

Short-term Response of Vegetation to Cattle Grazing in an Abandoned Orchard in Southwestern Japan

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ABSTRACT : An abandoned mandarin orange orchard in southwestern Japan was set-stocked by Japanese Black cows at two stocking rates (1.0 and 2.0 animals/ha), and vegetation dynamics and diet selection by cattle were monitored for two years, in an effort to obtain information on effective use of abandoned agricultural fields for low-cost animal production and environmental conservation. Two dominant species at the commencement of grazing, kudzu (*Pueraria lobata* Ohwi) and tall goldenrod (*Solidago altissima* L.), showed different responses to grazing during the two years; the composition of kudzu decreased, contrasting with that of tall goldenrod which increased at both stocking rates. This was caused by high preference for kudzu and avoidance or low preference for tall goldenrod by cattle. Retrogression of vegetation due to cattle disturbances occurred at both stocking rates, with the high stocking rate leading to a lower degree of succession than the low stocking rate. It was shown that cattle grazing, particularly at a high stocking rate, was effective in the management of vegetation of an abandoned orchard. (*Asian-Aust. J. Anim. Sci.* 2006. Vol 19, No. 4 : 514-520)

Key Words : Abandoned Orchard, Cattle Grazing, Retrogression, Botanical Composition, Diet Selection, Preference

INTRODUCTION

In Japan, the area of abandoned fields that were once used for cultivation of crops (e.g. paddy fields, orchards) has been steadily increasing. This has caused serious problems such as the deterioration of landscapes and damaging of crops in neighboring fields by feral animals inhabiting the present abandoned fields (Ide et al., 2001). Maintenance of farmlands has become even more important because the self-sufficiency ratio of Japan has been continuously declining. The major causes for this decline are the increased agricultural production costs, agricultural import liberalization, which is increasing international competition, and the declining prices of imported agricultural products because of the Japanese yen's appreciation (Kako, 2000). Therefore, to increase the food self-sufficiency ratio and to reduce the area of abandoned farmlands are imperative if Japan is to ensure its food security.

In Japan, as with the food self-sufficiency ratio, the feed self-sufficiency ratio is also low. Massive quantities of concentrate feed are imported to produce Japanese marbled beef, Wagyu. With the increasing intensity of livestock production in Japan, recycling of surplus livestock waste has become a problem for individual farms, causing serious environmental problems related to soil, water and air pollution (Sasaki et al., 2004). Japanese beef production should become focused on lessening environmental impacts and increasing the effective use of self-supplied feed. Kaku

et al. (2004) calculated that if barley had been planted in 100% of Japanese domestic land left fallow for the previous year in 2000, 802,830 tons of US imported corn would be replaced by barley supplied as concentrate feed to the Japanese domestic livestock industry in 2000. Furthermore, this new concentrate feed supply system could reduce the emission of greenhouse gases in the stage of feed transport (Kaku et al., 2005).

It is generally accepted that herbivores play important roles in the conservation and management of vegetation (Olff and Ritchie, 1998; Luginbuhl et al., 1999). It is anticipated that the use of abandoned farmlands for grazing beef cattle not only lowers the economic and labor costs of beef production but also enables prompt resurrection of crop fields at the time of necessity by preventing invasion of brush (Ide et al., 2001; Tanimoto et al., 2003). It would be possible to effectively use the existing biomass in abandoned farmlands, as this is an unutilized feed resource.

It is well known that grazing affects the transition of existing vegetation. A number of investigations have documented the effect of grazing on plant community succession (Ellison, 1960; Papolizio et al., 1994; Clary, 1995; Green and Kauffman, 1995; Sakanoue et al., 1995; Schulz and Leininger, 1998). Diet selection of herbivores and stocking rate affect the transition of vegetation; diet selection is also affected by the conditions of the vegetation (Gardener, 1980; Wallis de Vries and Daleboudt, 1994; Jones et al., 1995). As diet selection is influenced by the herbage allowance, the diet selectivity of each plant species can be expressed by the relationship between the botanical composition in vegetation and diet (Van Dyne and Heady, 1965; Gardener, 1980; Orsini, 1990). An understanding of the diet selectivity of cattle is important for estimations of vegetation transitions as well as for successful grazing

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management, and animal nutrition and production.

This study aimed to evaluate the response of vegetation to cattle grazing in an abandoned orchard by monitoring the diet selection of cattle in paddocks with two different stocking rates.

MATERIALS AND METHODS

Study site and grazing trial

The study was conducted in an abandoned mandarin orange (*Citrus unshiu* Marcov.) orchard in Bungotakada city, Oita prefecture, southwestern Japan (33°26'N, 131°26'E, about 150 m in elevation), where the long-term (from 1971 to 2000) averages of annual mean air temperature and annual rainfall are 15.1°C and 1,639 mm, respectively. The orchard had not been utilized for farming for more than 20 years after clearance of all mandarin trees, and was dominated by herbaceous species commonly occurring in abandoned farmland in southwestern Japan (e.g. *Pueraria lobata* Ohwi, *Solidago altissima* L. and *Miscanthus sinensis* Anderss).

Two paddocks (3.0 and 1.5 ha) were electrically fenced, and set-stocked by two groups of three Japanese Black cows (average age = 75 months, average body weight = 448 kg) from August 2002 to August 2004. These two stocking rates, 1.0 and 2.0 animals/ha, are referred to as LSR and HSR hereafter, respectively. The animals were fed a small amount of concentrate, only when they needed to be penned for health checks, body measurements and dosing with a fecal marker.

Measurements

The vegetation of the paddocks was measured at monthly intervals. Vascular plant species in contact with every 1-m position on three 100-m line transects laid in each paddock was recorded (one species at each position; no recording when no plant existed). The total number of plant species recorded over the three transects was taken as the number of plant species in each paddock.

Botanical composition of vegetation was expressed as the relative occurrence of five plant species or groups, i.e. kudzu (*Pueraria lobata* Ohwi), tall goldenrod (*Solidago altissima* L.), monocots, dicots (excluding kudzu and tall goldenrod) and shrubs.

The degree of succession (DS) of vegetation, defined by Numata (1969), was calculated as:

$$DS = \frac{\sum (l \times d)}{n} \times v \quad (1)$$

where l and d are, respectively, the life span and the abundance of individual species, and n and v are, respectively, the number of species and plant coverage

(from 0 to 1). l is 1 for therophytes, 10 for geophytes, hemicryptophytes and chamaephytes, and 50 for phanerophytes. An increase in DS indicates progression where long-lived species (e.g. phanerophytes) dominate, while a decrease in DS shows retrogression where short-lived species (e.g. therophytes) dominate. Regression analysis was performed to quantify the response of DS in HSR and LSR to grazing. Assuming that grazing (disturbance by cattle) decreases DS at a constant relative rate until an equilibrium, the following exponential equation was applied:

$$Y = b + (a - b)\exp(-ct) \quad (2)$$

where Y is DS and t is the month after the initiation of grazing. The parameters a , b and c give the initial DS (DS when $t = 0$), the asymptote (DS when $t = \infty$ or an equilibrium) and the relative rate of decrease.

Diet selection by cattle was observed at monthly intervals. Plant species selected by the three animals in each paddock were recorded at 3-min intervals for 6 h from 09:00 or 10:00 h (no recording during non-grazing activity) (Martin and Bateson, 1996). Botanical composition of diet was expressed as the relative occurrence of plant species recorded.

Preference by cattle for plant species and plant groups was evaluated by comparing their composition in vegetation and in diet. Relative preference index (RPI) was expressed as the ratio of the percentage of a plant or plant group in the diet to that available in the paddock (Van Dyne and Heady, 1965; Gardener, 1980). Species or groups showing a RPI higher than 1.0 were regarded as preferred, and those showing a RPI lower than 1.0 were regarded as avoided (no preference or avoidance when RPI = 1). For kudzu, RPI was sometimes calculated at an infinite because the species was recorded in the diet selection measurements despite no detection in the vegetation measurements, which was interpreted to show extremely high preference for this species by animals.

Statistical analysis

Data in the form of percentages (i.e. botanical composition of vegetation and diet) were transformed according to the arcsine-square root transformation before analysis of variance (ANOVA). Effect of stocking rate on the botanical composition of vegetation and diet and RPI was evaluated using a one-way ANOVA, dealing with the three transects or the three cows in each paddock as replications. Effect of stocking rate and period (year) on the botanical composition of vegetation and diet were evaluated using a two-way ANOVA (stocking rate × period) and Fisher's PLSD, with the period as a repeated measure because the time factor cannot be randomized.

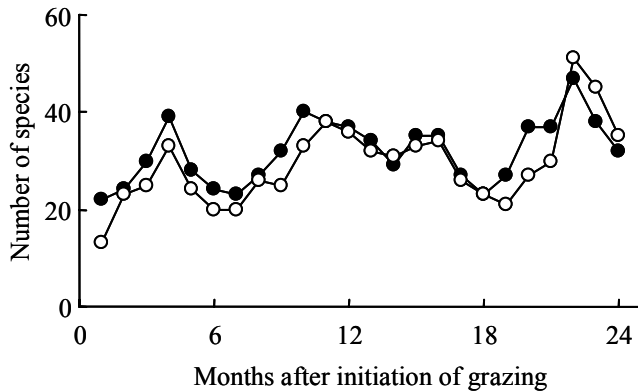


Figure 1. Changes in the number of plant species at high (●) and low (○) stocking rates.

RESULTS

Number of plant species

Over the two year monitoring period, vegetation measurements recorded 78 vascular plant species (72 for HSR and 68 for LSR). The number of plant species observed in each month trended to increase slightly, fluctuating with the season in both paddocks (Figure 1).

Botanical composition of vegetation

Seasonal and yearly changes in the botanical composition of vegetation at HSR and LSR are shown in Figure 2 and Table 1, respectively. During the period immediately after the initiation of grazing (Aug.-Oct., 2002), the composition of kudzu, a dominant species in both paddocks at the initiation of grazing, was not different

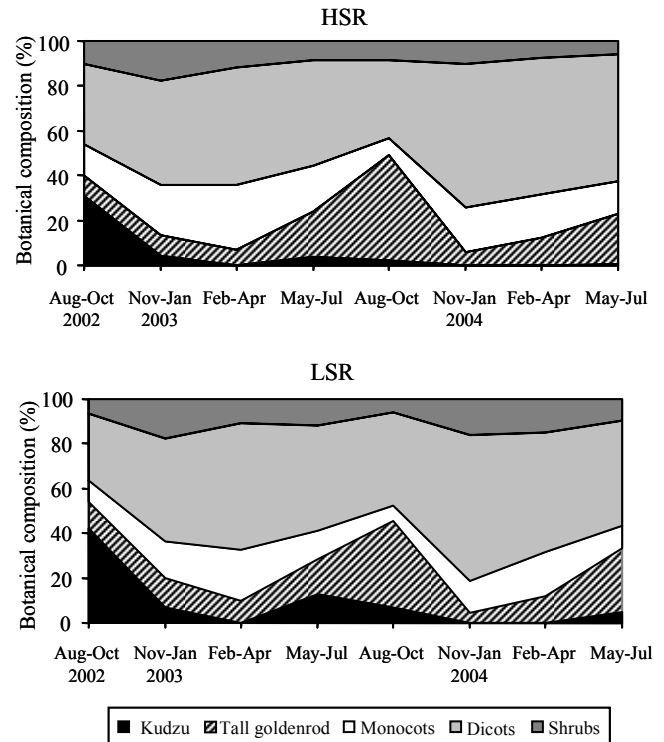


Figure 2. Changes in the botanical composition of vegetation at high and low stocking rates. Dicots exclude kudzu and tall goldenrod.

between the two stocking rates (31.2% for HSR and 42.1% for LSR, $p>0.05$). Then the composition decreased markedly with cattle grazing, though the low values from winter to spring (Nov.-Jan. and Feb.-Apr.) were partly due to leaf fall. In both the first (Aug., 2002 to Jul., 2003) and

Table 1. Yearly means of the botanical composition of vegetation at high and low stocking rates

Plant species	HSR		LSR		Significance	
	1st year	2nd year	1st year	2nd year	Stocking rate	Year
Kudzu	10.1 ^c	0.7 ^a	15.2 ^d	2.8 ^b	*	**
Tall goldenrod	10.0 ^a	20.4 ^b	12.0 ^a	20.8 ^b	NS	**
Monocots						
<i>Agropyron tsukusiense</i> Ohwi	7.9	7.4	7.4	5.6	NS	NS
var. <i>transiens</i> Ohwi						
<i>Miscanthus sinensis</i> Anderss.	5.5 ^b	1.3 ^a	4.3 ^b	0.6 ^a	NS	**
<i>Poa sphondylodes</i> Trin.	1.3	1.4	1.3	2.1	NS	NS
<i>Poa annua</i> L.	1.9 ^b	1.7 ^b	0.5 ^a	1.3 ^{ab}	*	NS
Dicots						
<i>Galium spurium</i> L.	5.7 ^{bc}	1.2 ^a	7.7 ^c	3.6 ^b	*	**
var. <i>echinospermon</i> Hayek						
<i>Clematis apiifolia</i> DC.	5.5 ^b	1.9 ^a	6.0 ^b	4.2 ^b	NS	**
<i>Torilis scabra</i> DC.	3.7	4.8	4.3	5.0	NS	NS
<i>Stellaria aquatica</i> Scop.	1.0 ^a	9.1 ^c	1.0 ^a	5.3 ^b	NS	**
Shrubs						
<i>Rosa multiflora</i> Thunb.	3.0 ^a	4.4 ^{ab}	4.6 ^{ab}	6.7 ^b	*	*
<i>Rubus hirsutus</i> Thunb.	5.8 ^b	2.1 ^a	5.4 ^b	3.2 ^a	NS	**
<i>Lonicera japonica</i> Thunb.	3.2 ^b	1.4 ^a	1.5 ^a	1.0 ^a	NS	*
<i>Broussonetia kaempferi</i> Sieb.	0.8 ^{ab}	0.3 ^a	0.9 ^b	0.4 ^{ab}	NS	*

** $p<0.01$, * $p<0.05$, NS: $p>0.05$.

a, b, c, d Values followed by different letters within each species are significantly different at $p<0.05$.

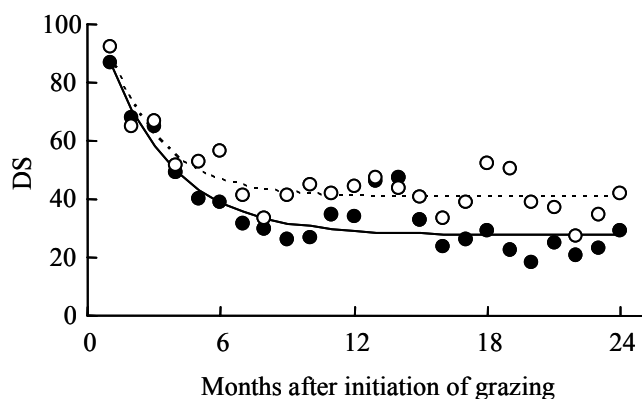


Figure 3. Changes in the degree of succession (DS) of vegetation at high (●) and low (○) stocking rates. Regression equations are: $Y_{HSR} = 27.7+(110.3-27.7)\exp(-0.33t)$ ($r = 0.911, p<0.001$) for high stockin rate; $Y_{LSR} = 40.5+(113.7-40.5)\exp(-0.41t)$ ($r = 0.884, p<0.001$) for low stocking rate, where t denotes time (months) after the initiation of grazing.

the second (Aug., 2003 to Jul., 2004) years, the composition of kudzu at HSR was significantly lower than that at LSR (Table 1, $p<0.05$).

The composition of tall goldenrod increased markedly after 12 months from the initiation of grazing, i.e. in the second year of grazing (Figure 2 and Table 1 ($p<0.05$)), receiving no significant effect of stocking rate ($p>0.05$). The effect of grazing on the composition of other major plant species was not constant. Species such as *Miscanthus sinensis* Anders. and *Rubus hirsutus* Thunb. decreased through the two years, whereas others such as *Stellaria aquatica* Scop. and *Rosa multiflora* Thunb. increased.

Degree of succession

DS declined during the first 12 months after the initiation of grazing, and reached a nearly steady level (an equilibrium) during the following 12 months (Figure 3):

$$Y_{HSR} = 27.7+(110.3-27.7)\exp(-0.33t) \quad (3)$$

$(r = 0.911, p<0.001)$

$$Y_{LSR} = 40.5+(113.7-40.5)\exp(-0.41t) \quad (4)$$

$(r = 0.884, p<0.001)$

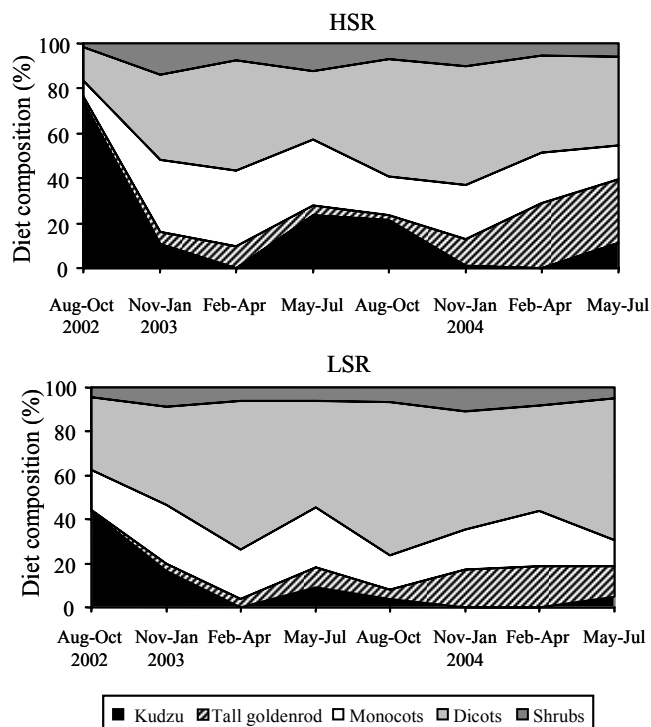


Figure 4. Changes in the botanical composition of diet of cattle at high and low stocking rates. Dicots exclude kudzu and tall goldenrod.

All parameters were significant ($p<0.01$). There were no significant differences between HSR and LSR in both the initial DS (110.3 vs. 113.7, respectively) and the relative rate of decrease (0.33 vs. 0.41 per month, respectively) ($p>0.05$). However, the asymptote was significantly lower at HSR than at LSR (27.7 vs. 40.5, respectively) ($p<0.01$), showing that the higher stocking rate resulted in greater retrogression of vegetation.

Botanical composition of diet

During the period immediately after the initiation of grazing (Aug.-Oct., 2002), kudzu accounted for the highest composition in diet of cattle grazing both paddocks (74.5% for HSR and 43.8% for LSR) (Figure 4). Then, the composition of kudzu in diet decreased in both paddocks, showing a significant effect of year (Table 2, $p<0.05$). The composition of kudzu was always higher at HSR than at

Table 2. Yearly means of the botanical composition of cattle diet at high and low stocking rates

Plant species or group	HSR		LSR		Significance	
	1st year	2nd year	1st year	2nd year	Stocking rate	Year
Kudzu	27.1 ^{d2)}	8.4 ^b	17.4 ^c	2.1 ^a	**	*
Tall goldenrod	5.3 ^a	17.8 ^b	4.2 ^a	13.6 ^b	NS	*
Monocots	25.5	19.8	23.5	17.6	NS	NS
Dicots ¹	33.1 ^a	47.0 ^b	48.8 ^b	59.2 ^c	*	*
Shrubs	8.9	7.0	6.1	7.5	NS	NS

** $p<0.01$, * $p<0.05$, NS: $p>0.05$.

^{a, b, c, d} Values followed by different letters within each species or group are significantly different at $p<0.05$.

¹ Excluding kudzu and tall goldenrod.

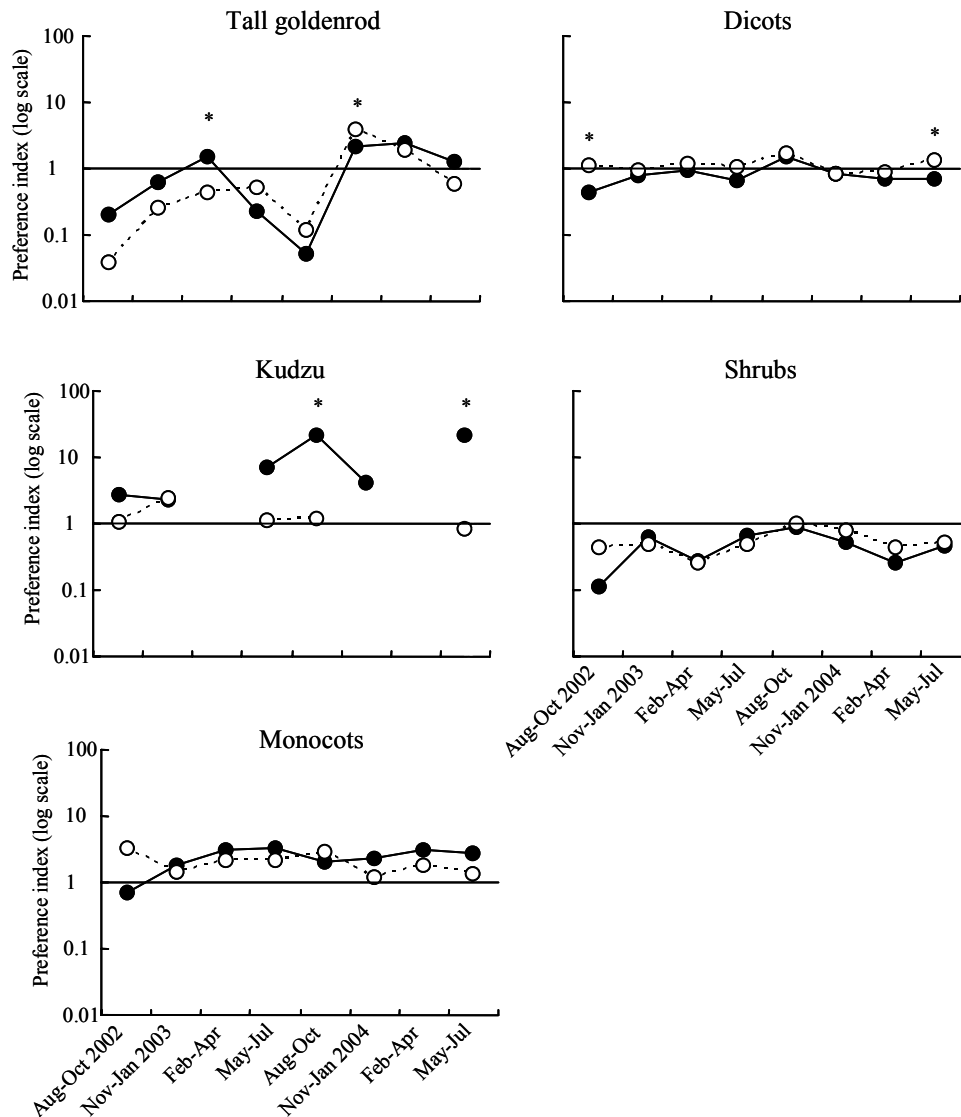


Figure 5. Changes in the relative preference index for kudzu, tall goldenrod and three plant groups at high (●) and low (○) stocking rates. Dicots exclude kudzu and tall goldenrod. An asterisk indicates a significant difference between the two stocking rates at $p < 0.05$. Refer to the text for missing data for kudzu.

LSR (Table 2, $p < 0.05$). Although the composition of tall goldenrod in diet increased significantly through the two years ($p < 0.05$), it was not affected by stocking rate ($p > 0.05$).

Relative preference index

Kudzu was highly preferred by animals at HSR and preferred or neutrally selected (no preference or avoidance) by animals at LSR, showing higher preference at a higher stocking rate (Figure 5). Tall goldenrod was generally avoided during the first five periods (Aug., 2002 to Oct., 2003), but neutrally selected or preferred thereafter (Oct 2003 to Jul, 2004). The selectivity for this species was particularly low in the late summer to mid autumn (Aug.-Oct.). Monocots, dicots (excluding kudzu and tall goldenrod) and shrubs were almost constantly preferred, neutrally selected and avoided by animals, respectively.

DISCUSSION

In this study, two dominant species at the commencement, kudzu and tall goldenrod showed different responses to cattle grazing. Kudzu was generally preferred by cattle throughout all grazing periods. And kudzu would have a low defoliation tolerance because this species has dormant latent buds above the ground where they encounter defoliated damage by cattle. Therefore, the composition of kudzu decreased because of a high preference by cattle and low defoliation tolerance. Moreover, as the RPI of kudzu at HSR was generally higher than that at LSR throughout all grazing periods, a lower composition of vegetation was showed at HSR than at LSR.

Tall goldenrod is an aggressive invading species that spreads with clonal growth, and is often a dominant plant in

abandoned fields and pastures, as well as roadsides (Root, 1996; Meyer, 1998; Stoll et al., 1998; Walck et al., 1999). Middleton (2002) stated that cattle grazing could provide tall goldenrod with bare ground to invade. And this species has a high defoliation tolerance because of having rhizomes and dormant latent buds below the ground (Meyer and Schmid, 1999). Tall goldenrod could increase in the composition of vegetation because of a high defoliate tolerance and low preference by cattle, particularly when it grew aggressively in the summer season. Seasonal variance in the RPI of tall goldenrod was larger than that of kudzu, monocots, dicots and shrubs. Stems of tall goldenrod emerge in a rosette form from overwintering rhizomes in spring, and grow vegetatively to reach approximately 2 m in height; with lignification occurring in late summer to early autumn (Meyer, 1998). Thus, it would be suggested that a plant species that dramatically changed their morphology within a year had a great variance in RPI. Tall goldenrod was generally avoided during the first five periods, but neutrally selected or preferred thereafter. Van Dyne and Heady (1965) noted that diet selection changed according to the decrease in herbage availability. Therefore, further analysis of herbage availability needs to be conducted. Furthermore, plants that were small and had low abundance in the paddocks could not be precisely recorded by the methods used in this study; thus, it is likely that diet and vegetation compositions of these species could have been underestimated.

The changes in the number of plant species and DS in both paddocks showed the retrogression of vegetation due to cattle disturbances, with the high stocking rate leading to a lower degree of succession than the low stocking rate. This result is in agreement with the general theory that retrogression occurs faster and greater in heavily grazed than lightly grazed areas (Holechek, 2004). In this study, it was showed that cattle grazing, particularly at a high stocking rate, was effective in the management of vegetation of an abandoned orchard. However, Williams and Ashton (1987) stated that cattle activity could not inhibit growth of established unpalatable vegetatively reproducing shrubs on grass and heathlands. Middleton (2002) also stated that cattle grazing actually promote the invasion of woody species. In this study, the composition of *Rosa multiflora* Thunb., a shrub with spines, increased during the two year period of grazing. As the composition in diet of shrubs such like *Rosa multiflora* Thunb. was low throughout all periods, attention needs to be paid to the increase in the composition of poisonous and unpalatable shrubs.

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