SEASONAL CHANGE OF BAHIAGRASS TILLER UNDER DIFFERENT NITROGEN FERTILIZER RATE AND CUTTING HEIGHT

(Perubahan Musiman Tiller Bahiagrass pada Tingkat Pemupukan Nitrogen dan Tinggi Pemotongan yang Berbeda)

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ABSTRAK

Perubahan musiman tiller bahiagrass pada tingkat pemupukan nitrogen dan tinggi pemotongan yang berbeda telah diteliti selama periode 4 tahun. Dinamika tiller diamati dengan menggunakan teknik tagging, dengan perlakuan dua level nitrogen [5 g N/m^2/tahun (LN) dan 20 g N/m^2/tahun (HN)] x tiga level tinggi pemotongan di atas permukaan tanah [20 mm (LH), 120 mm (MH) dan 220 mm (HH)]. Total kepadatan tiller pada tahun pertama atau kedua meningkat pada perlakuan LH, sedangkan pada perlakuan MH dan HH menurun. Selanjutnya kepadatan mencapai nilai konstan yang memperlihatkan fluktuasi musiman yang terdiri dari peningkatan pada musim semi dan selanjutnya menurun. Penurunan tinggi pemotongan selalu meningkatkan TAR, dan peningkatan nitrogen selalu meningkatkan TAR pada perlakuan LH. TDR meningkat dari musim semi kemusim panas dan selanjutnya menurun. Pada musim panas dan gugur, perlakuan HN/LH selalu memperlihatkan TDR yang lebih tinggi dibanding perlakuan yang lain. Perimbangan TAR dan TDR pada perlakuan LH meningkat dengan meningkatnya nitrogen. Pada bulan yang lain perimbangan selalu mendekati nol atau negatif, kecuali pada perlakuan LH pada tahun pertama. Half-life tiller cenderung meningkat seiring menurunnya tingkat nitrogen dan tinggi pemotongan. Tiller yang muncul pada musim gugur hidup paling lama dan yang muncul pada musim semi hidup paling singkat. Hasil penelitian memperlihatkan bahwa bahiagrass dapat hidup pada kondisi manajemen yang berat melalui peningkatan daya hidup tiller. Hal ini merupakan mekanisme penting untuk tingkat ketahanan pada rumput ini. Selain itu bahiagrass toleran terhadap pemotongan berat (perlakuan LH) juga melalui peningkatan TAR dan selanjutnya kepadatan tiller.

Kata kunci: Bahiagrass, Dinamika tiller, Pupuk nitrogen, Tinggi pemotongan,

ABSTRACT

Seasonal change of bahiagrass tiller under different nitrogen fertilizer rate and cutting height was investigated over a 4-year period. Tiller dynamics were examined using a tagging technique, with treatments of two nitrogen rates [5 g N/m2 /year (LN) and 20 g N/m2/year (HN)] x three cutting heights above ground level [20 mm (LH), 120 mm (MH) and 220 mm (HH)]. Total tiller density in the first one or two years increased in LH treatments, whereas that in MH and HH treatments decreased. Thereafter, the density reached annually constant values, showing seasonal fluctuations consisting of the spring increase and the subsequent decrease. The decrease in cutting height usually increased TAR, and the increase in nitrogen rate often increased TAR in the LH treatments. TDR increased from spring to summer and decreased thereafter. In summer and autumn, HN/LH treatment often showed higher TDR than the other treatments. The balance in LH treatments increased with increasing nitrogen rate. In the other months, the balance was usually close to zero or negative, except for LH treatments in the first year. The half-life of tillers tended to increase with decreasing nitrogen rate and cutting height. Tillers appearing in autumn survived longest, and those appearing in spring shortest. The results show that bahiagrass copes with severe management conditions by increasing its tiller longevity. This is taken as an important mechanism for the high persistence of the grass. In addition, bahiagrass tolerates severe defoliation (LH treatments) also by increasing TAR and thus tiller density

Key words: Bahiagrass, Tiller dynamics, Nitrogen fertilizer, Cutting height

INTRODUCTION

In grassland-based animal production systems, persistence of pasture is a crucial factor in the sustainability of the systems. It is therefore important to understand the mechanisms behind the persistence of a pasture. In a grass pasture, persistence is largely dependent on the ability of the plant to maintain a high tiller density, which in turn depends on tiller appearance rate (TAR), tiller death rate (TDR) and longevity of individual tillers.

Bahiagrass, a sod-forming, warm season perennial, forms a highly persistent sward which tolerates severe defoliation (Stanley *et al*., 1977; Hirakawa *et al*., 1985; Hirata, 1993a,b; Hirata and Ueno, 1993; Pakiding and Hirata, 1999). However, little information is available about the effect of management on tiller dynamics of this grass. Previous studies have reported that the tiller dynamics of grass sward are greatly affected by the interspecific competition between individual plants growing as a crowded community (Bullock *et al*., 1994; Lemaire and Chapman, 1996). This is closely related to the sward management, such as intensity of defoliation and nitrogen rate (Chapman *et al*., 1983; Fulkerson *et al*., 1993; McKenzie, 1997).

The intensity of defoliation of the sward determines the amount of plant part living as stubble. The death and accumulation of a large amount of this part may reduce light and temperature in the tiller bases, restricting TAR and survival of existing tillers (Ong *et al*., 1978). Similarly, despite the positive effect of N fertilizer on TAR, applying N fertilizer can lead to lower tiller density because of rapid development of leaves, increasing mutual shading and accelerate TDR (Lemaire and Chapman, 1996). Therefore, to develop understanding the mechanism of persistence in response to these managements, the experiment was carried out to examine the effects of nitrogen fertilization rate and cutting height on tiller dynamics of bahiagrass in terms of seasonal changes in TAR, TDR and survival of tillers appearing in different seasons.

MATERIALS AND METHODS

The experiment was conducted in an established sward of Pensacola bahiagrass (*Paspalum notatum* Flügge). Six 0.75 by 1.20 m plots were set on the sward, and a factorial arrangement of two nitrogen fertilization rates (LN, HN) x three cutting heights (LH, MH, HH) with three replications was randomly allotted to the plots. The nitrogen rate for LN and HN was 5 and 20 g N/m^2/year, respectively. In addition to nitrogen, each plot received 10 g P_2O_5/m^2/year and 10 g K_2O/m^2/year. The sources of N, P_2O_5 and K_2O were ammonium sulfate, superphosphate and potassium sulfate respectively. The fertilizer was applied in mid-April, early July and early September at equally-split rates. The plots were cut from May to October at half monthly intervals in fist year and at monthly intervals in the following years. The cutting height for LH, MH and HH was 20, 120 and 220 mm above ground level, respectively.

Three 200 by 200 mm permanent quadrates were established in each plot. All live tillers within the quadrates were tagged in the beginning of experiment with a wire ring (9 mm in diameter) with a colored bead at their base and grouped as the original tillers. This group consisted of tillers with different, unknown ages. Subsequent tagging was conducted at monthly intervals, when all quadrates were examined, any new tillers were tagged and the rings were removed from dead tillers. The number of new tillers tagged and the number of rings removed from dead tillers were recorded. Beads of a different color were used at each tagging. The tillers were classified as dead when all parts were completely dried.

The tillers were classified into the following 16 age categories according to the period of their initiation, with first category being the original tillers and the remaining 15 categories being tillers initiated in the following seasons.

Survived proportion of tillers (S) with time (t, days) was fitted by an exponential equation as:

$$S = \exp(-bt) \tag{1}$$

where b is the decay constant (proportion/day). Then the half-life of tillers ($t_{1/2}$) [the time (d) taken for half the tillers to die] was calculated as:

$$t_{1/2} = \ln 2/b \tag{2}$$

RESULTS

Tiller density

Total tiller density at the first tagging tended to be higher in HN treatments than in LN treatments (Figure 1). In the first one or two years, the total tiller density in LH treatments increased, whereas that in MH and HH treatments decreased. Thereafter, in the third and fourth years, the density reached annually constant values, showing seasonal fluctuations consisting of the spring increase and the subsequent decrease. The density of original tillers decreased with time and accounted for 20.5, 18.2, 31.6, 53.8, 24.5 and 34.8% of the final total tiller density in LN/LH, HN/LH, LN/MH, HN/MH, LN/HH and HN/HH, respectively. On the other hand, proportion of tillers appearing in the following seasons increased.

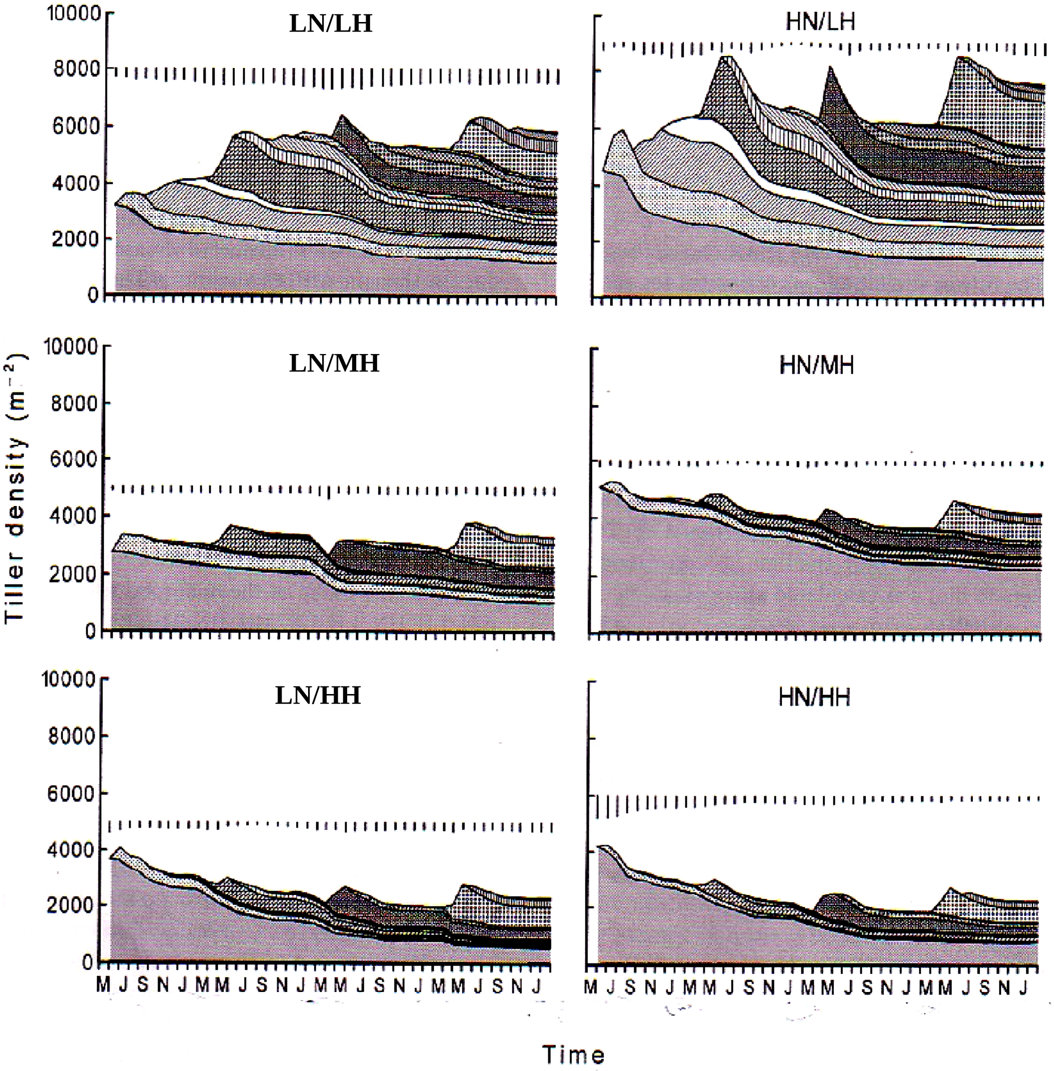

Figure 1. Tiller density in different seasons of initiation. Vertical bars show standard errors of the means of total tiller density.

Tiller appearance and death rate

Seasonal patterns of TAR, TDR and their balance were similar on a per unit ground area basis and on a relative basis (Figure 2). TAR was high in June in the first year, and in April and May in the following years. In the other months, TAR in LH treatments usually still maintained high values (above 5 tillers/m^2/day) in the first year and from June to October in the following years, whereas that in the other treatments was usually low or close to zero. The decrease in cutting height usually increased TAR. The increase in nitrogen rate almost always increased TAR in LH treatments, but had no consistent effect in the other treatments.

TDR increased from spring to late summer and decreased thereafter in all the treatments. In summer to autumn, HN/LH treatment usually showed higher TDR than the other treatments.

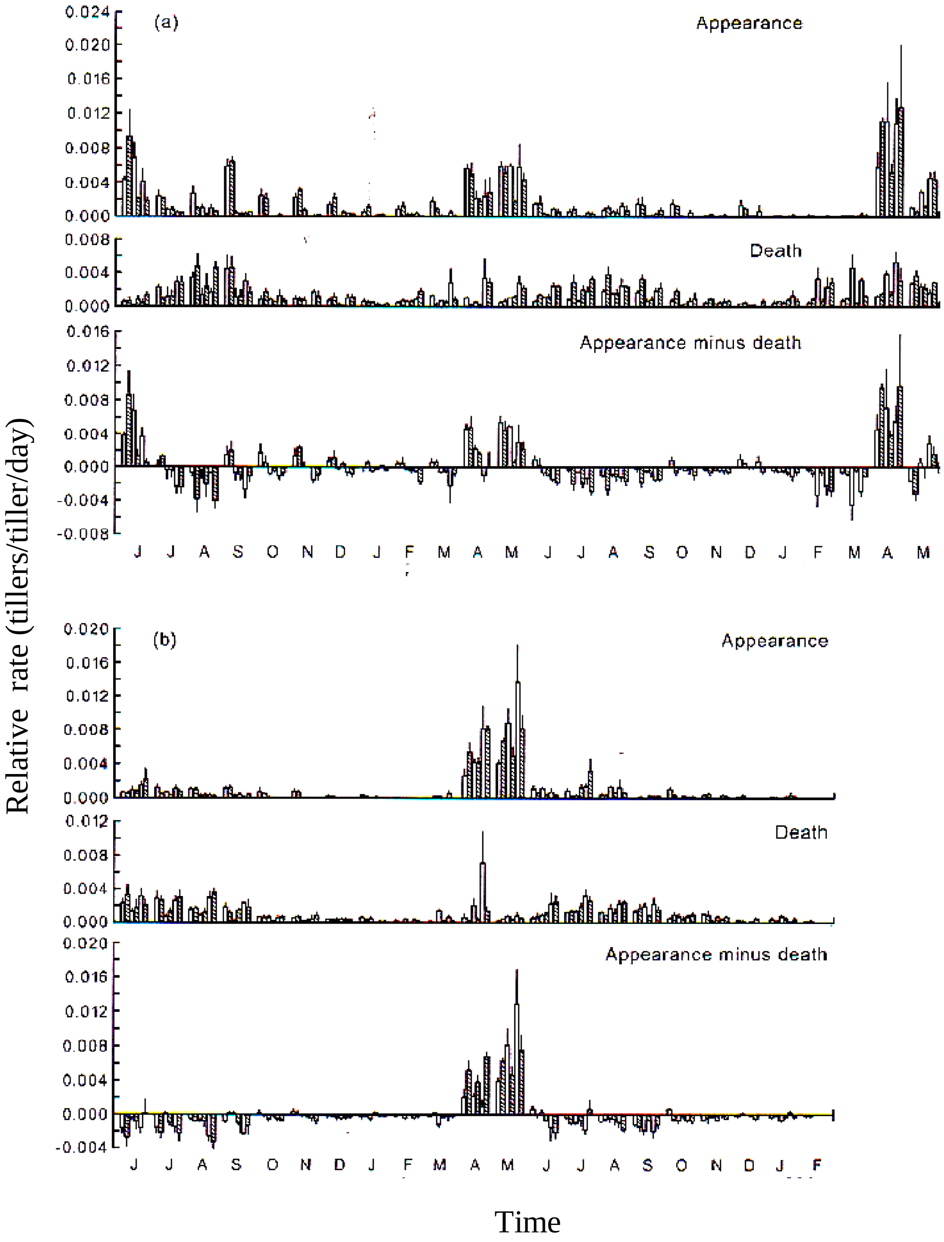

Figure 2. Relative tiller appearance rate, tiller death rate and their balance (appearance rate minus death rate) in the first (a) and second (b) two years of the experiment. Six columns in each month indicate LN/LH, HN/LH, LN/MH, HN/MH, LN/HH and HN/HH from left to right. Vertical bars show standard errors of the means.

The balance between TAR and TDR was positive and high in June in the first year, and April and May in the following years, except for May in the thirth year. In these months, the balance in LH treatments increased with increasing nitrogen rate. In the other months, the balance was usually close to zero or negative, except for LH treatments in the first year.

Tiller longevity

Survival of tillers was affected by nitrogen and cutting height treatments (P<0.05) (Table 1). The longevity tended to increase as the nitrogen rate and the cutting height decreased. Tillers in LN/LH treatment survived longest (half-life=537 day) and those in HN/HH treatment shortest (half-life=408 day). The survival of tillers was also affected by the time of their appearance (P<0.05) (Table 1). Tillers appearing in summer and autumn survived longest (half-life=506 to 521 day) and those appearing in spring and winter shortest (half-life=441 to 436 day).

Table 1. Regression coefficient (decay constant), half-life and correlation coefficient for survival of tillers in different treatments and seasons of initiation (Equations 1 and 2)

Category	Regression coefficient (proportion/day	Half-life (day)	Correlation coefficient	P	n
Treatment					
LN/LH	0.00129^{a}	537	-0.867	<0.001	120
HN/LH	0.00135^{a}	513	-0.865	<0.001	120
LN/MH	0.00136^{a}	510	-0.889	<0.001	104
HN/MH	0.00142^{ab}	488	-0.714	<0.001	116
LN/HH	0.00158^{bc}	439	-0.817	<0.001	111
HN/HH	0.00170^{c}	408	-0.750	<0.001	84
Season of initiation					
Spring	0.00159^{a}	436	-0.888	<0.001	144
Summer	0.00137^{b}	506	-0.827	<0.001	216
Autumn	0.00133^{b}	521	-0.814	<0.001	175
Winter	0.00157^{a}	441	-0.760	<0.001	120

^{a,b,c}Values followed by different letters with each category are significantly different at P<0.05.

DISCUSSION

The tiller density at the first tagging tended to be higher in HN treatments than in LN treatments (Figure 1). The greater initial tiller density at higher nitrogen rate would be attributed to the fact that the nitrogen treatment was started one and half months before the first tagging (mid-April). Therefore, it is considered that higher nitrogen rate raised TAR and/or reduced TDR before the first tagging (Fulkerson *et al*., 1993).

While the onset of the trial, the total tiller density changed considerably. The densities increased to reach annually constant density one year later in HN/LH and two years later in LN/LH treatment. On the other hand, the density decreased to reach annually constant density two years later in MH and HH treatments. This supports the results of Grant *et al.* (1981), Korte (1986), and Hirata (1993b) who found that severer cutting could be used as an option to increase tiller density.

In all treatments, tillering was most rapid in April and May (Figure 2). Therefore, the increase in the total tiller density in LH treatments and the decrease in MH and HH treatments before reach annually constant density are mainly affected by the patterns of TAR and TDR in the other months. With exception in April and May, the balance between TAR and TDR in this period was usually positive in LH treatments, whereas the balance was usually negative in MH and HH treatments. However, after the constant density was reached, the balance was positive only in April and May and usually negative in other months in all treatments. A similar period of intense tillering during late spring has been observed previously in perennial ryegrass sward under grazing (Chapman *et al*., 1983; Korte *et al*., 1984; Da Silva *et al*., 1993) or cutting (Korte, 1986).

During summer to autumn, TAR tended to decrease, whereas TDR increased. This probably associates with developing of reproductive tillers. The buds at the bases of flowering tiller were restrained from developing by hormonal influences from elongating stem internodes or developing inflorescence (Jewis, 1972), and by competition for assimilates (Ong *et al*., 1978). Defoliation of reproductive tillers removed these effects, allowing the buds to develop (Korte, 1986). This resulted a second tillering flush in autumn in perennial ryegrass (Garay *et al*., 1997). In this study, however, the tillering flush was not found after defoliation of reproductive tillers. The high TDR in this period may be also partly due to initiation of reproductive tillers. The reproductive tillers die soon after appearing, and therefore death of reproductive tillers can be considered to contribute to the greater TDR in this period. Thom (1991) suggested that reproductive tillers have a greater overall probability of drying than do vegetative tillers.

Increasing nitrogen fertilization rate increased TAR in LH treatments, but had no consistent effects in MH and HH treatments (Figure 2). This may be a result of the positive effect of N fertilization on leaf appearance rate (Vine, 1983; Bélanger, 1998; Hirata, 2000) which generates the increase in production of tiller sites (Davies, 1974; Simon and Lemaire, 1987). However, the appearance of these potential tillers is restricted by the increase in leaf area index (Simon and Lemaire, 1987). Therefore, it can be considered that the positive effect of nitrogen fertilization on TAR in LH treatments is because of low leaf area index in these treatments, especially in the beginning of cutting. The positive effect of N fertilization on TDR in LH treatments, probably relates to this phenomenon. As suggested by Lemaire and Chapman (1996) that applying N fertilizer could increase TDR because of the rapid development of leaf area index. Similarly, Sato *et al*. (1967) studying in orchardgrass noticed that some of the tillers appearing in April and May died in this period because they became weaker under thick mutual shading.

The survival of tillers decreased as the cutting height and nitrogen fertilization rates increased (Table 1). The survival of tillers appearing after the first tagging in MH and HH treatments reduced presumably because of competition. The herbage mass in these treatments was always high, and therefore the accumulation of foliage and surface litter in these treatments (Hirata and Ueno, 1993) reduced solar radiation and temperature at the soil surface, depressing the development of daughter tillers (Ong *et al*., 1978). In this circumstance, the daughter tillers are entirely dependent upon the parent tillers for nutrients and energy supplies (Ong, 1978). However, as an adaptation of the parent plants to severe competition, allocation of carbohydrate is mainly diverted for elongation of leaves, rather than for developing of daughter tillers (Simon and Lemaire, 1987). Similarly, Davies *et al* (1983) demonstrated that more dry matter is allocated to the growth of existing tillers and less to the development of new tillers in the shaded plants.

The effect of nitrogen fertilization rates on survival of tillers may associate with the above phenomenon. In fact that increase nitrogen fertilization rate increased the accumulation of herbage mass which finally generated the increase in competition.

The survival of tillers appearing in summer and autumn was superior to that of tillers appearing in spring and winter (Table 1). The long-life of autumn tillers has been reported previously with grazed bahiagrass (Pakiding and Hirata, 1999) and perennial ryegrass and prairie grass swards (Matthew *et al*., 1993). The long-life of these tillers may be attributable to the fact that the summer and autumn tillers initiated from reproductive tillers and replaced the space of reproductive tillers soon after they died. Therefore, these tillers are considered to be able to utilize substrates in stolons of dead reproductive tillers, which ensure survival (Matthew *et al*., 1989). Reproductive tillers in this experiment are developed in summer to early autumn.

CONCLUSIONS

Bahiagrass commonly forms a highly persistent sward. The results show that bahiagrass copes with severe management conditions (low nitrogen fertilizer and low cutting height) by increasing its tiller longevity. This is taken as an important mechanism for the high persistence of the grass. In addition, bahiagrass tolerates severe defoliation (LH treatments) also by increasing TAR and thus tiller density.

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