]			
		ND[b]	JD		
			0–10	10–30	30–50
1～4	TSSR	5215.6	5215.6	5215.6	5215.6
	NPP	38.4	46.8	40.3	39.7
	GH	21.0	24.0	21.8	23.4
	LP	13.9	22.3**	16.9	14.8
	ST	3.5	0.6	1.6	1.6

Period Nos.	Energy flow (MJ/m^2/year)[a]	Sward and place[c]			
		ND[b]	AD		
			0–10	10–30	30–50
2～5	TSSR	5096.4	5096.4	5096.4	5096.4
	NPP	31.1	32.6	39.4	33.5
	GH	22.8	20.5	22.9	25.1
	LP	12.5	16.5*	17.7**	13.8
	ST	−4.2	−4.5	−1.2	−5.3

a) TSSR (total short-wave solar radiation), NPP (net primary production), GH (grazed herbage), LP (litter production), ST (storage in plant).

b) Values in ND sward are shown on two annual bases because of the different annual periods between JD and AD swards.

c) For sward and place, see the text.

d) Values in JD and AD swards with * and ** differ significantly from those in ND sward at 5 and 1% levels, respectively.

0–10 cm and 10–30 cm places in AD sward showed larger LP than ND sward.

Discussion

MacDiarmid and Watkin[14] examined the plant growth beneath the dung pat in a sward dominated by temperate grasses and clover. When the dung pat remained on the sward for more than 15 days, most of the aboveground plant parts decayed, and most of the grass tillers and clover stolons died. Such a dung-induced killing of the underlying plant has also been reported by some other researchers. According to Castle and MacDaid[3], the dung-deposited place in a perennial ryegrass-clover pasture remained bare for more than six months after the complete dung disappearance. Weeda[17], in a mixed pasture of ryegrass, orchardgrass and clovers, found that the most plants underneath the dung pat were killed and the plant cover in that place was often sparse for 6–12 months. These observations infer that the cattle dung reduces the NPP in the dung-deposited place in temperate pastures with the increased LP and with the decreased GH and ST. In fact the 0–10 cm places of both JD and AD swards gave larger LP than ND sward in the first periods after the dung deposition (Table 2), which indicated some occurrence of plant killing by dung pat cover. However, the 0–10 cm places in those periods were never lower than ND sward in NPP. Thus bahiagrass pasture showed a remarkable tolerance to the cover by dung pat. This non-depressed NPP is noticeable particularly in AD sward where 83% of the dung still remained in 16 days after the deposition[9]. Authors observed that bahiagrass tillers elongated through the dung pat though their number decreased after the dung deposition. Such a vigorous regrowth of bahiagrass is considered to be primarily due to its stout stolons[2].

In period 1 JD sward was larger than ND sward in GH, though similar in NPP. This high GH in JD sward is not an unexpected fact when the changes in herbage consumption in JD sward with the rapid dung disappearance are taken into consideration. For the detailed consideration of this process, see the previous papers[9,11,12].

Then, in period 2, AD sward tended to give larger NPP than ND sward with the smaller GH and larger ST or with the larger ST. This is also an expected fact[11], since AD sward in period 2 gave heavier leaf, stem and stolon dry weights than ND sward[10]. Two factors are regarded as the major possible reasons for high NPP ; (1) the increment in leaf area index (LAI) caused by the dung-induced reduction in herbage consumption and (2) the increment in plant mineral contents caused by the dung-derived nutrients especially nitrogen (N) in leaf (lamina). As for the LAI, only AD sward in period 2 gave greater LAI than ND sward primarily because of the great reduction in herbage consumption with slow dung disappearance[9,11]. The values of LAI on this occasion were 1.3-2.5 higher than that in ND sward, and were considered to be high enough to raise the canopy photosynthesis of bahiagrass[11]. In fact the NPP in period 2 was positively correlated with LAI ($P<0.10$). As for the dung-derived N, authors measured the leaf N percentage (LN%) of ND, JD and AD swards (unpublished data). Evident dung-induced increment in LN% was not usually found except the 0-10 cm and 10-30 cm places immediately after the dung deposition (14-28 days). In accordance with this, the NPP in period 2 was not correlated with LN% ($P>0.10$). HAKAMATA[6], who compared the yield and N percentage of herbage in the dung-applied plot with those in the dung-free one during the four years after the application, also rarely obtained clear dung effect. KIMURA and KURASHIMA[13] using a N-tracer method observed that the recovery of dung-N in cut herbage was as low as 7-10% for the first seven months after the dung application. These observations are regarded to agree with the present result. Some researchers, on the other hand, obtained the results which suggest the stimulation of NPP due to the dung-derived nutrients[15].

In period 3 both JD and AD swards gave similar NPP to ND sward. This is certainly because the period corresponds to the winter where the growth of bahiagrass is greatly depressed (Table 1).

Further, the NPP in both JD and AD swards was smaller than ND sward in period 4 chiefly because of the lower ST or of the lower LP and ST. Moreover, the 0-10 cm place of AD sward still showed lower NPP in period 5 than ND sward with lower LP and ST. In case of AD sward, as already supposed[11], reduced canopy photosynthesis due to the shading by large standing dead and raised respiration due to the large non-photosynthetic organs are regarded as the main reasons for the small NPP. The reduced ST in AD sward supports this supposition. However, the reason why JD sward took lower NPP than ND sward with lower ST and LP is unexplainable, because JD sward in period 4 was similar to ND sward in both plant dry weight and canopy structure[10,11].

Last, both JD and AD swards were almost similar to ND sward in NPP, GH, LP and ST on the annual bases (Table 3). However, this result applies only to the case where no additional dung pat is deposited in JD and AD swards within a year. Actual pasture is repeatedly grazed by the cattle, and dispersion of dung pats in a pasture is uneven[6,8,15]. Besides, the previous[9-12] and present papers infer that the cattle dung effect on the energy flow through the producer is different according to the rate of dung disappearance. Therefore, in order to clear how the cattle dung influences the energy flow in the actual pasture, further study is needed to combine the present results with other cattle dung-related processes such as the dispersion and disappearance of dung pats, *etc.*

Acknowledgement

The cooperation by the staff of the Miyazaki Prefectural Animal Industry Experiment Station is gratefully acknowledged.

References

1) Akiyama, T., S. Takahashi, M. Shiyomi and T. Okubo (1984) *Oikos* **42**, 129-137.
2) Beaty, E.R., R.H. Brown and J.B. Morris (1970) *Proc. XI Int. Grassl. Congr.* 538-542.
3) Castle, M.E. and E. MacDaid (1972) *J. Br. Grassld Soc.* **27**, 133-137.
4) Coupland, R.T. and G.M. Van Dyne (1979) *In* Grassland Ecosystems of the World (ed. R.T. Coupland). Cambridge Univ. Press, Cambridge. pp. 97-106.
5) Fukuyama, M., M. Shimamura, M. Ushiyama, M. Oikawa and K. Tomii (1983) *J. Japan. Grassl. Sci.* **28**, 383-394. *
6) Hakamata, T. (1986) *Report Hokkaido Pref. Agric. Exp. Stn* **55**, 1-88. *
7) Hirata, M., Y. Sugimoto and M. Ueno (1986) *J. Japan. Grassl. Sci.* **31**, 387-396.
8) Hirata, M., Y. Sugimoto and M. Ueno (1987) *J. Japan. Grassl. Sci.* **33**, 128-139.
9) Hirata, M., Y. Sugimoto and M. Ueno (1988) *J. Japan. Grassl. Sci.* **33**, 371-386.
10) Hirata, M., Y. Sugimoto and M. Ueno (1988) *J. Japan. Grassl. Sci.* **33**, 387-395.
11) Hirata, M., Y. Sugimoto and M. Ueno (1988) *J. Japan. Grassl. Sci.* **34**, 108-118.
12) Hirata, M., Y. Sugimoto and M. Ueno (1988) *Bull. Fac. Agric. Miyazaki Univ.* **35**, 63-69.
13) Kimura, T. and K. Kurashima (1988) *In* Control of Production Environments in Agriculture, Forestry and Fisheries (III). Agriculture, Forestry and Fisheries Research Council Secretariat, Ministry of Agriculture, Forestry and Fisheries, Tokyo. pp. 52-76. *
14) MacDiarmid, B.N. and B.R. Watkin (1971) *J. Br. Grassld Soc.* **26**, 239-245.
15) Marsh, R. and R.C. Campling (1970) *Herb. Abstr.* **40**, 123-130.
16) Ricou, G.A.E. (1979) *In* Grassland Ecosystems of the World (ed. R.T. Coupland). Cambridge Univ. Press, Cambridge. pp. 147-153.
17) Weeda, W.C. (1967) *N.Z.J. Agric. Res.* **10**, 150-159.
*: In Japanese with English summary.

(Received on August 8, 1988)

バヒアグラス（*Paspalum notatum* Flügge）放牧草地における エネルギーと物質の流れにおよぼす家畜の排糞の影響

IV. 生産者をつらぬくエネルギーの流れ

平田昌彦・杉本安寛・上野昌彦

宮崎大学農学部（889-21 宮崎市学園木花台西 1-1）

要　　約

ホルスタイン育成牛が輪換放牧されるバヒアグラス草地に，6月（JD 区）と8月（AD 区）に人為的に糞を置いた。JD および AD 区の糞を置いた場所とその周辺における生産者をつらぬくエネルギーの流れは，糞を置かなかった場所（ND 区）に比べ，次のような変化を示した。(1) JD および AD 区の糞を置いた場所では，糞を置いた直後の期間に，糞に覆われることによる植物体地上部の枯死・脱落を反映し，ND 区よりもリター生産量が増加した。しかし，これらの場所でも一次純生産量は低下せず，バヒアグラスが糞の被覆に対して高い抵抗性をもつことが明らかになった。(2) AD 区では，糞を置いた直後の期間に，植物体蓄積量の増加により，ND 区よりも一次純生産量が上昇する傾向を示した。これは，主として，葉身窒素含有率の増加よりも，葉面積指数の増加によるものと考えられた。(3) JD および AD 区の一次純生産量は，冬を越した翌年になると，植物体蓄積量とリター生産量の減少により，ND 区より低下した。AD 区については，増加した立枯が光を遮ることによる光合成の低下と，増加した非同化器官による呼吸の増加が主な原因と考えられた。しかし，JD 区についての理由は不明であった。

キーワード：一次純生産，エネルギーの流れ，家畜の排糞，生産者，バヒアグラス放牧草地.

日草誌 **35** (2)：93-99 (1989)