Original Article (Full Paper)

Effect of Weed Control Management on Herbage Yield, Quality and Wintering Ability in the Established Dwarf Napiergrass (*Pennisetum purpureum* Schumach)

Renny Fatmyah UTAMY, Yasuyuki ISHII[1], Sachiko IDOTA[1] and Lizah KHAIRANI[2]

Interdisciplinary Graduate School of Agriculture and Engineering, University of Miyazaki, Miyazaki, Japan
[1] *Faculty of Agriculture, University of Miyazaki, Miyazaki, Japan*
[2] *Graduate School of Agriculture, University of Miyazaki, Miyazaki, Japan*

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ABSTRACT In our previous extension activity of dwarf variety of late-heading type (DL) napiergrass (*Pennisetum purpureum Schumach*) to southern Kyushu, weed control was found to be a crucial factor for obtaining good establishment and considerable herbage dry matter (DM) yield in an established year. The objective of this study was to examine the effect of several weed control practices, *i.e.* mixed sowing of annual setaria, which has no regrowth ability in stem-elongated tillers, paper-mulching and hand-weeding, compared with no weeding control on DM yield, quality and wintering ability of this species in 2008 and 2010. Growth attributes including herbage yield, *in vitro* DM digestibility (IVDMD) and crude protein (CP) content as herbage quality and percentage of overwintered plants (POP) as wintering ability of this species were determined in both years. Weed control practices had a significantly ($P < 0.05$) positive effect on plant height, tiller density, percentage of leaf blade and leaf area index in DL napiergrass, compared with no-weeding control, and paper-mulching had the highest yields in both years and highest POP at 100% in 2008-2009. Setaria-sowing had a partially mitigating effect of weed damage on growth of DL napiergrass, while additive DM gain from setaria could compensate the yield decrease in DL napiergrass. Neither IVDMD nor CP was affected by any weed control practice in either year. Thus, paper-mulching and annual setaria-sowing could be a good proposal in weed control management of DL napiergrass.

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Key words: annual setaria, dwarf napiergrass, herbage yield, paper mulch, weed control

Introduction

In many agricultural systems around the world, crop yields decrease due to various biological factors such as damage from plant diseases, pest insects and weeds. Competition between crops and weeds is one of the major obstacles in the establishment and early growth of crops, including forage crops. Hand-weeding was a sole weed control practice, which caused physical and spiritual burden for farmers before the launch of herbicides. Therefore, invention of easy and environmentally effective weed control technology has been strongly desired.

The competition between forage crops and weed for light, nutrients and water is the main problem for cultivation, especially at the establishment and early growth of the crops. Inadequate soil fertility should stimulate the competition of forage crops with weeds (Miller and Stritzke 1995). Weed invasion into the established forage crop fields is a visible sign of management problems (Berberet *et al*. 1987). Damages to forage crop production by weeds are mediated principally from loss in growth rate and yield, and secondarily from decline in forage quality. If the competition is so severe, forage crops might be killed at the early growth of establishment (Masters and Mitchell 2007). However, in forage crop production, use of herbicide should be avoidable because of the negative effect on livestocks and increase in production cost (Sakai and Kawanabe 1981).

Weeds in the inter-row space of dwarf variety of late-heading type (DL) napiergrass (*Pennisetum purpureum Schumach*) are normally controlled by hand-mowing machine 2-3 times before the first defoliation of this grass. Repeated weed control is essential until the leaf canopy is well established at the establishment. Even though close spacing is desirable from the weed control point of view, weeds do invade even at 50 x 50 cm plant spacing. Based on extension activity of DL napiergrass to southern Kyushu, weed control management is found to be a crucial factor to obtain good establishment of this grass and

Correspondence: Yasuyuki ISHII (tel・fax: +81-(0)985-58-7251, e-mail: yishii@cc.miyazaki-u.ac.jp)

achieve considerable herbage yield in the established year (Utamy *et al.* 2011).

Mulching at the inter- and intra-row spaces reduces weed problems by preventing the seed germination and suppressing growth of emerged weed seedlings, resulting in facilitating soil fertility and plant productivity (Salau *et al*. 1992). Mulching is a well-known method for the establishment of horticulture crop such as turmeric (*Curcuma longa*), lettuce (Moniruzzaman 2006), and tomato (Anzalone *et al*. 2010). In the grass cultivation, mulching is often used by living mulch or cover crops (Steinmaus *et al.* 2008), such as white clover (Deguchi *et al*. 2005), legume (Hiltbrunner *et al.* 2007) and hairy vetch (Mohammadi 2010). Mulching materials are greatly variable in costs, prevention of nutrient loss, permeability of rainfall, influences to the soil temperature, adding organic matters and dispersal problems once crops are harvested (Carter and Johnson 1988). Paper mulch is designed to act at the establishment and early growth of crops and to break down later in the growing season by soil microorganisms, which has no detrimental effect on agricultural environments and requires no removal cost because it can be plowed into soils after the crop harvest. However, paper mulch has not been applied to DL napiergrass as weed control management.

The other way for weed control management is the oversowing of annual grass species to compete weed at the early growth of perennial forage crops. DL napiergrass was oversown with temperate Italian ryegrass (*Lolium multiflorum* Lam.) to get herbage in the spring-early summer seasons (Ishii *et al.* 2005). In the present, tropical annual setaria (*Setaria italica* cv. Natsukanso), released from Snow Brand Seed Co. Ltd., is utilized as once-cutting herbage with no regrowth ability if it starts stem elongation at the harvest, gives early summer growth, and should be also ideal to suppress summer weeds at the early growth of perennial forage species (Wakamatsu 2004).

Therefore, the objectives of this study were to examine the effect of weed control management on dry matter yield, herbage quality and wintering ability in the established DL napiergrass by paper-mulching, oversowing of annual setaria and several time of weeding practices, compared with no weeding control in two years.

Materials and Methods

Site, treatments and management in 2008

This experiment was conducted in Sumiyoshi Livestock Science Station (SLSS, 31°98′N, 131°46′E, 10 m above sea level) in 2008. A soil is sandy Regosols. Mean temperature in the growing season from May to November was 22.3°C and total precipitation in this period was 2398 mm based on data by Miyazaki Meteorological Observatory.

The experiment was arranged in a Latin square design of 3 weed control treatments with 3 replications. Three weed control treatments were P-W, S+W and S-W, which were the combination of 3 practices, *i.e.* interrow space was covered with paper mulch (produced by Sanyo Seishi Co. Ltd., Tottori, Japan) and no hand-weeding (abbreviated as P-W), oversown in broadcasting with annual setaria (*Setaria italica,* cv. Natsukanso) at 2 g/m^2, which has no regrowth ability in stem-elongated tiller, and weeded by hands (as S+W), or no hand-weeding (as S-W). The area of each plot was 9 m^2 (3 x 3 m), including 4 rows and 7 plants (per each row) of DL napiergrass planted at 2 plants/m^2 (1 and 0.5 m in inter- and intra-row spacing, respectively) on 21 June, 2008. The spacings between plot and replication were 1 and 1 m, respectively.

The field was cultivated by hand tractor once and no basal fertilizer was supplied before weed control practices and transplanting of DL napiergrass. No irrigation was applied to any plots. Compound fertilizer, containing 14% each of N, P_2O_5 and K_2O, was split-applied at 5 g each element/m^2 three times on 12 July, 29 July and 12 August, 2008. Ordinary weeding was imposed into the inter plot area by hand-moving machine twice on 19 and 29 July, 2008.

Site, treatments and management in 2010

This experiment was conducted in Kibana Agricultural Science Station (KASS, 31°83′N, 131°41′E, 31 m a.s.l.) in 2010. A soil is a volcanic ash. Mean temperature in the growing season from May to October was 23.9°C and total precipitation in this period was 1886 mm based on data by Miyazaki Meteorological Observatory.

The experiment was arranged in a randomized complete block design with 3 replications each containing 4 randomly allocated treatments. Four treatments were P+S-W, S+W, S-W and -W, which were the combinations of 3 weed control practices same as in 2008, *i.e.* interrow space was oversown in broadcasting with annual setaria (cv. Natsukanso) at 3 g/m^2, covered with paper mulch and no hand-weeding imposed (abbreviated as P+S-W), oversown with annual setaria, combined with and without hand-weeding (as S+W and S-W, respectively), and no weeding control (as -W). The area of each plot was 6 m^2 (2 x 3 m), including 4 rows and 5 plants (per each row) of DL napiergrass planted at 2 plants/m^2 on 27 May, 2010. The spacing between plot and replication was 1 and 0.75 m, respectively.

The field was cultivated by hand tractor once, and cattle manure, lime and dolomite fertilizers were applied uniformly to all plots as basal fertilizer at rates of 400, 100 and 100 g/m^2, respectively. No irrigation was applied to any plots, except for irrigation at transplanting of DL napiergrass to maintain soil moisture. Compound fertilizer, containing 14% each of N, P_2O_5 and K_2O, was split-applied at 5 g each element/m^2 four times on 25 May, 22 June, 16 July and 16 August, 2010. Ordinary weeding was imposed into the inter plot area by hand-moving machine twice on 22 June and 16 July, 2010.

Data collection and analytical procedures

Growth attributes and dry matter (DM) yield

Growth attributes of DL napiergrass, such as plant height and tiller density, were determined at 10 plants per replication three times on 19 July, 29 July and 12 August in the first- and on 13 November in the second-defoliated plants in 2008, and 6 plants per replication on 16 July and 16 August in the first- and on 16 September and 18 October in the second-defoliated plants in 2010.

In both years, DM yield of DL napiergrass was determined randomly at 2 plants per replication defoliated at 10 cm above the ground on 12 August and 13 November, 2008 and on 16 August and 18 October, 2010. Harvested samples were separated into leaf blade (LB), stem inclusive of leaf sheath (ST) and dead parts (D) and oven-dried at 70° C for 4 days to determine percentage of DM. DM yields of setaria and weeds in S+W and S-W plots of the first-defoliated DL napiergrass was determined randomly at three 0.25 m^2 quadrats per replication defoliated at the ground level twice on 19 and 29 July in 2008, and those in all 4 plots twice on 16 July and 16 August, 2010. Prominent weed species were recorded on 19 July, 2008 and on 16 July and 18 October, 2010. DM yield of weeds in the second-defoliated DL napiergrass was determined only on 18 October, 2010. Fresh weight in whole plants and percentage of DM in subsample dried at 70° C for 4 days were determined to calculate DM yield according to Tarawali *et al.* (1995) as DM yield (Mg/ha) = (Tot FW x (DWss/FWss) x 10^{-2}), where: Tot FW = total fresh weight (g/m^2), DWss = dry weight of the subsample in g, and FWss = fresh weight of the subsample in g.

Herbage quality

Ground samples to pass through 1 mm screen in herbage LB and ST of DL napiergrass were analyzed for *in vitro* DM digestibility (IVDMD) and crude protein (CP) content in both 2008 and 2010. IVDMD was measured in duplication by pepsin-cellulase digestion method (Goto and Minson 1977) using *in vitro* incubator (Model: ANKOM DAISY II, ANKOM Technology, NY, USA). Total nitrogen (TN) content was determined in duplication by nitrogen and carbon determination unit (Sumigraph NC-220F, Sumika Chemical Analysis Service, Ltd., Japan) to determine CP content by TN content multiplied with 6.25.

Sustainability

Overwintering ability was determined by assessing percentage of overwintered plants (POP) in 2009 and 2011, and number of regrown tillers (RTN) per plant for 6 plants per replication on 14 June, 2011.

Efficiency of weed control practices

Efficiency of weed control practices in plant parameters, such as DM yield, IVDMD and CP content, was evaluated by the percentage of plant parameter value in each weed control practice to that in no weeding control as follows:

In 2008,

Efficiency of weeding (%) = (Value in S+W - Value in S-W) / (Value in S-W) x 100,

Efficiency of paper-mulching (%) = (Value in P-W - Value in S-W) / (Value in S-W) x 100,

In 2010,

Efficiency of weeding (%) = (Value in S+W - Value in S-W) / (Value in S-W) x 100,

Efficiency of paper-mulching (%) = (Value in P+S-W - Value in S-W) / (Value in S-W) x 100,

Efficiency of setaria-sowing (%) = (Value in S-W - Value in -W) / (Value in -W) x 100.

Statistical analysis

Analyses of variance (ANOVA) were carried out using SPSS for Windows ver. 16.0, (IL; USA) by one-way analyses procedures. Difference in mean was tested using the least of significance difference (LSD) at 5% level. Regression analysis between setaria DM yield and weed DM yield was tested using the statistical functions of EXCEL (Microsoft Corp., Redmond, WA, USA) only in 2010. Proportional data were arcsine transformed (McDonald 2009) to meet the assumption of normality and homogeneous variances prior to carrying out ANOVA.

Results

Growth attributes

Weed control management had a significant ($P < 0.05$) effect on the plant height and tiller density of DL napiergrass in both 2008 and 2010 (Figure 1). Plant height was significantly higher ($P < 0.05$) in plots of paper-mulching (*P*-W and P+S-W) than in the other plots especially at the second defoliation, and was the lowest in no weeding (S-W) plots at the second defoliation in both years (Figure 1 (A) and (B)). Tiller density increased with time and was significantly ($P < 0.05$) higher in P-W and P+S-W plots than in the other plots, and was the lowest in S-W and -W plots at both the first and second defoliation in both years (Figure 1 (C) and (D)). Percentage of leaf blade was the significantly ($P < 0.05$) highest in S+W plot at the first defoliation in both years, while it did not differ among treatments at the second defoliation in either year (Figure 2). Leaf area index was the significantly ($P < 0.05$) highest in plots of paper-mulching (P-W and P+S-W) at

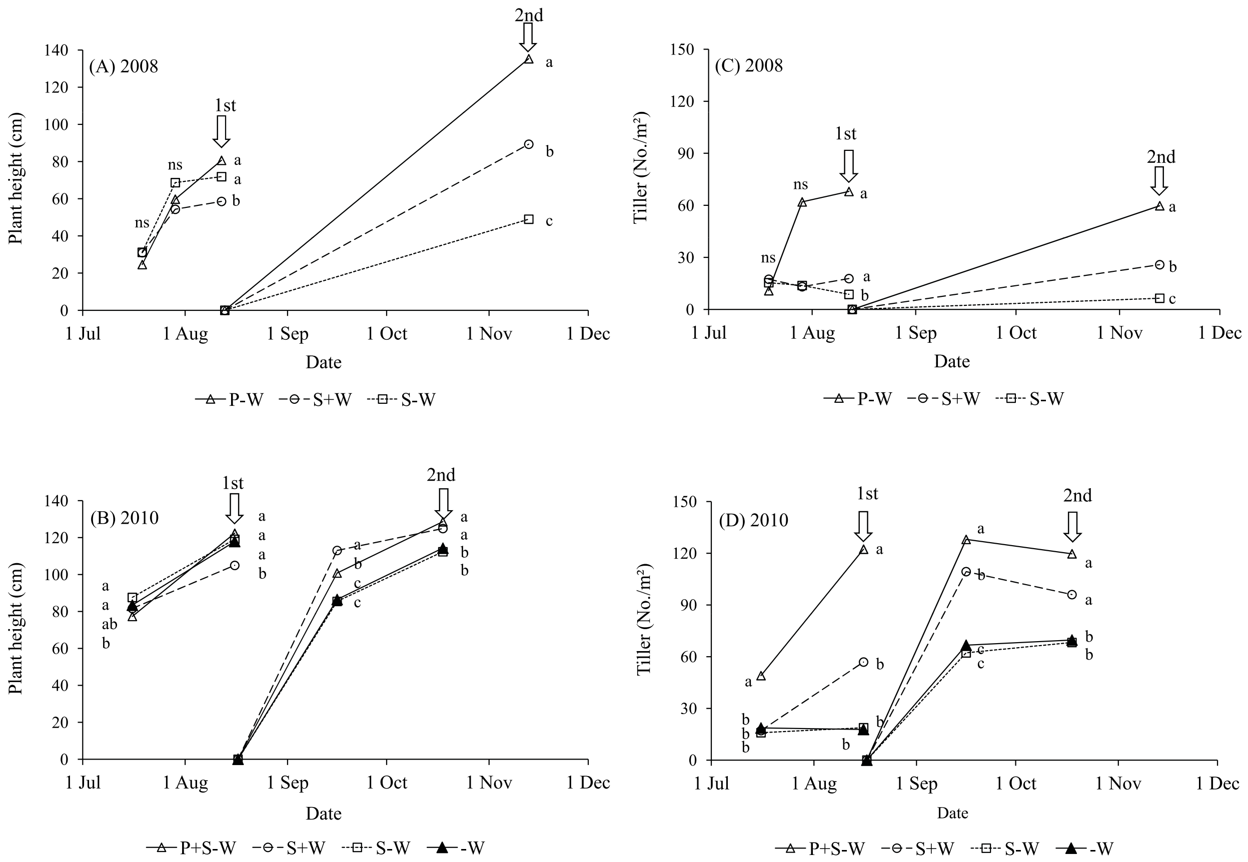

Figure 1 Changes in plant height and tiller density of dwarf-late (DL) napiergrass under several weed control management in 2008 (A, C) and 2010 (B, D).
Arrows indicate the time for the first (1st) and second (2nd) defoliation.
In weed control management, P denotes that interrow space was covered by paper mulch; S, oversown with setaria; W, weeding and -W, no weeding control.
Symbols with different letters are significantly different among weed control management at each date by LSD method at 5% level. ns: $P > 0.05$.

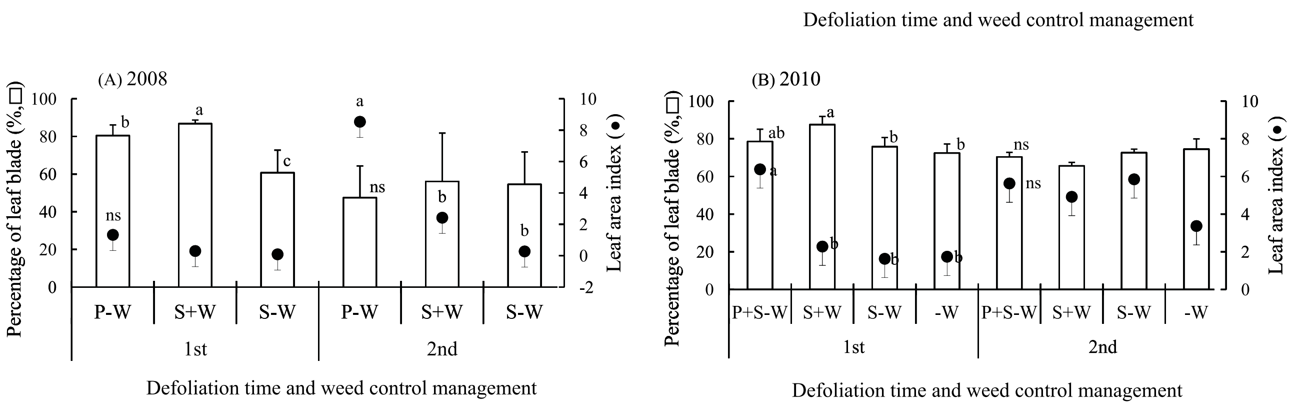

Figure 2 Percentage of leaf blade to plant dry weight (□) and leaf area index (●) of DL napiergrass under several weed control management in 2008 (A) and 2010 (B).
Values are expressed as means ± standard deviation of the mean.
As for the abbreviations of weed control management, refer to Figure 1.
Means with different letters are significantly different among weed control management at each defoliation time by LSD method at 5% level. ns: $P > 0.05$.

the second and first defoliation in 2008 and 2010, respectively, while it did not differ at the other defoliation in either year (Figure 2). Leaf area index ranged in 0.11-7.20 and 1.63-6.38 in 2008 and 2010, respectively.

DM yield

Weed control management had a significantly (P < 0.05) positive effect on DM yield of DL napiergrass in both 2008 and 2010 (Figure 3). The DM yield in P-W plot was the highest at the first and second defoliation among treatments in 2008, while that in P+S-W plot was only highest at the first defoliation and the DM yield did not differ among treatments at the second defoliation in 2010 (Figure 3). Annual DM yield of DL napiergrass ranged in 0.14-4.89 and 4.31-9.43 Mg/ha in 2008 and 2010, respectively. Therefore, paper-mulching had a significantly positive effect on DM yield of DL napiergrass, compared with the opposite management (P-W vs. S-W and P+S-W vs. S-W in 2008 and 2010, respectively).

DM yield of setaria was only higher (P < 0.05) in S+W plot than S-W plot in 2008, and weed control management by sowing setaria had no significant (P > 0.05) effect to suppress weed DM yield (S-W vs. -W plot) in 2010.

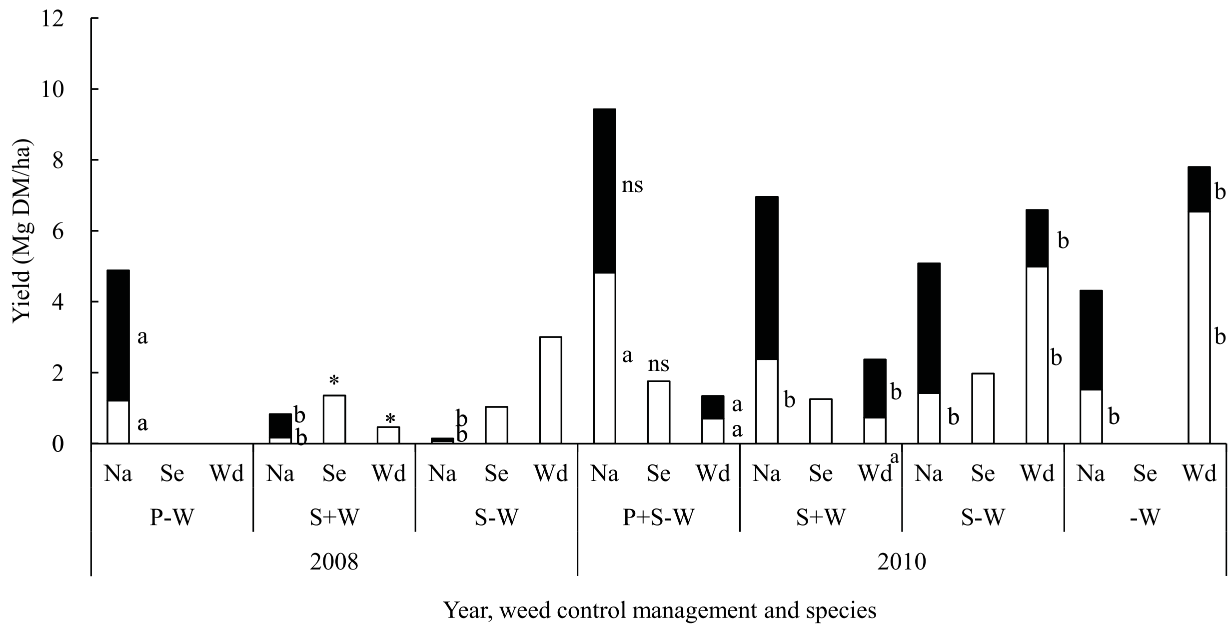

Figure 3 Dry matter yield of DL napiergrass (Na), setaria (Se) and weeds (Wd) at the 1st (□) and 2nd (■) defoliation under several weed control management.
As for the abbreviations of weed control management, refer to Figure 1.
Means with different letters are significantly different among weed control management at each defoliation time for each plant species by LSD method at 5% level. ns: P > 0.05. *: P < 0.05 by t-test.

Table 1 Effect of weed control practices on weed species in 2008 and 2010

Year	Date of observation	Species
2008	19 July	*Cyperus rotundus, Digitaria adscendens, Imperata cylindrica, Panicum maximum, Sorghum halepense, Vicia hirsuta*
2010	16 July	*Artemisia princeps, Cayratia japonica, Commelina communis, Cyperus microiria, Digitaria adscendens, Equisetum arvense, Glycine soja, Humulus japonicas, Oenothera biennis, Oxalis corniculata*
	18 October	*Artemisia princeps, Cayratia japonica, Commelina communis, Cyperus rotundus, Digitaria timorensis, Eleusine indica, Erigeron annuus, Erigeron canadensis, Euchlaena mexicana, Glycine soja, Humulus japonicas, Hydrocotyle maritima, Imperata cylindrica, Mosla dianthera, Oxalis corniculata, Paspalum urvillei, Polygonum longisetum, Rumex acetosa, Setaria viridis, Solanum carolinense, Sorghum halepense, Viola grypoceras*

However, 1 g/m^2 of DM production from setaria tended to reduce 4 g/m^2 of DM production from weeds (y = 104.5 - 0.247x, r = 0.52, P > 0.05). DM yield of DL napiergrass was not negatively affected by sowing setatia (S-W vs. -W plot) in 2010.

Weed species

Weeds at the first weed control on 19 July, 2008 were only detected for 6 species, while intra-space of DL napiergrass was almost occupied by natural reseeded guineagrass (*Panicum maximum*) and rhizomatous Johnsongrass (*Sorghum halepense*) and cogongrass (*Imperata cylindrica*) (Table 1), which reduced DM yield of DL napiergrass significantly (Figure 3). Number of weed species increased from 10 species at the first weed

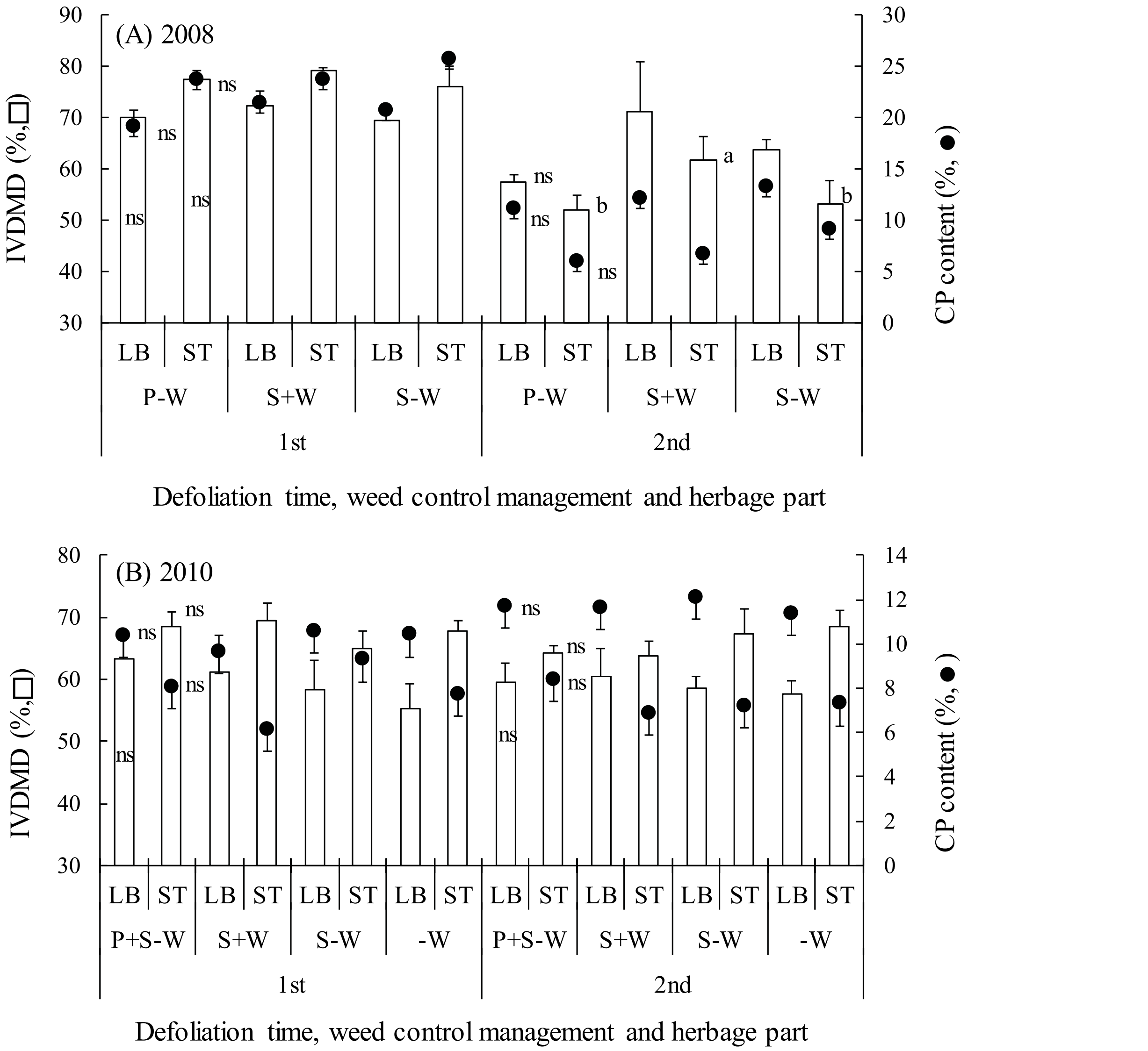

Figure 4 *In vitro* dry matter digestibility (IVDMD, □) and crude protein (CP, ●) content of DL napiergrass under several weed control management in 2008 (A) and 2010 (B).
Values are expressed as mean ± standard deviation.
As for the abbreviations of weed control management, refer to Figure 1.
Means with different letters are significantly different among weed control management at each defoliation time by LSD method at 5% level. ns: $P > 0.05$.

control on 16 July to 22 species at the second defoliation in 2010 (Table 1). However, weed DM yield decreased from the first to the second defoliation at no-weeding (S-W and -W) plots in 2010 (Figure 3).

Herbage quality

Measured quality attributes such as IVDMD and CP

Table 2 Effect of weed control practices on percentage of overwintered plant (POP) and regrown tiller number (RTN) in DL napiergrass in 2008–2009 and 2010–2011

Year	Parameter	Weed control management †					Level of significance
		P-W	P+S-W	S+W	S-W	-W	
2008-2009	POP (%)	$100^{a} \pm 0$ ‡	–	$73.3^{ab} \pm 37.9$	$40.0^{b} \pm 26.5$	–	$P < 0.05$
2010-2011	POP (%)	–	77.8 ± 38.5	88.9 ± 19.2	88.9 ± 19.2	88.9 ± 19.2	$P > 0.05$
	RTN (No./m²)	–	5.9 ± 4.5	6.0 ± 4.0	3.4 ± 2.0	4.3 ± 2.2	$P > 0.05$

† P, interrow space was covered by paper mulch; S, oversown with setaria; W, weeding; -W, no weeding control.
‡ Mean ± standard deviation.

content did not differ among treatments in either 2008 or 2010, except for the highest IVDMD of ST in S+W plot at the second defoliation in 2008 (Figure 4). IVDMD tended to be higher in ST averaged at 77% than in LB at 71% at the first defoliation in 2008, and at both the first and second defoliations in 2010. IVDMD in the average of LB and ST tended to be higher at the first defoliation averaged at 74% across treatments than at the second defoliation at 60% in 2008, while IVDMD did not differ among two defoliations in 2010. CP content, which is usually higher in LB than in ST, was almost fitted to two defoliation times in both years, except for the opposite trend at the first defoliation in 2008. Differences in CP content between two defoliations were similar with those in IVDMD in both years. Combined with major differences in DM yield among treatments, no negative loss in any quality attribute was suffered from higher DM yield in the prominent weed control management such as P-W and P+S-W in 2008 and 2010, respectively (Figure 4).

Table 3 Effect of weed control practices on efficiency (%) in several parameters of plant total in DL napiergrass at each defoliation in 2008 and 2010

Year	Defoliation	Parameter†	Practice		
			Weeding	Paper-mulching	Setaria-sowing
2008	1st	DM Yield	248	2466	－
		IVDMD	4	1	－
		CP content	2	-9	－
	2nd	DM Yield	7554	54091	－
		IVDMD	14	-6	－
		CP content	-16	-24	－
2010	1st	DM Yield	74	275	-4
		IVDMD	6	7	1
		CP content	-19	-6	11
	2nd	DM Yield	73	73	36
		IVDMD	-1	-1	0
		CP content	-3	9	3

† DM yield, dry matter yield; IVDMD, *in vitro* dry matter digestibility; CP content, crude protein content.

Sustainability

Effect of weed control practices on sustainability of DL napiergrass, assessed by percentage of overwintered plants (POP), were different between the wintering period in 2008-2009 and that in 2010-2011 (Table 2). POP in P-W plot was the highest, followed by S+W plot and the lowest in S-W plot, which was the same order with DM yield and several growth attributes in 2008-2009. However, either POP or regrown tiller number (RTN) did not differ among treatments in 2010-2011, although RTN tended to be higher in P+S-W and S+W plots than in S-W and -W plots ($P > 0.05$), which was fitted to the non-significant differences in the second-cut DM yield in 2010-2011.

Discussion

Adoption of several weeding practices such as hand-weeding, paper-mulching and annual setaria-sowing can be assessed by the percentage of gain or loss in attributes of DL napiergrass under the particular practice relative to those under no adoption of the practice (Table 3). Adoption of paper-mulching facilitated to obtain largest positive gain of DM yield in DL napiergrass at two defoliations in both 2008 and 2010. Situation was similar for the positive gain by adoption of hand-weeding, while the degree of gain was reduced from paper-mulching (Table 3). The advantage of paper-mulching in DM yield was closely corresponded with positive gain in plant height, tiller density and leaf area index through improvement in light penetration (Peltzer and Köchy 2001) under paper-mulching plots. Mulching in plant cultivation was beneficial for a great deal aspects, such as improvement of plant growth, prevention of plant damage from weeds, reduction in water demand, increase in soil fertility, improvement of soil texture and enhancement of nutrient uptake under living mulch (Deguchi *et al*. 2005; Steinmaus *et al*. 2008). Positive effect of paper-mulching on DM yield in DL napiergrass matched with several crops, such as lettuce (Moniruzzaman 2006) and tomato (Anzalone *et al*. 2010).

Effect of weed control practices such as weeding and paper-mulching on DM yield was apparently higher in 2008 than in 2010 (Table 3), while DM yield of DL napiergrass was limited among treatments in 2008 (Figure 3). Natural reseeding of guineagrass following the previous field management was so evident and dominated in the plots that annual setaria-sowing and even hand-weeding failed to suppress growth of weeds, especially guineagrass, although weeding and harvest of setaria were conducted twice before the first defoliation of DL napiergrass, as suggested by Miller and Stritzke (1995) that noted the frequent weeding was essential at the establishment of perennial crops.

On the contrary, sowing of annual setaria cv. Natsukanso did not affect negatively ($P > 0.05$) on DM yield of DL napiergrass at the first defoliation in 2010, comparing between S-W and -W plot (Table 3), and annual setaria had higher DM yield than DL napiergrass in S-W plot (Figure 3). Annual setaria-sowing obtained limited advantage in DM yield (36%) only at the second defoliation in 2010, derived from lack in regrowth ability of this species, once it had stem-elongated (Wakamatsu 2004). In several stand establishments of perennial crop species, annual species are used to suppress weeds and mitigate the competition of crops from weeds. In the present study, annual setaria has characteristics to give good growth in early summer and suppress summer weeds (Wakamatsu 2004). Perennial setaria (*Setaria sphacelata*) is a competitive species to suppress annual weeds, once it is established (Cook *et al.* 2005) by releasing allelopathic compounds (Boonman 1993; Fujii 2001).

Consistent positive effect of any weed control practice on quality attributes was hardly obtained in either year, while decline in CP content under weeding and paper-mulching practices was common at the second and first defoliation in 2008 and 2010, respectively (Table 3). Living mulch with white clover improved plant nutrition by enhancing phosphorus uptake in maize (Deguchi *et al*. 2005). The present paper-mulching and hand-weeding could not contribute to herbage quality of DL napiergrass, possibly due to the negative correlation of DM yield with quality attributes under the similar fertilization in this species. Dwarf napiergrass cv. Mott, which has almost equivalent plant attributes to DL napiergrass, had IVDMD and CP content at 67.5 and 13.2%, respectively (Sollenberger *et al.* 1988), almost corresponded with the present IVDMD at 74 and 60% at the first and second defoliation, respectively, in 2008.

Significant differences in POP among treatments during the wintering season in 2008-2009 were fitted to the significant differences in DM yield at the second defoliation in this year, while non-significant variation in DM yield at the second defoliation led to non-significant variation in POP among treatments in 2010-2011 (Table 2). Severe damage by natural reseeded guineagrass completely suppressed growth of DL napiergrass after the first defoliation at S+W and S-W plots in 2008, which reduced POP in 2008-2009 significantly. Colder wintering season in 2010-2011, when mean temperature averaged at 7.9°C in December-February, should reduce POP to 78-89% in this year, compared with 100% in P-W plot averaged at 9.4°C in 2008-2009. In the wintering season, paper mulch started to disperse and lose the function of increasing soil temperature, because almost 7 months passed after setting to the field.

Conclusions

Paper mulch is not common to use DL napiergrass cultivation, while it proved to be effective to avoid weed damage and facilitate good growth with high DM yield of this species. Cost of paper mulch is 50 yen/m (Sanyo Seishi Co. Ltd., Tottori, Japan) and setting of paper mulch is a labor-intensive weed control practice. Thus, based on the amount of natural seed bank of weeds, paper mulch or other degradable mulching material can be applied to DL napiergrass, so as to reduce weed competition at the establishment. Annual setaria-sowing gave advantage to get herbage yield at the first defoliation of DL napiergrass, although prompt harvest time of annual setaria should be examined in the mixed cropping with DL napiergrass.

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要　約

雑草防除管理が造成した矮性ネピアグラスの粗飼料の収量，品質および越冬性に及ぼす影響

Renny Fatmyah UTAMY・石井康之[1]・井戸田幸子[1]・Lizah KHAIRANI[2]

宮崎大学大学院農学工学総合研究科・[1]宮崎大学農学部・[2]宮崎大学大学院農学研究科
連絡者：石井康之（tel・fax: 0985-58-7251, e-mail: yishii@cc.miyazaki-u.ac.jp）

要　約　ネピアグラスの矮性晩生品種（DLネピアグラス）を南九州の生産者へ普及する過程で，造成年における雑草防除が本牧草の良好な定着と粗飼料収量を確保する重要な要因であることが明らかとなった．本研究は，3種類の雑草防除管理，すなわち節間伸長茎では再生能力を欠く一年生セタリアの混播，ペーパーマルチの設置および手取り除草と雑草防除なしについて，乾物収量，粗飼料品質および越冬性を2カ年（2008～2009年および2010～2011年）にわたって検討した．いずれの雑草防除管理も雑草防除なしと比べて，草高，茎数密度，葉身比率および葉面積指数などの植物体の各形質に有意な正の効果をもたらした．特に，ペーパーマルチの設置は，両年ともに最も高い収量が得られ，2008～2009年では越冬率が最も高く100%であった．一年生セタリアの混播は，雑草によるDLネピアグラスの収量減を部分的に補完する効果があった．粗飼料品質としての*in vitro*乾物消化率（IVDMD）と粗タンパク質（CP）含量に対する雑草防除の効果は認められなかった．したがって，ペーパーマルチの設置と一年生セタリアの混播はともに，造成したDLネピアグラスの収量性を確保するため，また越冬性改善の可能性のある有効な雑草防除手法として提起できるものと推察された．

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