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Effect of Patch Characteristics on Progressive Pasture Utilization by Cattle

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Abstract: Patch selection is defined as the non-randomness grazing of available patches, based on inherent patch characteristics. Six Japanese black cows were used to study the progressive patch selection and utilization in heterogeneous patches. First, grazing time vs. forage quantity as Rising Plate Height (RPH) values were assessed. Second, we investigated patch selection through variations in daily patch grazing time of cattle as centipedegrass (*Eremochloa ophiuroides* (Munro) Hack.) coverage changes (qualitative characteristic). The relationship between forage quantity and grazing time during August revealed a Pearson's r values of -0.328, -0.051, -0.304 and -0.017 for days one, two, three and four; respectively. The same relationship was generally negative during September, but was significant in day one at p=0.05 (r=-0.313). Correlating forage quality and grazing time showed significant r values in days one and two during August, days one, two and three during September. Variations in patch selection, therefore, evolve around a trade-off process between forage quality and quantity. As soon as grazing animals learn about the characteristics of their surroundings, they tend to select higher quality patches until intake maximization drops below a threshold. At which stage cattle switch to higher quantity patches because of the cost involved in seeking scarce higher quality patches.

Key words: Sward depletion・patch selection・grazing behaviour

INTRODUCTION

Understanding cattle diet selection at small scales helps improve our perception on grazing preference at larger scales, although findings at small scales cannot be simply extrapolated to understanding at larger scales. Simply because foraging decisions by animals in one scale influence species selection at bigger scales [1]. Forage selection was defined as the non-randomness grazing of available species [2]. Patch selection, by deduction, could be defined as the non-randomness grazing of available patches, based on inherent patch characteristics. Cattle prefer swards with high quantitative and qualitative characteristics [3]. It is believed that linking spatial and behavioural features would result in better management decisions regarding forage consumption and consequently pasture production. Feed consumption associated with pasture production [4]. Furthermore intake is dependent on forage quality [5], whereas preference is predicted by both quality and quantity [1]. The importance of selection as a tool used to manipulate forage intake is significant.

Unfortunately, little is understood about cattle patch selection based on quantity and quality of available forage. Perhaps, cattle would use a strategy of intake maximization on either a momentary [6] or daily [7]; basis [8], which in turn would result in selective grazing based on patch characteristics (i.e., quantity and quality). In either case, cattle will exhibit preference through higher total daily grazing time in favoured patches, thereby increasing sward depletion. This argument is in part based on suggestions [1] with regard to the importance of momentary maximization and [8] vis-à-vis the use of daily maximization of intake by cattle. Thus time spent in a food patch would be relative to food availability [1]. This attempt is primarily to understand progressive patch selection and utilization in heterogeneous patches, through monitoring grazing time vs. forage quantity as Rising Plate Height (RPH) values and then assessing patch selection through observing daily patch grazing time of cattle as centipedegrass (*Eremochloa ophiuroides* (Munro) Hack.) cover changes (qualitative characteristic). Some investigators such as [8] suggested grazing time as a better criterion to study patch selection. Here we use

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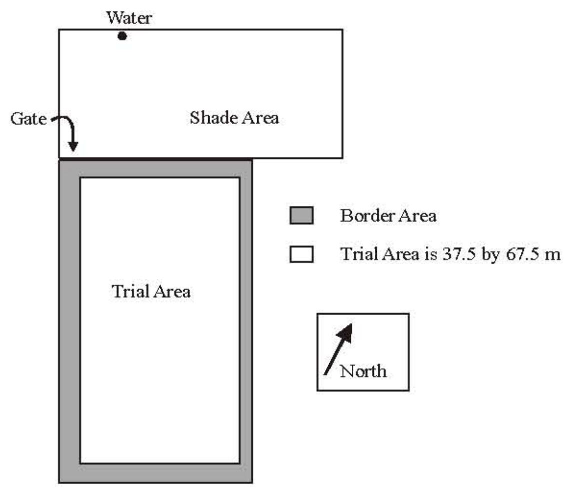

Fig. 1: Layout of the experimental pasture

centipedegrass coverage as a surrogate to sward quality since anecdotal evidence suggest that cattle prefer centipedegrass over bahiagrass (*Paspalum notatum* Flügge), a dominant pasture species in the study area (M. Hirata personal communication, November 2001). A secondary aim of this study is to highlight the importance of RPH measurements and centipedegrass coverage as surrogates to patch quantitative and qualitative characteristics, respectively. In general terms, the information gained from patch selection at these settings could be broadly applied to other patchy environments, such as rangelands.

MATERIALS AND METHODS

Study site and experimental pasture: The study was conducted at the Sumiyoshi Livestock Farm (lat 31°59'N, long 131°28'E), Faculty of Agriculture, University of Miyazaki, Japan. The experimental pasture consisted of a grazing paddock (0.34 ha) and a shade area (0.27 ha) (Fig. 1).

The central part of the grazing paddock (37.5 m × 67.5 m trial area) was originally dominated by bahiagrass (Scientific Name) and sown with centipedegrass after cultivation in May 1999 as an establishment experiment. This establishment experiment divided the area into 45 plots (7.5 × 7.5 m each, arrangement of 5 × 9) and treated the plots with combinations of 5 seeding rates × 3 nitrogen fertilizer rates in 3 randomized blocks. Consequently, during the present study, the vegetation of the trial area was a mosaic of 7.5 m × 7.5 m patches (identified by a column number of 1 to 5 and a row name of A to I) having different compositions of sown centipedegrass and regrown bahiagrass. For instance, plant coverage for individual plots in September 2001 was 26-94% for centipedegrass and 63-89% for other species (mainly bahiagrass) with higher coverage of centipedegrass and lower coverage of bahiagrass in patches at higher seeding rates of centipedegrass). Both bahiagrass and centipedegrass are prostrate-type warm-season perennials, but centipedegrass forms shorter, denser, leafier, more palatable swards than bahiagrass [9].

The border area of the grazing paddock, inside the fenced paddock and outside the trial area and dominated by bahiagrass, was designed to minimize the fence effect on grazing behaviour. The shade area, where a water trough was placed, was covered by tall trees with little herbaceous vegetation.

During the grazing season (May-October) of 2001, the paddock was grazed by 17 dairy cows (Holstein cows; mean liveweight = 650 kg) and 3-6 beef cows (Japanese Black cows; mean liveweight=470 kg) at a rate of 843 cow·day·ha^{-1}. The annual fertilizer rates in the trial area of the paddock were 50, 80 and 110 kg N·ha^{-1} in plots of low, medium and high N levels, respectively, with a common dose of 29 kg P·ha^{-1} and 33 kg K·ha^{-1}. The border area received fertilizer equivalent to 50 kg N·ha^{-1}, 29 kg P·ha^{-1} and 33 kg K·ha^{-1}. The meteorological conditions in the study site in 2001 as compared with the long-term averages are shown in Fig. 2.

Measurement periods and grazing animals: Measurements were conducted during three 5-day periods, i.e., 20-24 August, 20-24 September and 25-29 October 2001. These dates are referred to as Days 0-4 of August, September and October measurements hereafter.

On Day 0 of each measurement period, white plastic plates (20×30 cm) showing a column number (1 to 5) or a row name (A to I) and nylon tapes showing the division line between plots were fixed on the fence-lines surrounding the grazing paddock to facilitate identification of animal location in the trial area at the scale of 7.5 × 7.5 m plots (refer to animal measurements).

On Days 1-4, 6 Japanese Black cows grazed the experimental pasture between 09:00 and 16:00 hours daily. This daily grazing period was chosen to coincide with the grazing management system used at the Sumiyoshi Livestock Farm. During the grazing period, cows were able to access the shade area (Fig. 1) freely to drink or rest. The animals were locked in the shade area to spend the nights (1600 to 0900 h) of Days 1-3.

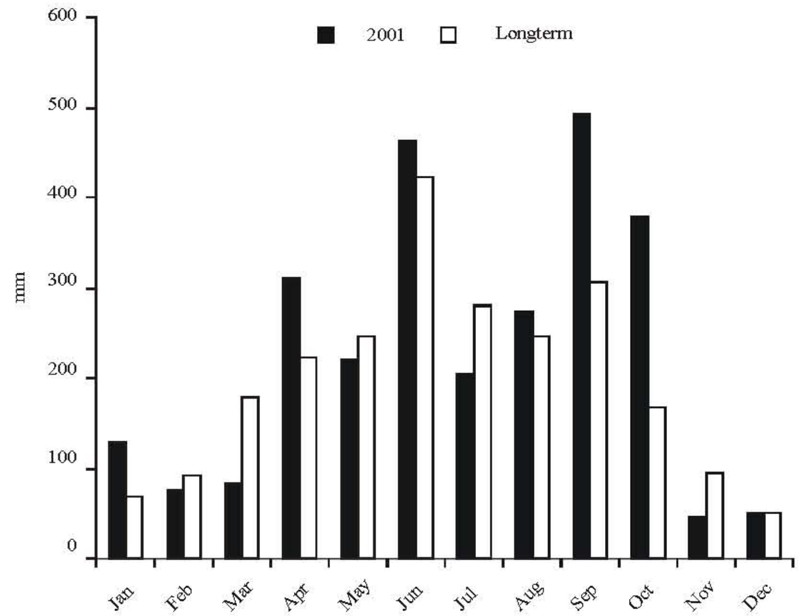

Fig. 2: Longterm and 2001 mean monthly temperature for the Sumiyoshi Livestock Farm, Miyazaki, Japan [Change the colour to black and whit!!!!!]

The experimental animals had no experience of grazing the trial area before they were first used on Day 1 in August (i.e., they did not know the plant species and their locations in the area).

Vegetation measurements: On Day 0 of each measurement period (before the 4-day grazing), ropes were laid-out to form a grid of 7.5 m × 7.5 m plots. Five 0.5×0.5 m quadrats were sampled within each plot (4 corners and centre). Sampling consisted of rising plate height (RPH; Jenquip, New Zealand) and coverage of centipedegrass and bahiagrass. One quadrat which showed nearest values to the average height and coverage over the 5 quadrats was clipped from each plot at a height of 3 cm from ground level. The collected 45 samples were oven dried at 85° C for about 60 h and then dry weight of each sample was taken.

On Days 1 to 4, as soon as daily grazing period ended (i.e., after 1600 h), ropes were laid-out again to form the 45 plots. Approximate locations of the 5 quadrats within each plot (i.e., 4 corners and centre) were then identified and RPH and coverage of centipedegrass and bahiagrass were measured again within each quadrat.

Herbage mass in each of the 45 plots on Days 1-4 was estimated from sward bulk density of the plot on Day 0 (as herbage mass/[RPH-cutting height]) and the mean RPH of the plot on the following respective dates (Days 1-4).

Animal measurements: Animal measurements were conducted during the daily grazing period (0900-1600 h) on Days 1-4. Three animals out of 6 were used as focal animals. The same animals were used throughout the trial except for the October measurement, when we had to replace 2 animals because one was pregnant and the other got sick. One was a focal animal, which was replaced with one out of the initial 3 non-focal cows, because we wanted to assess the ability of animals to develop a learning process over time.

Grazing behaviour by each focal animal was observed every 1 min as location in the pasture (individual plot in the trial area, border area or shade area; Fig. 1) and activity (grazing, walking, resting, ruminating and other). The plot where the animal existed was identified by the column number and the row name using the plastic plates and nylon tapes on the fence-lines. The observation interval of 1 minute was selected based on Hirata *et al.* [9] who concluded that intervals between 1 and 5 min provided reliable estimation on grazing time of cattle under a 7-h daytime grazing system. The grazing activity included both eating (biting, chewing, swallowing) at a feeding station and searching for a new feeding station (moving between feeding stations). Daily total grazing time (minutes) in individual plots by each animal was calculated as the total counts of 'grazing' activity in respective plots, assuming that each count is equivalent to 1 min continuation of activity.

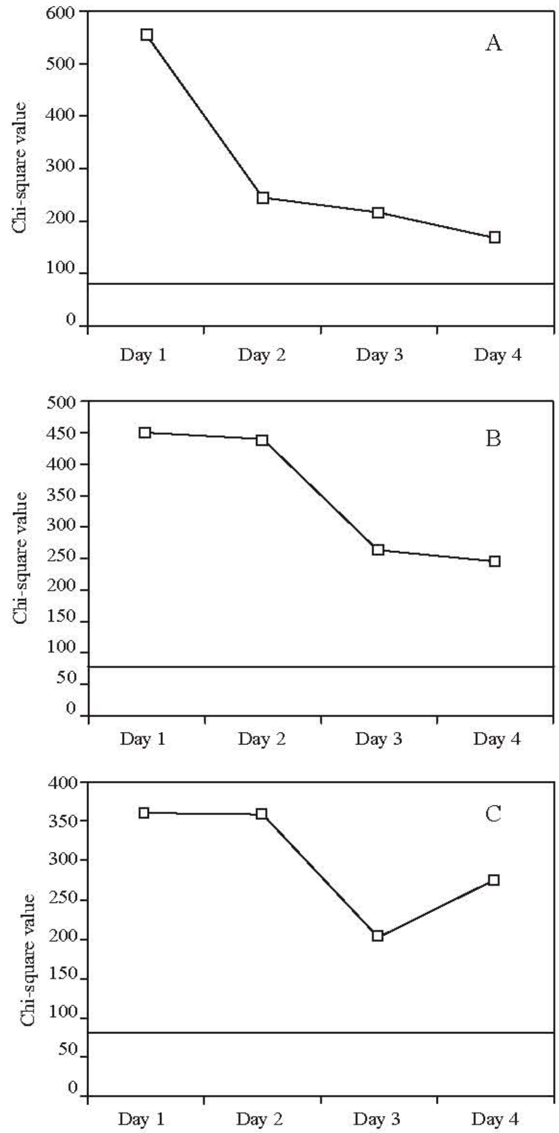

Fig. 3: Chi-square values for randomness of progressive forage utilization by cattle for four days during the months of A) August 2001, B) September 2001, C) October 2001. Horizontal lines indicate areas of significance at p=0.001 (n=45)

Data analyses: A Chi-square analysis was initially performed to test the non-randomness of the grazing time spent in individual plots for each day of each of the 3 months, using count data of grazing activity in the plots (Fig. 3).

The effect of the shading area on the grazing time in the individual plots was assessed by a correlation (Pearson r) between the grazing time and the distance of the plots from the shading area.

Correlation analysis was further used to assess the contribution of quantity and quality of plots to selection by animals. Herbage mass and coverage of centipedegrass were used as criteria of quantity and quality, respectively and grazing time was used as a criterion of plot selection.

RESULTS AND DISCUSSION

The animals spent 51.92, 67.26 and 73.83% of their time grazing in the trial area in August, September and October, respectively. Time spent in the shading area was 33.54, 16.47 and 10.46% and that in the border area was 14.54, 16.27 and 15.71% in August, September and October, respectively.

Grazing of plots by animals was always non-random, because the Chi-square was highly significant for each of the 4 days of August, September and October (p=0.001; Fig. 2). This non-random grazing of plots was not attributed to the shading area, because the grazing time in plots was not correlated with the distance of the plots from the shade area. A correlation analysis showed that the Pearson r values were -0.307 (significant at p=0.05), 0.091 and 0.181 for August, September and October; respectively. This phenomenon contrasts with the observations that the more vicinity of water is utilized more frequently and more intensively by cattle in the extensive grazing systems [10]. Figure 4 shows variations in r values and their significance for grazing time vs. herbage mass and grazing time vs. centipedegrass coverage (CGC). It is important to remind the reader that grazing time is equal to number of minutes per patch as cattle observations were recorded every one minute during the daily grazing periods.

Grazing time and herbage mass were correlated to estimate the relationship between relative utilization on the patches and forage quantity. There was a significant negative relationship (p=0.05) in August for days one and three (Fig. 4a). Pearson's r values were -0.328, -0.051, -0.304 and -0.017 for days one, two, three and four, respectively. The relationship was generally negative during September (Fig. 4a). The correlation was significant (p=0.05) in day one (r=-0.313). There was no relationship during October (Fig. 4a).

In order to assess if cattle are spending more time in plots with high forage quality, grazing time and CGC were correlated. The relationship was found (p=0.05) only in days one and two during August (Fig. 4b). Pearson's r values were -0.445 and -0.347, respectively. During September, the r values were significant (p=0.05) for all days except day four (Fig. 4b). Pearson's r values were

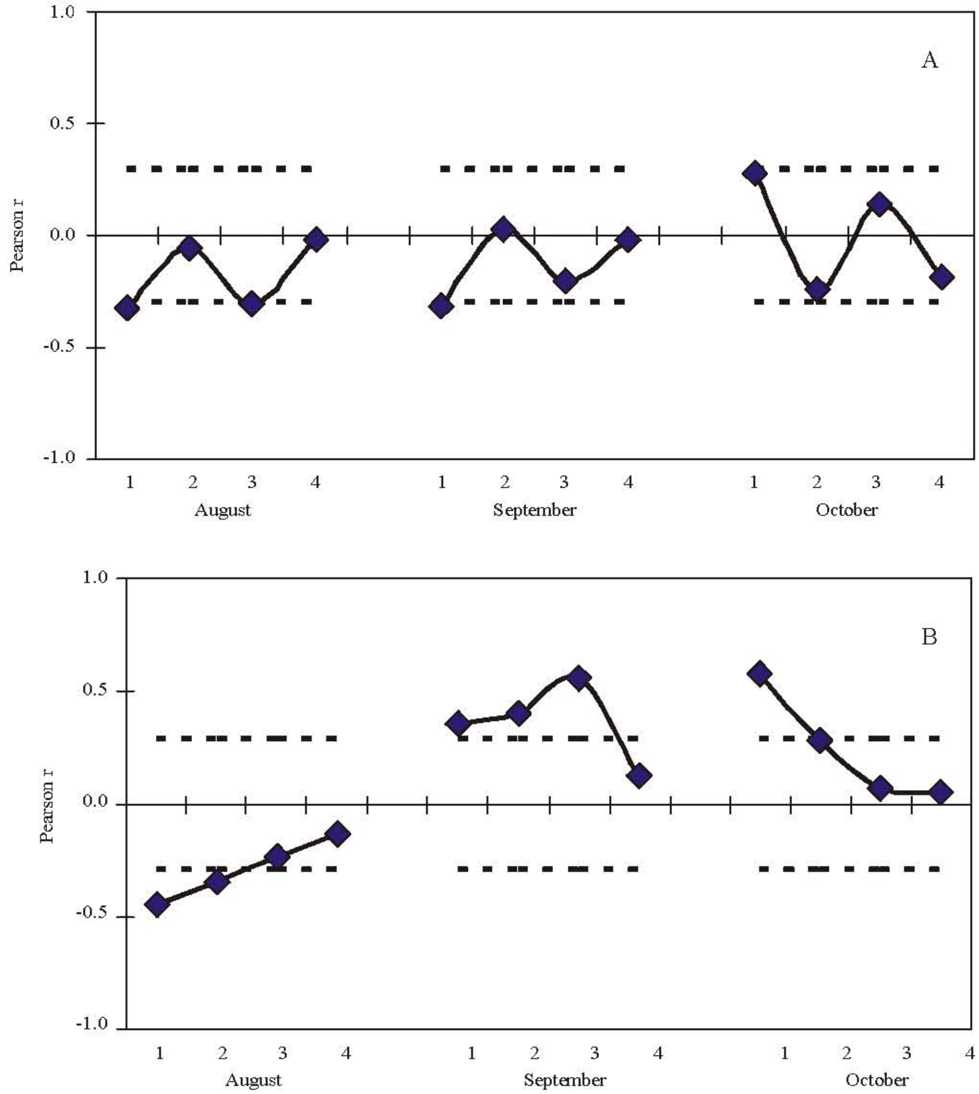

Fig. 4: Pearson correlation values (r) for progressive forage utilization by cattle. A) grazing time vs. forage quantity available. B) grazing time vs. forage quality (centepedegrass cover). Horizontal lines (at ±0.2939) represent areas of significance of r at p=0.05 (n=45)

0.351, 0.405, 0.560 and 0.124 for days one, two, three and four; respectively. Pearson's r was not significant for days one, two and three during October.

Our attempt has been to improve our understanding of progressive patch selection and utilization in heterogeneous swards. The data showed that the Rising Plate Meters are not the best option when measuring progressive sward depletion. Especially because RPH readings are highly influenced by species composition, trampling and time of day and do not give accurate readings when dealing with a variety of pasture species with high vertical differences. Knowing that RPH readings actually estimate bulk density of the forage. Many other studies, however, have praised the use of RPH mainly because of speed of measurements [11]. Also, there is clear trend in the importance of quality and quantity in sward depletion. Particularly when grazing time is used as a factor in the correlation analysis.

During August, our findings suggest that cattle were learning about their environment and therefore were focusing on neither quantitative nor qualitative intake maximization. This contradicts the arguments presented elsewhere [8]. In other words, they were filling-up, trying to balance both quantity and quality, before the end of the grazing period. Remember that the cattle are used to the 7-h daylight grazing periods. There was, however, a trend of increasing r values (grazing time vs. CGC; Fig. 4b) from one day to the next, during August. So it is suggested that as cattle were learning about their surroundings, they were using quantity as determinant of sward selection. There were negative correlations with quantity as well as quality attributes. Results reported by Ogura *et al.* [12] suggest that bahiagrass defoliation did not correlate with herbage mass. Ogura *et al.* [12] also reported that quality (nitrogen concentration and Dry Matter Digestibility) declined as bahiagrass herbage mass increased during the July-October period. What added to this delay in quality-based selection is that, although both grasses are prostrate, centipedegrass forms shorter and denser swards than bahiagrass. Centipedegrass, therefore, could be easily covered with bahiagrass, contributing to the delay in the quality-based selection by cattle.

During September, cattle are more familiar with their surroundings; particularly the presence of a higher quality feed (i.e., centepedegrass) and also developed a memory of the location of these higher quality patches. Cattle do explore their environment and develop a spatial memory for preferred food [13] from other animals [14]. During September the trend of increasing r values continued. In fact, all r values were positive, with only day four showing a non-significant correlation coefficient. This is a good indication of the quality-based patch selection strategy adopted at this stage by the animals. Moreover, the correlation coefficients of grazing time vs. herbage mass were mostly negative or close to zero, during all days of observation during September (Fig. 4a). The results reported by Kassily [15] also indicate that season influences adaptation of animals to quality changes in their diets by modifying their feeding patterns. Length of the grazing periods becomes more critical as quality declines.

During October, cattle developed a solid experience on the location of high quality patches, yet they were not able to maximize intake on centipedegrass alone as it was starting to deplete. This was detected from the declining trend of r values between day 1 and day 4, even though a significant r value was observed only during day 1 (Fig. 4b). So as patch quality declines, cattle visited lesser quality patches as a trade-off between quantity and quality. Therefore, the variations in patch selection evolves around a trade-off process between forage quality and quantity. As soon as grazing animals learn about the characteristics of their surroundings, they tend to select higher quality patches. When forage quality declines and "intake maximization" drops below a certain threshold, cattle switch to higher quantity patches because of the cost involved (i.e., Grazing time) in seeking scarce higher quality patches. The cost of increased selectivity may be higher than the benefits at micro-levels of vegetation units [16].

We anticipated that information gained from the present study could be used to predict pasture use in rangelands. As spatial distribution of pasture species requires knowledge of what's available and the importance of forage quality and quantity trade-offs. We are aware of the single scale that our findings are limited to but Wallis de Vries *et al.* [17] stated that selectivity in grazers is facilitated by heterogeneity at large-scales. And discrimination between feeding stations and larger selection units is enhanced [17]. A development of key species in a paddock, with a seasonal variation in quality would be a good alternative to setting animal stoking rates based predominantly on total forage availability alone.

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REFERENCES

1. Senft, R.L., M.B. Coughenour, D.W. Bailey, L.R. Rittenhouse. O.E. Sala and D.M. Swift, 1987. Large herbivore foraging and ecological hierarchies. BioScience, 37: 789-799.
2. Heady, H.F., 1975. Rangeland management. New York, NY: McGraw Hill, pp: 325.
3. Bailey, D.W., L.R. Rittenhouse, R.H. Hart and R.W. Richards, 1989. Characteristics of spatial memory in cattle. Applied Animal Behavior Science, 23: 331-340.
4. Clary, W.P., P.F. Ffolliot and F.R. Larson, 1978. Factors affecting forage consumption by cattle in Arizona Ponderosa Pine Forest. Journal of Range Management, 31: 9-17.
5. Hart, R.H., O.M. Abdalla, D.H. Clark, M.B. Marshall, M.H. Hamid, J.A. Hager and J.W. Waggoner, Jr. 1983. Quality of forage and cattle diets on the Wyoming High Plains. Journal of Range Management, 36: 46:51.

6. Distel, R.A., E.A. Laca, T.C. Griggs and M.W. Demment, 1995. Patch selection by cattle: maximization of intake rate in horizontally heterogeneous pastures. Applied Animal Behavior Science, 45:11-21.
7. Fryxell, J.M., 1991. Forage quality and aggregation by large herbivores. Ame. Naturalist, 138: 478-498.
8. Wallis de Vries, M.F. and C. Daleboudt, 1994. Foraging strategy of cattle in patchy grassland. Oecologia, 100: 98-106.
9. Hirata, M., T. Iwanmoto, W. Otozu and D. Kiyota, 2002. The effects of recording interval on the estimation of grazing behavior of cattle in a daytime grazing system. Asian-Australas Journal of Animal Sciences, 15: 745-750.
10. Holechek, J.L., R.D. Pieper and C.H. Herbel, 1989. Range Management: Principles and Practices. Prentice Hall, Endlewood Cliffs, New Jersey.
11. Rook, A.J., C.A. Huckle and P.D. Penning, 1994. Effects of sward height and concentrate supplementation on the ingestive behavior of spring-calving dairy cows grazing grass-clover swards. Applied Animal Behavior Science, 40: 101-112.
12. Ogura, S., H. Hasegawa and M. Hirata, 2002. Effects of herbage mass and herbage quality on spatially heterogeneous grazing by cattle in a bahiagrass (*Paspalum notatum*) pasture. Tropical Grassland 36: 172-179.
13. Ksiksi, T. and E.A. Laca, 2000. Can social interactions affect food searching efficiency of cattle? Rangeland Journal, 22: 235-242.
14. Bailey, D.W., L.D. Howery and D.L. Boss, 2000. Effects of social facilitation for locating feeding sites by cattle in an eight-arm radial maze. Applied Animal Behavior Science, 68: 93-105.
15. Kassilly, F.N., 2002. Forage quality and camel feeding patterns in Central Baringo, Kenya. Livestock Production Science, 78: 175-182.
16. Wallis de Vries, M.F. and P. Schippers, 1994. Foraging in a landscape mosaic - selection for energy and minerals in free-ranging cattle. Oecologia, 100: 107-117.
17. Wallis De Vries, M.F., E.A. Laca and M.W. Demment, 1999. The importance of scale of patchiness for selectivity in grazing herbivores. Oecologia, 121: 355-363.