氮肥對狼尾草硝酸態氮含量之影響 (1)

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摘 要

本試驗的目的在探討氮肥施用量對狼尾草 (*Pennisetum purpurem*) 臺畜草二號 (NPcv.TS2) 植體內硝酸態氮含量的影響。試驗分別施用 0、300、600、900 及 1,200 kg/ha/year 的氮素。試驗結果顯示，狼尾草全株的硝酸態氮及銨態氮含量隨著氮肥施用量的增加而提高，且硝酸態氮顯著大於銨態氮含量。氮肥施用量提高至 1,200 kg/ha/year 時，硝酸態氮含量達到 913 mg/kg，接近可能對動物健康有危害的 1,000 mg/kg，但施用 900 kg/ha/year 時，其硝酸態氮含量僅 543 mg/kg。硝酸態氮及銨態氮占總氮的百分比隨著氮肥的增加而提高，但當施肥量超過 600 至 1,200 kg 時硝酸態氮百分比則未顯著差異。狼尾草莖部硝酸態氮及銨態氮含量顯著高於葉部，當施肥 1,200 kg 時，莖部硝酸態氮含量達 1,023 mg/kg。葉部之硝酸態氮及銨態氮占總氮的百分比，並未隨著氮肥施用量的增加而提高。莖部硝酸態氮及銨態氮占總氮的百分比，則隨著氮肥施用量的增加而提高。牧草鮮重及粗蛋白質年產量隨著氮肥施用量增加而提高，但由 600 kg/ha/year 提高至 1,200 kg/ha/year，牧草產量增加並未達顯著差異。提高氮肥用量雖然可提高產量及粗蛋白質含量，但氮素的利用效率，則隨著氮肥施用量增加而降低。本試驗結果顯示，目前國內狼尾草臺畜草二號栽培所推薦之氮肥每公頃每年適當施用量 920 kg，在此氮肥量下牧草及粗蛋白質產量可達最高，且不論全株、莖或葉之硝酸態氮含量，亦不超過對動物健康危害的程度。

關鍵詞：氮肥、硝酸態氮、狼尾草。

緒 言

氮肥是影響作物 (包括牧草) 生長及產量最重要的成分，已經有很多研究報告顯示，氮素不僅是影響乾物產量，也影響植體蛋白質含量 (George *et al.*, 1971; Laurialt *et al.*, 2002; Reich *et al.*, 2003; De Bona and Monteiro, 2010)。因此對草農而言，大量施用氮肥是增加產量的主要方法。植物吸收氮素的主要型態為硝酸態氮 (NO_3^--N) 及銨態氮 (NH_4^+-N)，施用的肥料主要也是於此兩種型態之氮肥為主 (Mengel and Kirkby, 1982; Marschner, 1995)。當植物由土壤中吸收 NO_3^--N 後，正常情況下，NO_3^--N 會很快的轉變成 NO_2^--N 再轉變成 NH_4^+-N，然後合成胺基酸及蛋白質，植體中很少有 NO_3^--N 大量累積的現象 (Beevers and Hageman, 1969; George *et al.*, 1971; Raven and Smith, 1976; Pate, 1980; Mengel and Kirkby, 1982; Rufty *et al.*, 1983; Marschner, 1995; Britto and Kronzucker, 2002)。但在特殊的條件下，如過量的施用氮肥 (Baker and Truck, 1971; Maynard *et al.*, 1976; Goh and Haynes, 1986; Whitehead, 1995)，或天候不良如連續下雨、過於乾燥、或天氣太冷，造成植物生長受阻，就會有 NO_3^--N 累積的現象 (Crawford *et al.*, 1961; George *et al.*, 1971; May *et al.*, 1990)，牧草種類也可能影響 NO_3^--N 的累積 (Hanway and Englehorn, 1958; Murphy and Smith, 1967; Gillingham *et al.*, 1969)。牧草中如含有過量的 NO_3^--N，動物攝食後，其血液中顯示嚴重缺氧，而呈現深咖啡色，嚴重呈現 NO_3^--N 中毒，甚至可能造成動物快速死亡 (Crawford *et al.*, 1961; Wright and Davison, 1964; Emerick, 1974; Harms and Tucjer, 1973; Rasby *et al.*, 1988; Fjell *et al.*, 1991; Bruningfann and Kaneene, 1993a and 1993b; Hill, 1999)。國內芻料作物一向只注重其營養價值，而忽略芻料中所含的有害成分，所以時有動物產生不明病症之現象，如嚴重便祕或流產，而此種現象又時常於更換芻料來源時發生。因此，不得不考慮是否芻料中有害物質所造成。本試驗目的即在探討氮肥對狼尾草 (*Pennisetum purpurem*) 硝酸態氮累積的影響，提供酪農及草農種植狼尾草及餵飼動物之參考。

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材料與方法

I. 田間試驗

試驗面積 5 m × 4 m = 20 m^2，本試驗區位於行政院農業委員會畜產試驗所芻料作物試驗場 (臺南新化)，其土壤質地屬壤土 (砂粒、坋粒及及粘粒分別為 47、30 及 23%)，有機質 1.20%、pH 6.41、EC 0.20 mS cm^{-1}、全氮 0.082%、有效性磷 62.3 mg kg^{-1}、交換性 K、Ca 及 Mg 分別為 50.2、665 及 42.3 mg kg^{-1}。

II. 試驗材料

狼尾草臺畜草二號栽植後，經兩個月生長全部青割，待其再生二週後，開始進行試驗。

III. 氮肥施用量

每年每公頃施用 0、1,500、3,000、4,500 及 6,000 kg 臺肥複合肥料一號 (20-5-10)，相當於施用 0、300、600、900 及 1,200 kg N/ha/year。分別於 3、5、7、9 及 11 月青割後平均施用。肥料施用量以 RCBD 處理，每處理三重複。

IV. 狼尾草每二個月青割一次，調查產量並採樣約 2 kg (全株、葉及莖) 以 75℃烘乾 48 小時後，磨成小於 1 mm 大小之粉粒，作為分析材料，分析植體中硝酸態氮、銨態氮及全氮含量。

V. 分析方法

(i) 植體前處理：植體利用濃硫酸及 H_2O_2，於 400℃高溫分解至澄清後，稀釋至 50 ml (分解液) ，貯存於冰箱中，作為分析全氮 (Wolf, 1982) 之用。植體硝酸態氮及銨態氮利用蒸餾水萃取 (Mills, 1980)，以 1：10 (樣品：水)，震盪 30 分鐘後，以 No.5 之濾紙過濾 (萃取液)，貯存於冰箱中，以待分析。

(ii) 分析方法：全氮、硝酸態氮及銨態氮利用蒸餾法測定 (Bremner and Keeney, 1965; Jones, 1987)。銨態氮測定：分別取前述 (i) 之分解液或萃取液各 5 mL，利用德製 Gerhardt 廠牌之蒸餾器，加入 5 mL 之 10 N NaOH 蒸餾 5 分鐘，以內含 Methyl red 及 Bromocresol green 混合指示劑之 4% H_3BO_3 溶液吸收，再以 0.025 N H_2SO_4 滴定，其滴定結果換算為銨態氮之濃度。硝酸態氮之測定：分解液或萃取液各 5 mL 先加入 3 g 之 Devard 合金粉，將硝酸態氮還原成銨態氮，再依前述銨態氮測定方法蒸餾，其測定結果減掉銨態氮之量則為硝酸態氮之量。以分解液測得之銨態氮及硝酸態氮之和為植體之全氮。

結果與討論

不同氮肥施用量對狼尾草植體中無機氮 (銨態氮及硝酸態氮) 的含量之影響如圖 1 所示，植體中銨態氮及硝酸態氮的含量隨著氮肥的增加而提高，而硝酸態氮又高於銨態氮。氮肥施用量提高至 1,200 kg/ha/year 時，硝酸態氮含量達到 913 mg/kg，接近可能對動物健康有危害的 1,000 mg/kg (Wright and Davison, 1964; Crawford *et al.*, 1966; Emerick, 1974; Rasby *et al.*, 1988; Fjell *et al.*, 1991; Bruningfann and Kaneene, 1993a and 1993b; Hill, 1999)，但施用 900 kg/ha/year 時，其硝酸態氮含量僅 543 mg/kg。目前國內狼尾草肥料推薦量為每公頃每年氮素施用量為 920 kg，依本試驗結果顯示，如果依推薦施用化學肥料，採收後整株餵飼動物，並不會造成硝酸態氮過高之問題。

表 1 係狼尾草植體中銨態氮及硝酸態氮含量占總氮的百分比。植體中總氮含量隨著氮肥施用量增加而提高，多位學者之研究結果亦顯示，牧草中粗蛋白質含量隨著氮肥的增加而提高 (Tiwana *et al.*, 2003; Verna *et al.*, 2006; Ayub *et al.*, 2009; Piri and Tavassoli, 2012; Shahin *et al.*, 2013)。施肥小於 600 kg 時，硝酸態氮占總氮的百分比隨著氮肥的增加而提高，由 3.51 － 5.25%，但當施肥量超過 600 至 1,200 kg 時，硝酸態百分比雖有增加的趨勢，但未達顯著差異，由 5.25 － 5.74%。銨態氮占總氮的百分比則隨著氮肥的增加而提高，由 1.15 － 3.94%。過高的銨態氮濃度對植物具有毒害作用，降低其代謝能力 (Anderson and Boswell, 1964; Johns and Hedlin, 1970; Malhi and Mcgill, 1982; Britto and Kronzucker, 2002)，本試驗中當氮肥年施用量達到 1,200 kg 時，已超過其氮肥推薦量，可能造成狼尾草的毒害作用，使其合成氨基酸及含氮化合物能力降低，所以植體內殘留了較高比例的銨態氮。植物吸收氮源的主要型態為銨態氮及硝酸態氮，但兩者在植物體內的生理作用，卻有很大的不同。植物吸收銨態氮後，很快的合成氨基酸及含氮化合物，但硝酸態氮則需經一連串反應還原成銨態氮後，再合成氨基酸及含氮化合物，所以植物代謝硝酸態氮較銨態氮需消耗更多的能量 (Cox and Reisenauer, 1973; Haynes and Goh, 1978; Mengel and Kirkby, 1981; Rufty *et al.*, 1983; Britto and Kronzucker, 2002)。本試驗中結果亦顯示，狼尾草植體中銨態氮含量顯著低於硝酸態氮含量。

不同氮肥施用量對狼尾草莖部及葉部植體中無機氮的含量之影響如圖 2 及圖 3 所示，狼尾草不論莖部或葉部硝

酸態氮含量均隨氮肥施用量的增加而提高。但莖部的含量顯著高於葉部，施肥量由 0 至 1,200 kg/ha/year，莖部硝酸態氮的含量由 250 mg/kg 提高至 1,023 mg/kg，而葉部的硝酸態氮含量則僅由 140 mg/kg 提高至 269 mg/kg。葉部可能由於光合作用關係，代謝速度較快 (Oaks, 1994)，所以硝酸態氮含量較莖部為低。銨態氮含量與硝酸態氮含量有相同的趨勢，莖部的銨態態氮含量顯著高於葉部，施肥量由 0 至 1,200 kg/ha/year，葉部銨態氮的含量由 53 mg/kg 提高至 157 mg/kg。莖部含量由 61 mg/kg 提高至 743 mg/kg。

表 1. 氮肥對狼尾草草硝酸態氮及銨態氮占總氮百分比之影響

Table 1. The effects of nitrogen fertilizer on the percents of nitrate and ammonium nitrogen to total nitrogen of napiergrass

N fertilizer	Total N (T-N)	NO_3^--N/T-N	NH_4^+-N/T-N
kg/ha/year	-----------------------	%------------------------	
0	0.49^{d}	3.51^{b}	1.15^{c}
300	0.62^{c}	4.21^{b}	1.76^{c}
600	0.98^{b}	5.25^{a}	2.06^{bc}
900	1.42^{a}	5.54^{a}	3.21^{ab}
1,200	1.59^{a}	5.74^{a}	3.94^{a}

[a, b, c, d] Means with the same letter in the same column are not significantly different at 5% level.

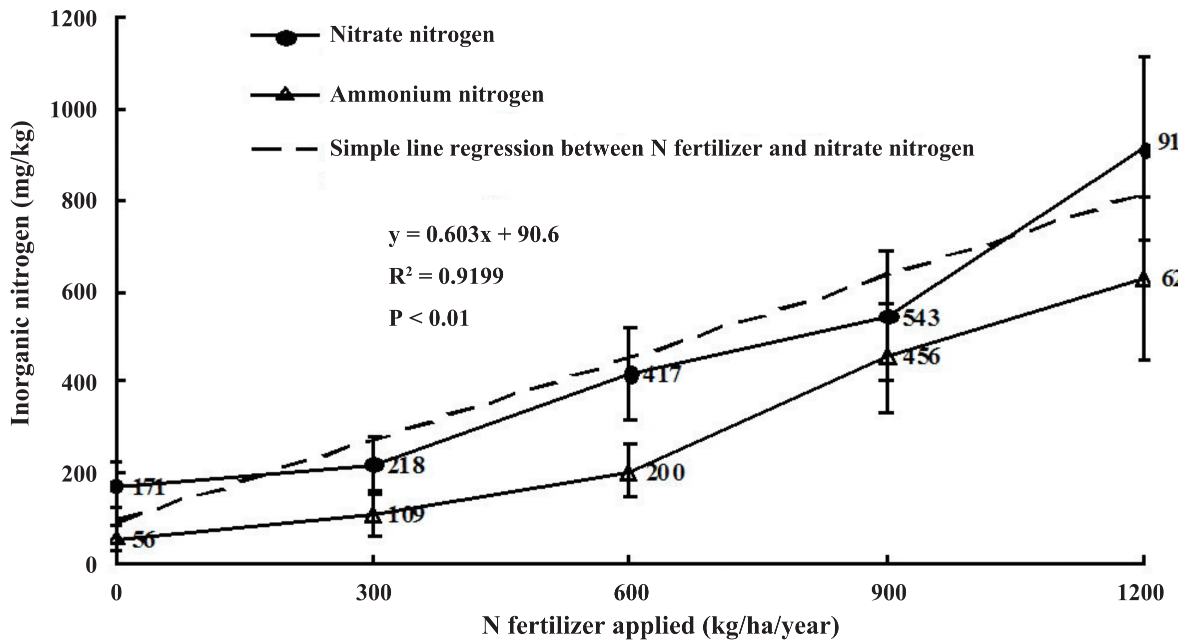

圖 1. 氮肥對狼尾草硝酸態氮及銨態氮含量之影響。

Fig. 1. The effects of nitrogen fertilizer on the content of nitrate and ammonium nitrogen of napiergrass.

本試驗施用複合肥料 1 號，其氮素的型態為銨態氮，銨態氮肥施用於土壤後，在通氣良好的情況下，銨態氮會很快的轉變為硝酸態氮 (Russell, 1973; Clarkson and Hanson, 1980)，本試驗施肥直接撒施於牧草地表面，所以在通氣良好下，亦有部分銨態氮肥轉化為硝酸態氮。Donaldson and Henderson (1990) 及 Biederbec *et al.* (1998) 的研究報告指出，銨態氮含量是影響土壤中硝化菌族群的重要因素，銨態氮肥施用愈多，硝化菌族群就愈大，也就會有更多的銨態氮氧化成硝酸態氮。本試驗不因施用的氮肥為銨態氮，就能避免硝酸態氮在植體中的累積。

表 2 及表 3 分別為狼尾草葉部及莖部硝酸態氮及銨態氮含量占總氮之百分比。氮肥施用量由 0 至 1,200 kg/ha/year，葉部之硝酸態氮及銨態氮占總氮的百分比，除未施肥處理銨態氮百分比較低外，其餘處理並未隨著氮肥施用量的增加而提高。莖部硝酸態氮及銨態氮占總氮的百分比，則隨著氮肥施用量的增加而提高，但由表 3 亦可發現約需增施氮素 600 kg，才會顯著提高莖部硝酸態氮百分比 (施用 300 及 600kg、900 及 1200 kg 均未顯著差異)，而銨態氮百分比則隨著氮肥施用量的增加而顯著提高 (各處理均顯著差異)。土壤中的銨態氮濃度太高時，會降低硝化作用的發生 (Anderson and Boswell, 1964; John and Hedlin, 1970; Malh and McGill, 1982)，因此提高銨態氮肥的施用，對於增加植體中硝酸態氮占總氮百分比，不若銨態氮占總氮的百分比來的明顯。葉部由於光合作用關係，氮

的同化作用較快 (Oaks, 1994)，所以葉部的硝酸態氮及銨態氮均保持低於莖部的水準。多位學者研究指出，植體中硝酸態氮含量增加，可促進硝酸還原酵素 (nitrate reductase) 活性，加速植體中硝酸態氮的轉化 (Skrdleta *et al.*, 1979; Sivasankar *et al.*, 1997; Chen *et al.*, 2004; Sadegh and Gholamreza, 2011)。本試驗中提高氮肥濃度，葉部中硝酸態氮含量雖然增加，但其含硝酸態氮占總氮百分比並未顯著增加，因硝酸態氮含量增加，促進硝酸還原酵素活性，同時葉片光合作用能量較充分，所以硝酸態氮同化成胺基酸或含氮化合物較快，因此降低了硝酸態氮在葉片的累積。而莖部能量較低，硝酸態氮同化速度慢，所以莖中硝酸態氮百分比隨著施肥量增加而提高。

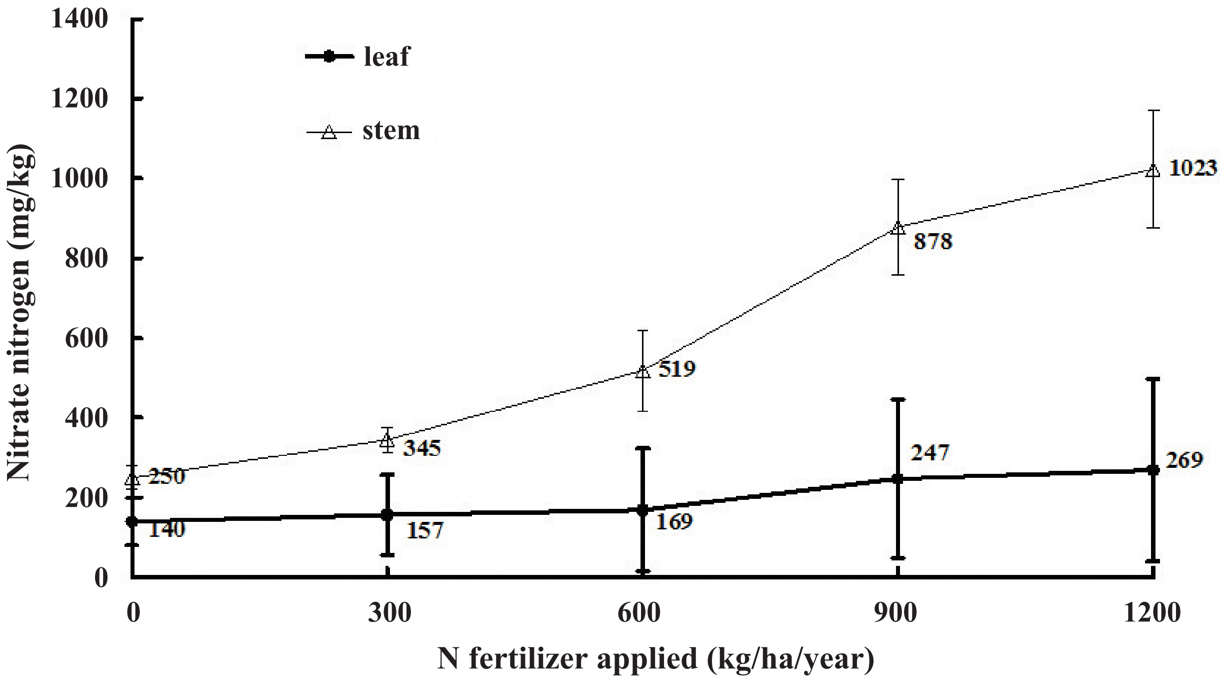

圖 2.　氮肥對狼尾草莖及葉之硝酸態氮含量之影響。

Fig. 2. The effects of nitrogen fertilizer on the contents of nitrate nitrogen in the stem and the leaf of napiergrass.

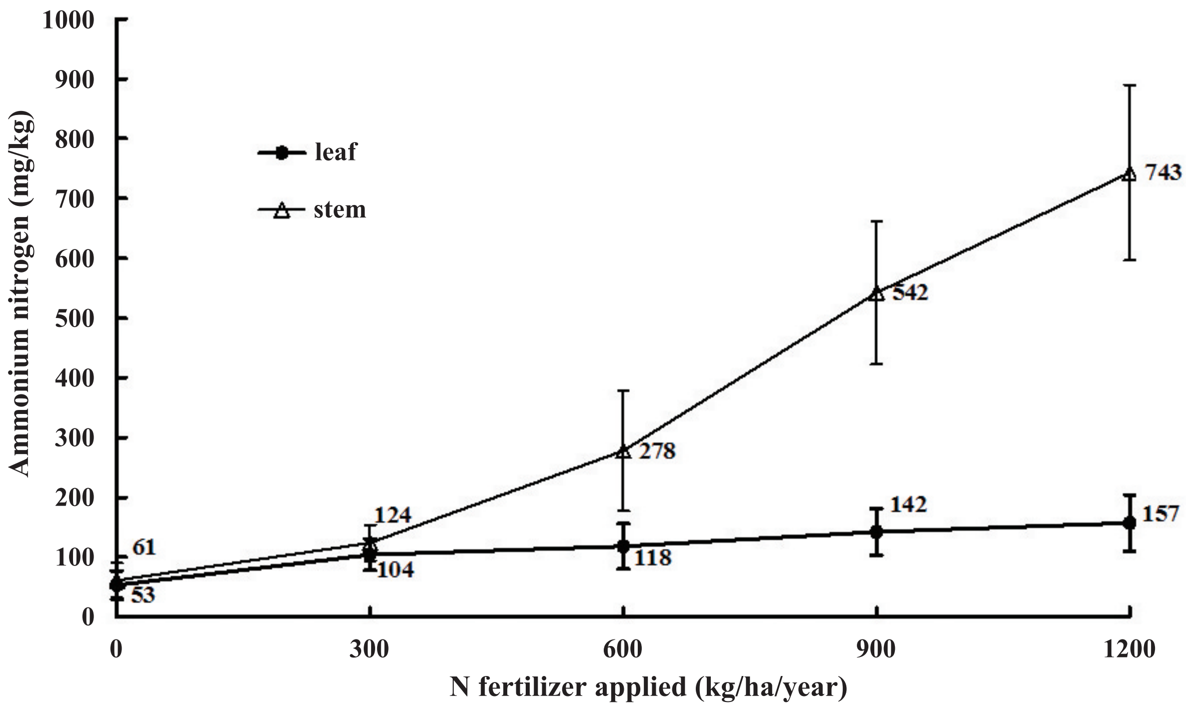

圖 3.　氮肥對狼尾草莖及葉之銨態氮含量之影響。

Fig. 3. The effects of nitrogen fertilizer on the contents of ammonium nitrogen in the stem and the leaf of napiergrass.

表 2. 氮肥施用量對狼尾草葉部硝酸態氮及銨態氮占總氮百分比之影響

Table 2. The effects of nitrogen fertilizer on the percents of nitrate and ammonium nitrogen to total nitrogen in the leaf of napiergrass

N fertilizer	Total N (T-N)	NO_3^--N/T-N	NH_4^+-N/T-N
kg/ha/year	-----------------------	%	-----------------------
0	1.57^{c}	0.89^{a}	0.34^{b}
300	1.85^{bc}	0.85^{a}	0.56^{a}
600	2.24^{b}	0.75^{a}	0.53^{a}
900	2.78^{ab}	0.89^{a}	0.51^{a}
1,200	2.92^{a}	0.92^{a}	0.54^{a}

$^{a, b, c, d}$ Means with the same letter in the same column are not significantly different at 5% level.

表 3. 氮肥施用量對狼尾草莖部硝酸態氮及銨態氮占總氮百分比之影響

Table 3. The effects of nitrogen fertilizer on the percents of nitrate and ammonium nitrogen to total nitrogen in the stem of napiergrass

N fertilizer	Total N (T-N)	NO_3^--N/T-N	NH_4^+-N/T-N
kg/ha/year	-----------------------	%	-----------------------
0	0.54^{c}	4.63^{c}	1.13^{e}
300	0.67^{c}	5.15^{bc}	1.85^{d}
600	0.95^{b}	5.46^{b}	2.93^{c}
900	1.23^{ab}	7.14^{a}	4.41^{b}
1,200	1.35^{a}	7.58^{a}	5.50^{a}

$^{a, b, c, d}$ Means with the same letter in the same column are not significantly different at 5% level.

表 4 為氮肥施用量對狼尾草牧草產量、粗蛋白質產量及氮肥的利用率。牧草鮮重及粗蛋白質產量隨著氮肥施用量增加而提高，但由 600 kg/ha/year 提高至 1,200 kg/ha/year，牧草產量增加並未達顯著差異。提高氮肥用量雖然可提高產量及粗蛋白質含量，但氮素的利用效率，則隨著氮肥施用量增加而降低 (600 － 900 kg/ha/year 無顯著差異)，此結果顯示，狼尾草臺畜草二號之氮肥推薦量 640 － 920 kg/ha/year 是合宜的。氮肥用量提高至 1,200 kg/ha/year 雖可增加粗蛋白質產量，但對於牧草產量則增加有限，考量植體中硝酸態氮含量，其莖已超越對動物有害的 1,000 mg/kg，全株亦接近 1,000 mg/kg，氮肥不宜提高至 1,200 kg/ha/year。

表 4. 氮肥施用量對狼尾草牧草產量、粗蛋白質產量及氮肥利用率之影響

Table 4. The effects of N fertilizer on the yields of forage and crude protein of napiergrass and N recovery

N fertilizer	Total N (T-N)	NO_3^--N/T-N	NH_4^+-N/T-N
kg/ha/year	t/ha/year	t/ha/year	%
0	132^{c}	0.84^{e}	-
300	225^{b}	2.01^{d}	49.7^{a}
600	272^{a}	3.33^{c}	43.6^{b}
900	280^{a}	4.97^{b}	44.6^{b}
1,200	288^{a}	5.73^{a}	39.6^{c}

$^{a, b, c, d}$ Means with the same letter in the same column are not significantly different at 5% level.

$^{\#}$ (Total N in plant applied N fertilizer applied – total N in plant without N fertilizerapplied) / N fertilizer applied × 100%.

結　　論

本試驗結果顯示，目前國內狼尾草臺畜草二號栽培所推薦之氮肥每公頃每年施用量 920 kg 是適當的，在此氮肥量下牧草及粗蛋白質產量可達最高，且不論全株、莖或葉之硝酸態氮含量亦不超過對動物健康危害的程度。提高氮肥用量至 1,000 kg 以上，雖可增加粗蛋白質產量，但對於牧草產量則增加有限，同時植體中硝酸態氮含量，尤其莖

的部分可能超越對動物有害濃度。由本試驗結果獲悉，國內狼尾草臺畜草二號之生產，在兼顧產量及品質的情況下，氮素之施肥量每年每公頃以不超過 920 kg 為宜。

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Effects of N fertilizer on the contents of NO_3^--N in napiergrass [1]

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Abstract

Objective of this study was to determine the effects of fertilizer on the accumulation of NO_3^--N content in napiergrass (*Pennisetum purpurem*). Five levels of N fertilizer, i.e., 0, 300, 600, 900 and 1,200 kg N/ha/year were applied to the pasture of napiergrass Taishu No2. (NP cv Taishu 2). The results showed that the NO_3^--N content of whole plant of napiergrass increased as the levels of N fertilizer applied increased. The changes for NO_3^--N content were much more significant than those of NH_4^+-N content. The NO_3^--N content of NP cv Taishu 2 reached to 913 mg/kg with N fertilizer 1,200 kg/ha/year applied, while, NO_3^--N content was only 543 mg/kg with N fertilizer 900 kg/ha/year applied. The percentages of NO_3^--N or NH_4^+-N to total nitrogen (NO_3^- / N or NH_4^+ / N) also increased as level of N fertilizer applied increased. However, no significant difference was observed for NO_3^- / N as level of N fertilizer applied exceeded beyond 600 kg/ha. Both contents of the NO_3^--N and NH_4^+-N in stem were much higher than those in leaf. The content of NO_3^--N in stem reached to 1,023 mg/kg with N fertilizer 1,200 kg/ha/year. The percentages of NO_3^- / N and NH_4^+ / N in stem increased significantly as the levels of N fertilizer applied increased, while no significant difference was observed for those in leaf. In addition, no significant difference was observed for forage yield as the level of N fertilizer was exceeded beyond 600 kg/ha. It was suggested that the level of N fertilizer applied recommended for NP cv Taishu 2 was recommended 900 kg N/ha/year, which was adequate for both forage yield and crude protein content. Simultaneously, the NO_3^--N content in napiergrass tissue would not exceed the harmful level to affect the health of animal health.

Key words: Nitrogen fertilizer, Nitrate nitrogen, Napiergrass (*Pennisetum purpurem*).

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