Spatial Distribution of Urination by Cattle in a Daytime Grazing System

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ABSTRACT : Spatial distribution of urination by Japanese Black heifers and steers was investigated, and compared with the distribution of defecation. The animals grazed a bahiagrass (*Paspalum notatum* Flügge) pasture in the daytime, and spent the rest of the day in a barn. The distribution of urination to the pasture was greater than that expected from the proportion of time that the animals spent in the pasture. Correspondingly, the distribution was smaller in the barn. Such a distribution pattern of urination to the pasture and barn was similar to that of defecation, and affected by the intake of supplement on the previous day. The distribution of urination within the pasture, i.e. the distribution to the paddock, alley and resting area, was often uneven on an area basis. The animals often urinated sparsely in the alley and resting area, while they urinated in the paddock almost proportionally to its area. This was a clear contrast to the distribution pattern of defecation, which was sparse in the paddock and dense in the resting area. The degree of aggregation of urination in the paddock, alley and resting area varied with the meteorological factors and the intake of supplement.
(**Key Words :** Beef Cattle, Daytime Grazing, Urination, Spatial Distribution)

INTRODUCTION

In animal production systems, animal excreta, viz. feces and urine, are one of the main outputs of concern (Spedding, 1995). In some systems they are utilized as a fertilizer or fuel, while in other systems they cause environmental pollution. Furthermore, in intensive grazing systems, feces from animals are often responsible for increased patchiness of sward vegetation and reduced utilization of pastures (Marsh and Campling, 1970; Watkin and Clements, 1978; Wilkins and Garwood, 1986; Hirata et al., 1987, 1991). Thus, animal excreta cannot be neglected in the management of animal production systems.

From this viewpoint, the authors selected a beef production system (heifers and steers) utilizing a bahiagrass pasture in the low altitude region of southwestern Japan as a case study, and investigated the spatial distribution of feces in terms of the number of defecations and the fecal weight (Hirata and Higashiyama, 1996). It was shown that the feces were not distributed evenly within the system, and the degree of fecal aggregation in the paddock, alley and resting area of the pasture was influenced by the supplementary feed intake of the animals and the meteorological conditions.

In this study, we examined the spatial distribution of urine in terms of the number of urinations, using the data obtained simultaneously with the data on feces (Hirata and Higashiyama, 1996). Because it has been reported that urination shows a different distribution pattern from defecation (Suzuki et al., 1983; Sugimoto et al., 1987), we also analyzed the inter-relationships between the distributions of defecation and urination to highlight their similarity and dissimilarity.

MATERIALS AND METHODS

The study was conducted between May and October in 1994 in a Japanese Black heifer/steer system at the Sumiyoshi Livestock Farm, Faculty of Agriculture, Miyazaki University (31° 59′ N, 131° 27′ E). In the system, 5 to 12 animals rotationally grazed three paddocks of a Pensacola bahiagrass (*Paspalum notatum* Flügge) pasture (figure 1) in the daytime between 9 a.m. and 4 p.m. The animals spent the rest of the day in a loose housing barn. The pasture, in addition to the three paddocks, included an alley and a resting area. The resting

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area had a watering place and shade trees. During the grazing, the gate leading to the barn was closed. Except for late May to mid-June, the animals were supplemented with hay in the barn immediately after the grazing. The previous paper (Hirata and Higashiyama, 1996) gives more details of the system and its management.

Measurements were made in 27 periods of 24 hours (table 1). In each period, by 4-5 observers, all the urinations by the animals were counted, and, during the grazing, the place of urination (paddock, alley or resting area) was recorded. For the measurements of the animal liveweight, intake of supplement, herbage mass of the paddocks and meteorological conditions shown in table 1, refer to the previous paper (Hirata and Higashiyama, 1996).

The statistical analyses adopted the same techniques as in the previous study (Hirata and Higashiyama, 1996). The χ^2 test for goodness of fit was used to evaluate the bias in the spatial distribution of urination. When the distribution to the pasture and barn was examined, as a null hypothesis, the number of urinations was assumed to follow the proportion of time that the animals spent in the

Table 1. Outlines of measurement periods

Period no.	Date[a]	Paddock grazed[b]	Number of animals[c]	Mean liveweight (kg/hd)[d]	Intake of supplement (kg DM/hd)[e]	Herbage mass (g DM/m²)[f]	Mean air temperature (℃)[g]	Solar radiation (MJ/m²)[h]	Rainfall (mm)[h]
1	10-11 May	2	5	297	2.2	46	23.5	15.9	0.0
2	11-12 May	2	5	298	0.8	–	21.1	2.4	19.0
3	12-13 May	2	5	299	1.9	33	24.7	20.9	0.0
4	24-25 May	3	5	307	–	110	24.0	20.1	0.0
5	25-26 May	3	5	308	–	–	22.0	5.6	0.5
6	26-27 May	3	5	308	–	–	22.6	7.4	1.0
7	27-28 May	3	5	309	–	–	25.4	10.8	0.0
8	28-29 May	3	5	310	–	89	22.8	21.8	0.0
9	29-30 May	1	5	310	–	–	21.8	10.0	0.0
10	13-14 June	2	6	304	–	–	22.6	4.5	27.0
11	14-15 June	2	6	304	–	121	24.9	12.5	0.0
12	15-16 June	3	6	305	–	–	24.9	19.1	0.0
13	5- 6 July	2	6	313	1.5	–	31.8	21.5	0.0
14	6- 7 July	2	6	313	1.5	211	31.4	21.4	0.0
15	7- 8 July	3	6	313	1.5	–	30.4	21.0	0.0
16	12-13 Aug.	2	6	326	3.3	205	28.4	12.6	5.5
17	26-27 Aug.	3	12	289	2.7	326	30.9	15.1	0.0
18	27-28 Aug.	3	12	290	2.7	–	28.2	11.5	6.5
19	28-29 Aug.	3	12	290	2.6	–	30.0	17.5	0.0
20	14-15 Sep.	2	12	300	1.5	–	28.0	17.7	0.0
21	15-16 Sep.	2	12	300	1.6	310	27.2	17.4	0.0
22	16-17 Sep.	3	12	301	1.6	–	28.5	18.1	0.0
23	28-29 Sep.	3	12	309	1.5	206	23.3	1.1	5.5
24	11-12 Oct.	3	12	309	1.6	–	24.6	8.1	4.5
25	28-29 Oct.	2	12	312	3.1	–	24.1	14.1	0.0
26	29-30 Oct.	2	12	312	3.0	217	23.6	13.9	0.0
27	30-31 Oct.	3	12	313	3.1	–	22.4	14.0	0.0

[a] The duration of each period is 24 hours from 9 a.m. to 9 a.m.
[b] See figure 1.
[c] Heifers until Period 16, and 9 heifers and 3 steers thereafter.
[d] Calculated from half-monthly data.
[e] Intake on the previous day of each period. – indicates no supplement feeding.
[f] Herbage mass above a 5 cm height. – indicates no measurement.
[g] Mean temperature over the daytime grazing from 9 a.m. to 4 p.m.
[h] Total value over the daytime grazing from 9 a.m. to 4 p.m.

two places (29.2 and 70.8% for the pasture and barn, respectively). When the distribution to the paddock, alley and resting area was examined, the number of urinations was assumed to follow the proportion of area of the three places (83.6 - 89.6%, 4.0 - 6.3% and 6.4 - 10.1% for the paddock, alley and resting area, respectively) (figure 1). Because of the small probabilities for the alley and resting area, expected values for these places were often smaller than 1, when the total number of urinations in the pasture was less than 20 (table 2). Although this may invalidate the χ^2 test, the two places were not combined, because the combination did not meet the objective of this study.

Multiple regression analyses were used to relate spatial distribution to the intake of supplement and the three meteorological factors in table 1. The regression analyses adopted a forward selection method (F_{IN} level = 0.05, variance inflation factor < 10), and tested the four variables and their non-linear transformations (square, square root, logarithmic and inverse) as predictors of the spatial distribution. No interactions of the variables were considered.

Table 2. Number of urinations in pasture and barn, and in paddock, alley and resting area

Period no.	Number of urinations		P[c]	Number of urinations			P[d]
	Pasture[a]	Barn		Paddock[a]	Alley[a]	Resting area[a]	
1	19 (43.2)[b]	25 (56.8)[b]	<0.05	16 (84.2)[b]	3 (15.8)[b]	0 (0.0)[b]	<0.25
2	27 (50.9)	26 (49.1)	<0.001	18 (66.7)	8 (29.6)	1 (3.7)	<0.001
3	17 (37.8)	28 (62.2)	<0.25	12 (70.6)	0 (0.0)	5 (29.4)	<0.05
4	15 (42.9)	20 (57.1)	<0.1	15 (100.0)	0 (0.0)	0 (0.0)	<0.5*
5	17 (41.5)	24 (58.5)	<0.1	17 (100.0)	0 (0.0)	0 (0.0)	<0.5*
6	15 (38.5)	24 (61.5)	<0.25	15 (100.0)	0 (0.0)	0 (0.0)	<0.5*
7	13 (37.1)	22 (62.9)	<0.5	12 (92.3)	0 (0.0)	1 (7.7)	<0.9*
8	16 (39.0)	25 (61.0)	<0.25	15 (93.8)	0 (0.0)	1 (6.3)	<0.75*
9	14 (35.0)	26 (65.0)	<0.5	14 (100.0)	0 (0.0)	0 (0.0)	<0.5*
10	23 (41.8)	32 (58.2)	<0.05	15 (65.2)	7 (30.4)	1 (4.3)	<0.001
11	14 (42.4)	19 (57.6)	<0.1	14 (100.0)	0 (0.0)	0 (0.0)	<0.5*
12	17 (41.5)	24 (58.5)	<0.1	17 (100.0)	0 (0.0)	0 (0.0)	<0.5*
13	17 (37.8)	28 (62.2)	<0.25	11 (64.7)	0 (0.0)	6 (35.3)	<0.01
14	17 (38.6)	27 (61.4)	<0.25	15 (88.2)	0 (0.0)	2 (11.8)	<0.75
15	17 (38.6)	27 (61.4)	<0.25	17 (100.0)	0 (0.0)	0 (0.0)	<0.5*
16	21 (39.6)	32 (60.4)	<0.1	15 (71.4)	3 (14.3)	3 (14.3)	<0.25
17	33 (34.4)	63 (65.6)	<0.5	19 (57.6)	0 (0.0)	14 (42.4)	<0.001
18	26 (35.1)	48 (64.9)	<0.5	25 (96.2)	0 (0.0)	1 (3.8)	<0.5
19	40 (34.5)	76 (65.5)	<0.25	20 (50.0)	1 (2.5)	19 (47.5)	<0.001
20	30 (31.6)	65 (68.4)	<0.75	20 (66.7)	2 (6.7)	8 (26.7)	<0.01
21	35 (34.7)	66 (65.3)	<0.25	26 (74.3)	0 (0.0)	9 (25.7)	<0.01
22	30 (30.3)	69 (69.7)	<0.9	23 (76.7)	0 (0.0)	7 (23.3)	<0.001
23	25 (31.6)	54 (68.4)	<0.75	16 (64.0)	9 (36.0)	0 (0.0)	<0.001
24	35 (27.6)	92 (72.4)	<0.75	26 (74.3)	7 (20.0)	2 (5.7)	<0.001
25	44 (30.6)	100 (69.4)	<0.75	39 (88.6)	4 (9.1)	1 (2.3)	<0.25
26	42 (32.8)	86 (67.2)	<0.5	35 (83.3)	5 (11.9)	2 (4.8)	<0.25
27	42 (36.5)	73 (63.5)	<0.1	35 (83.3)	1 (2.4)	6 (14.3)	<0.25
Total	661 (35.5)[e]	1201 (64.5)[e]	<0.001	522 (79.0)[e]	50 (7.6)[e]	89 (13.5)[e]	<0.001

[a] Pasture = Paddock + Alley + Resting area (see figure 1).

[b] Percentage distribution.

[c] Probability that the number of urinations in the pasture and barn follows the proportion of the time that the cattle spent in the respective places is accepted by the χ^2 goodness-of-fit test (see text).

[d] Probability that the number of urinations in the paddock, alley and resting area follows the proportion of the area of the respective places is accepted by the χ^2 goodness-of-fit test (see text). * indicates that the expected value for the alley and/or resting area is less than 1 (also see text).

[e] Percentage distribution for total number of urinations.

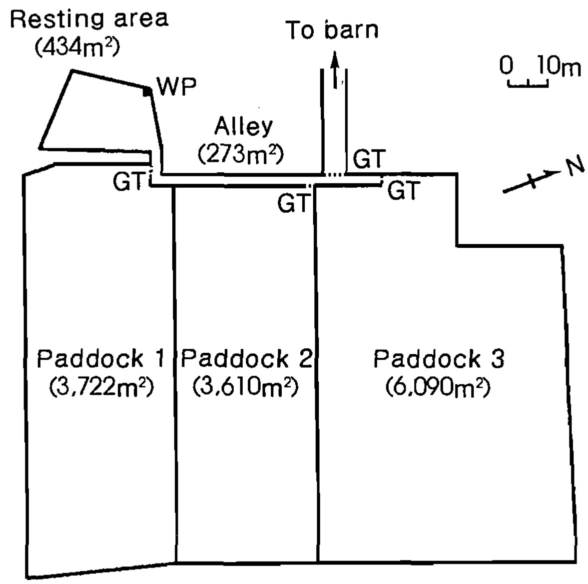

Figure 1. Layout of pasture. GT and WP show a gate and a watering place, respectively. The resting area includes shade trees as well as WP.

RESULTS

Distribution to the pasture and barn

The number of urinations in the pasture and barn is shown in the left half of table 2. The number is expressed on the basis of the herd rather than on the basis of an animal so that the number can be used for the χ^2 test for goodness of fit. In each period, 27.6-50.9% of urinations occurred in the pasture, and 49.1-72.4% in the barn. In total, 35.5 and 64.5% of urinations occurred in the pasture and barn, respectively. Thus, the percentage distribution of urination to the pasture ($PD_{uri,past}$) was always greater than that expected from the proportion of time (29.2%) except for Period 24, though the χ^2 goodness-of-fit test indicated that the null hypothesis was not accepted at 5% level only in 3 periods and in the total periods.

$PD_{uri,past}$ showed a negative correlation with the intake of supplement (*SUPINT*, table 1) ($r = -0.438$, $p < 0.05$). This means that the percentage distribution of urination to the barn ($PD_{uri,barn}$) was positively correlated with *SUPINT*, because $PD_{uri,barn}$ equals 100 minus $PD_{uri,past}$. Multiple regression analyses resulted in the following equation:

$$PD_{uri,past} = 40.22 - 9.291\log(SUPINT+1) \quad (r=0.455,\ p<0.05) \quad \cdots\cdots (1)$$

Distribution to the paddock, alley and resting area

The number of urinations in the paddock, alley and resting area is shown in the right half of table 2. In each period, 50.0-100.0% of urinations occurred in the paddock, 0.0-36.0% in the alley, and 0.0-47.5% in the resting area. In total, 79.0, 7.6 and 13.5% of urinations occurred in the paddock, alley and resting area, respectively. Thus, the percentage distribution to the paddock generally fluctuated around the value expected from the proportion of area (83.6-89.6%). The percentage distribution to the alley and resting area varied considerably between zero and values far above the expected percentage (4.0-6.3% for the alley and 6.4-10.1% for the resting area). The χ^2 goodness-of-fit test showed that the null hypothesis was not accepted at 5% level in 11 periods and in the total periods.

Similarly to the previous study (Hirata and Higashiyama, 1996), the degree of aggregation of urination in the paddock, alley and resting area was expressed as the ratio of the observed number of urinations to the expected number (O/E ratio of urination). The expected number was calculated on the previously-described assumption that the number of urinations follows the proportion of the area of the three places. As illustrated in figure 2, the ratio in the paddock ($O/E_{uri,pad}$) fluctuated around 1. The ratio in the alley ($O/E_{uri,alley}$) was often below 1, though it showed distinct peaks of 4.7-9.0 in Periods 2, 10 and 23. Also, the ratio in the resting area ($O/E_{uri,rest}$) was often below 1, in spite of the peaks of 2.9-7.4 in Periods 3, 13, 17, 19 and 22. There were negative correlations between $O/E_{uri,pad}$ and $O/E_{uri,alley}$ ($r = -0.435$, $p < 0.05$), and between $O/E_{uri,pad}$ and $O/E_{uri,rest}$ ($r = -0.737$, $p < 0.001$).

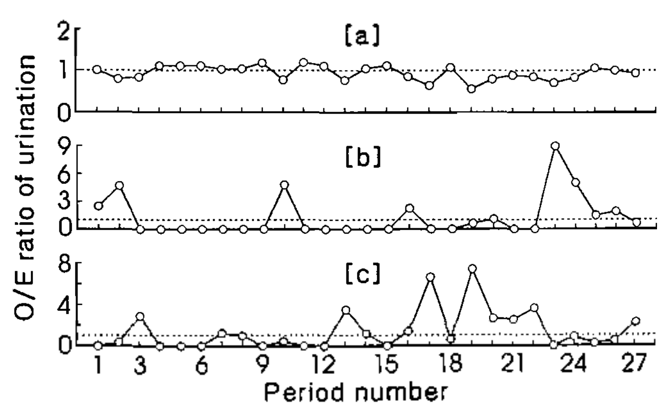

Figure 2. The ratio of observed number of urinations to expected number of urinations (O/E ratio of urination) in the paddock (a), alley (b) and resting area (c). The expected number was calculated assuming that the number of urinations follows the proportion of the area of the three places (see text).

Analyses of the relationships of $O/E_{uri,pad}$, $O/E_{uri,alley}$ and $O/E_{uri,rest}$ to $SUPINT$ and the three meteorological factors (table 1) indicated a negative correlation between $O/E_{uri,pad}$ and $SUPINT$ ($r=-0.434$, $p<0.05$). $O/E_{uri,alley}$ was correlated negatively with the solar radiation ($SRAD$) ($r=-0.671$, $p<0.001$) and positively with the rainfall ($RAIN$) ($r=0.596$, $p<0.01$) during grazing. $O/E_{uri,rest}$ was positively correlated with $SUPINT$ ($r=0.427$, $p<0.05$) and the air temperature during grazing ($TEMP$) ($r=0.606$, $p<0.001$). Multiple regression analyses resulted in the following equations:

$O/E_{uri,pad}=0.780+0.329/(SUPINT+1)-0.000448RAIN^2$ ($r=0.656$, $p<0.01$) ……………………………… (2)

$O/E_{uri,alley}=-1.378+2.301\log(SUPINT+1)+17.44/(SRAD+1)+0.0864RAIN$ ($r=0.894$, $p<0.001$) · (3)

$O/E_{uri,rest}=-3.194+0.00695TEMP^2$ ($r=0.609$, $p<0.001$) ……………………………………… (4)

DISCUSSION

Distribution to the pasture and barn

$PD_{uri,past}$ was almost always greater than the percentage expected from the proportion of time, though the null hypothesis was usually accepted (table 2). This fact means that the animals tended to urinate more frequently per unit time in the pasture than in the barn, and is supported by other studies which have reported more frequent urination by grazing cattle during the day than at night (Arnold and Dudzinski, 1978; Suzuki et al., 1983; Sugimoto et al., 1987).

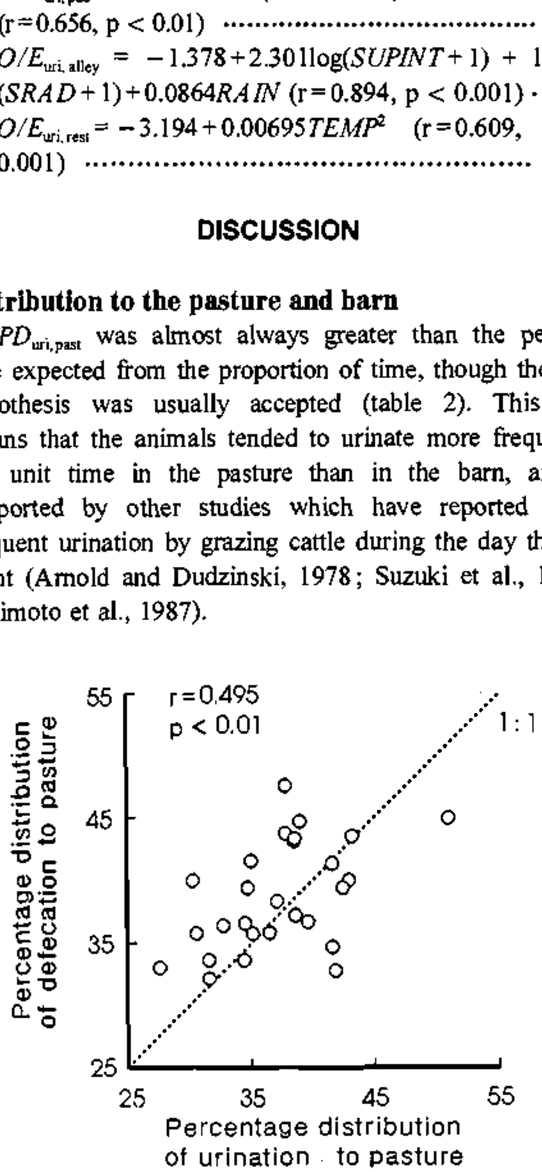

Figure 3. Relationship between percentage distributions of defecation and urination to the pasture.
The percentage distribution of defecation derives from the previous study (Hirata and Higashiyama, 1996).

The previous study showed that the animals also defecated more frequently in the pasture than in the barn (Hirata and Higashiyama, 1996). When the percentage distribution of defecation to the pasture shown in the previous study was plotted against $PD_{uri,past}$ in the present study, there was a positive correlation between them ($r=0.495$, $p<0.01$) with data scattering around the 1 : 1 line (figure 3). The relationship demonstrates that defecation and urination had similar patterns of distribution to the pasture and barn.

Distribution to the paddock, alley and resting area

As indicated by the O/E ratios (figure 2), the animals often urinated sparsely in the alley and resting area, while they urinated in the paddock almost proportionally to its area. This is a clear contrast to the distribution pattern of defecation. The previous study showed that the animals defecated sparsely in the paddock and densely in the resting area (Hirata and Higashiyama, 1996).

Such a difference in the distribution patterns between defecation and urination was confirmed when the O/E ratios of defecation shown in the previous study were plotted against the O/E ratios of urination ($O/E_{uri,pad}$, $O/E_{uri,alley}$ and $O/E_{uri,rest}$) in the present study. Although there were positive correlations between the O/E ratios of defecation and urination in the paddock, alley and resting area, the data tended to scatter below the 1 : 1 line in the paddock and above the line in the alley and resting area (figure 4). Suzuki et al. (1983) and Sugimoto et al. (1987) have also reported different spatial distribution patterns between defecation and urination.

The mechanisms of the effects of $SUPINT$ and the three meteorological factors on the O/E ratios of urination (equations 2 - 4) should be broadly similar to those in defecation (Hirata and Higashiyama, 1996), because of the positive correlations between the O/E ratios of defecation and urination (figure 4). The positive effect of $TEMP$ on $O/E_{uri,rest}$ (equation 4) agrees with a widely-observed phenomenon that cattle on a pasture stop grazing and rest under shade trees at high air temperature (Kurosaki et al., 1982; Suzuki et al., 1984; Sakurai and Dohi, 1988). The positive effect of $RAIN$ and negative effect of $SRAD$ on $O/E_{uri,alley}$ (equation 3) reflect a phenomenon that the animals gathered and kept standing in front of the gate leading to the barn (figure 1) for a few hours when it rained intensively in the afternoon. Furthermore, the positive effect of $SUPINT$ on $O/E_{uri,alley}$ (equation 3) and the negative effect of $SUPINT$ on $O/E_{uri,pad}$ (equation 2) are taken to reflect the tendency of the animals to rely less on the grazing intake and more on the supplementation in the barn with the increasing intake of

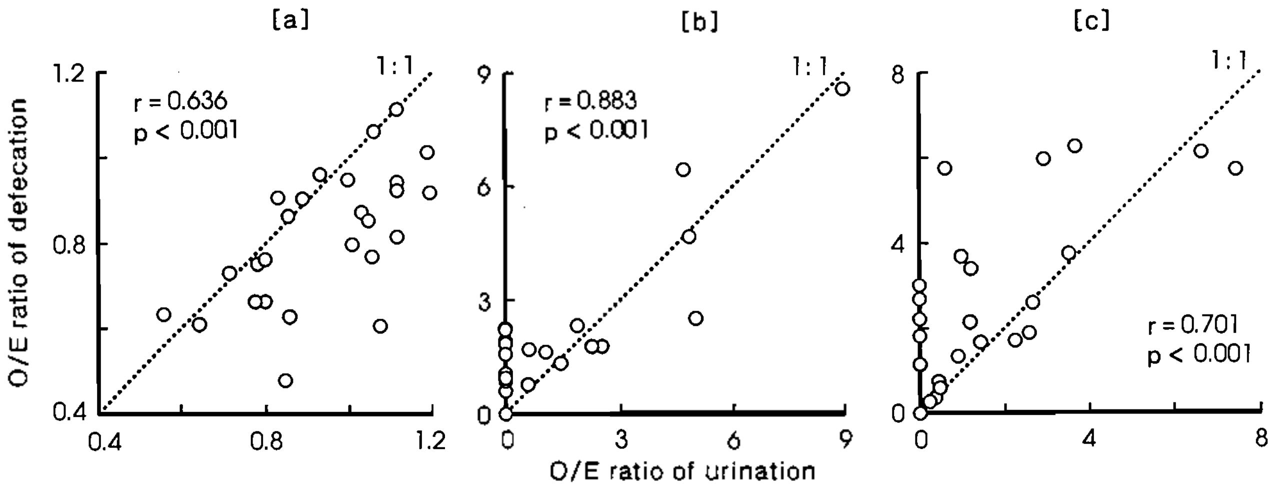

Figure 4. Relationships between O/E ratios of defecation and urination in the paddock (a), alley (b) and resting area (c). The O/E ratio of defecation derives from the previous study (Hirata and Higashiyama, 1996).

supplement (Higashiyama and Hirata, 1995).

Implications to the system management

In animal production systems, animal excreta are one of the main outputs of concern (Spedding, 1995). In the present system, the excreta produced in the barn are utilized as a fertilizer to the arable land component of the system, where most of the supplements are produced. The excreta produced in the pasture can also work as a fertilizer, if they are distributed to the paddock. However, if the excreta are distributed to the alley or resting area where little sward vegetation grows, they may work as an environmental pollutant. There is a need to estimate and control the distribution of excretal nutrients within the system for a better system management.

For this purpose, information of the excretal distribution is needed in such aspects as the number of excretions, amount of excreta per excretion and nutrient contents of excreta. The previous study investigated the number of defecations and fecal weight (Hirata and Higashiyama, 1996), and the present study the number of urinations. Thus, there remain some aspects to be investigated in the future.

Tropical grasses are characterized by their low herbage quality. Therefore, in grazing systems utilizing tropical grasses such as the present system, supplementation is often necessary for maintaining animal production at an acceptable level. However, the previous study showed that increasing *SUPINT* raised the distribution of defecation to the alley (Hirata and Higashiyama, 1996). In addition, the present study showed that increasing *SUPINT* increased the distribution of urination to the alley (equation 3) and reduced the distribution to the paddock (equation 2). These facts suggest that keeping compatibility of high animal production with a closed nutrient cycle is not easy particularly in the system with tropical grasses.

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