# Summer lamb production and grazing management of pure swards of plantain (*Plantago lanceolata*)

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## Abstract

Plantain is a productive and persistent pasture species known for its capacity to feed livestock over summer, but there has been limited research published on grazing management and lamb production from Tonic plantain in summer without irrigation. Farmlet scale (individual plots ranged from 0.44 – 0.75 ha over the three years), randomised and replicated experiments, with grazing lambs on pure swards of Tonic plantain were undertaken over three summers. The treatments were sward height at pre- and post-grazing and stocking rate. Study one was in a wet summer and the plantain was not water-stressed, whereas in study two, it was mainly dry and the plantain was regularly under stress, and in study three, the summer rainfall was erratic, resulting in a period of water stress at the beginning of the experiment. The average daily weight gains (ADG) of the lambs ranged from 81 to 219 g/day across the three studies. The highest ADGs were when soil moisture was not limiting plantain growth and post-grazing sward height was greater than 5 cm (approximately 1500 kg DM/ha). The crude protein concentration of plantain was low (156 -175 g/kg DM) when plants were water stressed and high (236 g/kg DM) when rainfall was adequate. It was concluded ADG of lambs grazing Tonic plantain in summer was greatest when pre- and post-grazing sward heights were 8 and 5 cm, respectively (2000 and 1500 kg DM/ha herbage mass) and the plantain was not water stressed. It is recommended that Tonic plantain be sown with pasture legumes to increase its feeding value and crude protein concentration.

**Keywords**: Tonic; average daily weight gain; live weight; carcass weight; sward height; herbage mass

## Introduction

Ceres Tonic plantain was released in 1993 as a potential herb pasture species (Stewart 1996). Over the ensuing years, the popularity of Tonic plantain has increased in New Zealand and other countries, including Australia and Uruguay. The key features of Tonic plantain that have attracted the attention of farmers are its high annual herbage production, good growth during summer with concomitant livestock performance, better cool season growth than other plantain cultivars, and ease of establishment (Stewart 1996; Kemp et al. 2010). Additionally, the high mineral content and presence of secondary chemicals, notably aucubin, acteoside, and catalpol, have created interest in the potential for positive effects on animal health (Stewart 1996; Tamura 2002).

Lamb performances on pure-swards of plantain have been variable, ranging from 50g/day on Lancelot plantain (Robertson et al. 1995) to 222g/day on a well irrigated, pure-sward of Tonic plantain (Moorhead et al. 2002). These differences have been regarded as due to the superiority of Tonic over Lancelot, the increased production and nutritive value resulting from irrigation, and differences in grazing management which affected nutritive value (Deaker et al. 1994, Labreveux et al. 2006) and the proportion of stem in the herbage (Fraser & Rowarth, 1996).

Despite the uptake of Tonic plantain by farmers, the only replicated grazing experiment on the performance of lambs on Tonic plantain was on irrigated pasture (Moorhead et al. 2002). A comprehensive experiment by Fraser and Rowarth (1996) examined lamb live weight gain and carcass weight on Lancelot plantain relative to some other species in summer and early autumn, and concluded Lancelot plantain was similar in performance to perennial ryegrass and inferior to chicory and white clover. However, since then, Tonic has become preferred over Lancelot due to features such as superior growth in cooler months, more erect leaves and fewer seedheads (Stewart 1996). Therefore, it is timely to examine the management and growth of lambs on Tonic plantain, particularly over the summer months when plantain, like all pasture species, will be most challenged by soil moisture deficit.

The objectives of this research were to measure lamb live weight and carcass gain and the effect of sward height on lamb growth on pure pastures of Tonic plantain over three summers.

## Materials and Methods

The three studies were undertaken in consecutive summers on the same area of plantain (*Plantago lanceolata* cv Ceres Tonic) on the Pasture and Crop Research Unit, located at Massey University, Palmerston North, 34m above sea level on a Tokomaru silt loam soil. The plantain sward was sown at 8 kg/ha in November 2008 using a roller drill on a cultivated seedbed. The Olsen P of the plantain plots was between 27-32 μgP/g. The three studies were undertaken with the approval of the Massey University Animal Ethics Committee.

Weather data for the three years and the long-term average weather data were obtained from the Met Service weather station at AgResearch, Palmerston North, near to the research site. Soil moisture data were obtained from a permanent sensor at the Massey University No. 4 Dairy Farm, Palmerston North (David Horne, pers. comm.), which is located adjacent to the research site and has the same soil type.

***Study One - Experimental design***

Sixty two ram and 108 ewe weaned Romney-cross lambs, with an average live weight of 30.4 kg and approximate age of six months, were randomly allocated to one of two grazing sward height treatments on plantain (*Plantago lanceolata* cv. Ceres Tonic); high (n = 75, planned average sward height of 11 cm) or low (n = 75, planned average sward height of 6 cm). Ewe and ram lambs were randomly allocated to each treatment. Each treatment included three replicates (n = 25), each with an initial stocking rate of 50 lambs/ha and an area of 0.5 ha. An additional 1.0 ha was available to enable adjustments in lamb stocking rate, if needed, to help ensure planned sward height treatments were achieved.

Lambs were introduced to their respective treatments on the 2nd February 2009 (D1), where they were allowed an approximate two-week adjustment period. A 30-day experimental period followed from the 17th February 2009 (D16) to 18th March, 2009 (D45). Lambs were drenched with a composite drench (Matrix) on D1.

Grazing was managed to ensure the sward treatments remained within their designated height range, in addition to providing *ad libitum* intake at all times. To ensure this, the designated herbage allowance was at least three times the lambs predicted daily intake of 1.5kg DM/ha/day. Lambs were rotationally grazed to ensure sward treatment heights were achieved. Further the number of lambs per area (stocking rate) was adjusted in the high treatment by the removal of 5 lambs from replicate three to ensure planned sward heights were met. When sward heights were determined to be too far above their planned target, a few mature ewes were used to control excess growth. Live weight and carcass data from these lambs and ewes were not used at the end of the study.

***Animal measurements*** Unfasted live weights of all lambs were recorded at D1, D9, D16, D23, D30, D37 and D45. At D1, 20 lambs from the original 170 were randomly selected, 10 for each sward height treatment and slaughtered on D17 (18th February) at a commercial abattoir (Canterbury Meat Packers (CMP), Marton, New Zealand) and carcass weights recorded. On the morning of slaughter (D17), a further unfasted live weight was taken on these lambs. To estimate D16 carcass weights, the regression equation, carcass weight = 1.19 + 0.411 X live weight ($R^2$=0.555, $p < 0.05$), derived from all experiment lambs (n=170) was used. At D45, the remaining lambs were slaughtered and a carcass weight recorded.

***Herbage mass and sward height*** Herbage mass was measured by cutting six 0.1$m^2$ quadrats to ground level every two weeks, from a selection of grazed and non-grazed plots. Samples were washed and then dried in a draught oven at 70° for approximately 24 hours. An average dry matter weight was then calculated for the six samples and then converted to kg DM/ha. The pre- and post-sward heights were measured every three to five days using a sward height stick. Mean height was determined by measuring 50 random heights within each replicate.

***Study Two - Experimental design***

Forty two ram and 98 ewe Romney cross lambs, with an average live weight of 33.5 kg and approximate age of six months, were randomly allocated to one of two grazing sward height treatments of Tonic plantain; high (n = 60, planned sward height range of 8 – 10 cm) and low (n = 60, planned sward height range of 4 – 6 cm). Ewe and ram lambs were randomly allocated to each treatment. Each sward treatment included three replicates (0.44 ha/replicate), with an initial average stocking rate of 45 lambs/ha. To maintain the planned sward heights, lambs were rotationally grazed.

Lambs were introduced to their respective treatments on the 3rd February 2010 (D1), for a two-week adjustment period. A 29-day experimental period followed from 17th February 2010 (D15), to 17th March 2010 (D43). Lambs were drenched with a composite drench (Matrix) on D1. The designated herbage allowance was at least three times the lambs predicted daily intake of 1.5kg DM/ha/day. As with study one, mature ewes were used when required to ensure sward heights did not go above their targets. In addition, 12 and 6 lambs, respectively, were removed from the high and low sward height treatments on 10th March 2010, when it became apparent sward heights would go below their planned target heights.

***Animal measurements*** All lambs were weighed unfasted at D1, D8, D15, D22, D29, D36 and D43. At D1, 20 lambs were randomly allocated to the two sward height treatments (n = 10 for each). At D15, these lambs were slaughtered and hot carcass weights were recorded. On the morning of slaughter (D15), an unfasted live weight was recorded. To estimate D15 carcass weights, the regression equation was derived from all lambs (n=120) used in the experiment (carcass weight = 7.53 + 0.212x, $R^2$=0.198, $p < 0.05$). At D44 (18th March), all remaining lambs were slaughtered and their carcass weights recorded.

***Herbage mass and sward height*** Herbage mass was measured by cutting four 0.1$m^2$ quadrat cuts to ground level for each replicate pre- and post-grazing. Samples were washed and then dried in a draught oven at 70°C for approximately 24 hours. An average dry matter weight was calculated for the four samples and converted to kg DM/ha. The mean sward height, 50 measurements per replicate, of each treatment was measured on D1, D8, D15, D22, D29, D36, and D43. These heights were used to adjust grazing management

to maintain swards within the defined treatment heights.

***Nutritive value analysis*** A herbage enclosure cage was placed randomly within each replicate during three time periods: between D15 and D18, between D26 and D28, and between D36 and D43. One 'hand plucked' sample was taken from within each cage at post-grazing so as to be representative of what the lambs were eating. Values were the average of one randomly selected replicate at each of the three measurement dates. A random selection of one replicate from both treatments was taken at the start, middle and end of the experiment, freeze dried, and then ground to fine particle size for analysis at the Massey University Nutrition Laboratory. Samples were analyzed for nitrogen (total combustion method), dry matter (convection oven 105°C), ash (furnace 550°C), NDF/ADF/lignin (Robertson & Van Soest 1981) and in vitro digestibility (and thus metabolisable energy) (Roughan & Holland 1977).

### *Study Three - Experimental design*

Forty two ram and forty two ewe weaned Romney x Dorset lambs, with an average carcass weight of 32.4 kg, and approximate age of six months were randomly allocated to two stocking rate treatments, 19 lambs/ha and 24 lambs/ha, on a pure plantain sward. Each stocking rate treatment was replicated three times with an average area of 0.75 ha per plot. All lambs were introduced to the plantain for two weeks in December 2010. On the 12th January 2011, lambs were allocated to the treatments. A 35 day experimental period followed from the 19th January 2011 (termed D1) to the 23rd February 2011 (D36).

***Animal management*** Lambs were managed to achieve a targeted pre-grazing height for plantain of 7 cm and a post-grazing height of 5 cm, while feeding the lambs *ad libitum*. The lambs were rotationally grazed and moved when the post-grazing height was reached.

***Animal measurements*** Unfasted live weights were recorded at D1 (19th January 2011), D8, D15, D22, D29 and D35 (23rd February 2011), at the same time each week. All eighty four lambs were slaughtered on the D36 at Canterbury Meat Packers (CMP) in Marton and hot carcass weights were recorded.

***Herbage measurements*** Herbage height pre-grazing and post-grazing was measured using a sward stick. Fifty measurements were taken randomly at each time point. Herbage mass was calculated by making four 0.1 $m^2$ quadrant cuts to ground level using an electric hand piece for each pre- and post-grazing event. Herbage samples were washed and then dried in a draught oven at 70°C for 48 hours. An average dry matter weight was calculated for the four dry matter samples and converted to kg DM/ha.

***Nutritive value analysis*** A herbage enclosure cage was placed in each replicate in each treatment pre-grazing. One 'hand plucked' sample was taken from within each cage post-grazing to match the grazing by the lambs. The final sampling was on D35, the day before the experiment finished.

Samples were frozen at -35$^0$C immediately after sampling, and were later freeze dried and then ground to a fine particle size for analysis at the Massey University Nutrition Laboratory. The samples were analysed for organic matter digestibility (Roughan & Holland 1977), crude protein (total combustion method), ash (furnace 550°C), neutral detergent fibre (NDF) (Robertson & Van Soest 1981) and dry matter (convection oven 105°C).

### *Statistical analysis*

All data from studies one, two and three were analyzed using Minitab 16 Statistical Software®. Live weight, carcass weight, dressing out percentage and live weight gain data for the lambs were analyzed with a two-sample *t* test using treatment as the subscript to determine significant differences. Replicate interactions were assessed through conducting a two-way analysis of variance (ANOVA) using the variable of concern (e.g. live weight) as the response, and treatment and replicate as the row and column factors, respectively. The sex of the lambs was also used as a fixed effect in the models.

In studies one and two, a regression analysis was undertaken to determine the relationship between carcass weight and live weight for the 20 lambs slaughtered at the start of the main study (D16 and D15 for study one and two respectively) and the strength of the relationship assessed using adjusted $R^2$ and *P* values. At the end of the main study (D45 and D44 for study one and two, respectively) the regression relationship between carcass weight and live weight was again tested. The measured carcass weight was divided by the most recent live weight to determine a dressing-out percentage (carcass weight/live weight X 100/1).

To determine a 'predicted' carcass weight at the beginning of the experimental period (D16 and D15 for study one and two respectively) a regression analysis of the relationship between carcass weight and live weight for all lambs, including the 20 early slaughtered lambs, was calculated. This equation was then used to calculate a 'predicted' carcass weight at D16 and D15 for study one and two, respectively, for all lambs at the start of the experiments.

Dry matter yields and sward height measurements were analyzed using a one-way ANOVA. Replicate interactions were assessed by conducting a two-way analysis of variance (ANOVA) using the variable of concern (e.g. dry matter yield) as the response, and treatment and replicate as the row and column factors, respectively.

## Results

### *Weather*

For study one, there was a higher than average rainfall in February, proceeded by a very dry March,

**Table 1** Weather data for 2009 (study one), 2010 (study two), 2011 (study three) and the 30-year mean for February and March.

| | Year | January | February | March |
|---|---|---|---|---|
| **Rainfall (mm)** | 2009 | Na | 212.8 | 15.2 |
| | 2010 | Na | 35.2 | 40.6 |
| | 2011 | 71.4 | 49.8 | Na |
| | 1979-2009 (mean) | 62.6 | 70.9 | 70.5 |
| **Soil temp (10cm)** | 2009 | Na | 18.1 | 14.8 |
| | 2010 | Na | 18.8 | 16.1 |
| | 2011 | 19.3 | 19.4 | Na |
| | 1979-2009 (mean) | 18.2 | 18.1 | 16.2 |

where rainfall was almost five times lower than the 30-year average (Table 1). Throughout the experiment period (D16-45), the soil moisture deficit remained above the readily available water level.

Study two experienced lower than average rainfall in February and March, in conjunction with the Manawatu region suffering a summer drought (Table 1). Volumetric soil moisture levels decreased from 28.9% at D1 (experiment adjustment period) to 17.2% at D44 (experiment end) (figure 4.5) and reached wilting point by approximately 10th March (D37).

For study three, January was dry, with rain on only 11 of the 31 days. The overall rainfall for the month of January was higher than average but this was due to a heavy rainfall event of 45 mm on 23rd January. As a result, at the start of the experiment (19th January) the soil water deficit level was -72mm but this decreased to -20mm after rainfall on 23 and 24th of January. Warm temperatures and little rain at the end of January increased the soil moisture deficit to -40mm, which was followed by a drier than average February.

The soil temperatures for the three years were similar to the 30-year average (Table 1), except for being cooler in March 2009 (study one) and warmer in February 2011 (study three).

***Study one***

***Live weight*** Live weight of lambs did not differ at D16 (Table 2). However, live weight at D45 and total live weight change and average daily gain between D16 and D45 were greater in the high (11 cm) than the low (6 cm) sward height treatments. Mean daily live weight gain was 219 g/day on the high sward height and 121 g/day on the low sward height (Table 2).

***Carcass weights*** The predicted carcass weight of lambs at D16 did not differ between treatments (Table 3). The carcass weight at D45 of lambs from the high treatment group was 10 % greater ($P<0.05$) than that of the low treatment group, although dressing-out percentage did not differ ($P<0.05$) (Table 3).

**Table 2** Mean (±SEM) live weight (kg) at the start and end of the of the main study period in three experiments and total live weight change (kg) and average daily gain (ADG g $d^{-1}$) of lambs grazing high and low sward heights and lambs at two stocking rates on plantain.

| Treatment | n | | n | Live weight | LW Change | ADG g $d^{-1}$ |
|---|---|---|---|---|---|---|
| | Study One | | | | | |
| | | D16 | | D45 | | |
| **High (11 cm)** | 75 | 33.9±0.4 | 70 | 40.1±0.5[a] | 6.1±0.35[a] | 219±12[a] |
| **Low (6 cm)** | 75 | 33.2±0.3 | 75 | 36.6±0.4[b] | 3.4±0.25[b] | 121±9[b] |
| | Study Two | | | | | |
| | | D15 | | D44 | | |
| **High (8 cm)** | 60 | 35.9±0.41 | 48 | 39.2±0.44 | 3.3±0.25[a] | 109±8[a] |
| **Low (5 cm)** | 60 | 36.5±0.35 | 54 | 38.7±0.45 | 2.3±0.27[b] | 81±10[b] |
| | Study Three | | | | | |
| | | D1 | | D36 | | |
| **19 lambs/ha** | 42 | 34.2±0.51 | 42 | 41.4±0.55 | 7.2±0.35 | 205±10 |
| **24 lambs/ha** | 54 | 34.2±0.35 | 54 | 40.8±0.36 | 6.6±0.27 | 188±10 |

***Herbage measurements*** The average sward height and pre- and post grazing heights over the period D16 – D45 were greater ($P<0.05$) in the high than low treatment (Table 4). Herbage mass at D16, D30 and D45 was greater ($P<0.05$) in the high than the low treatment groups (Table 5).

***Study two***

***Live weight*** At D15, live weights did not differ between treatments ($P<0.05$, Table 2). However, live weight at D44 and total live weight change and average daily gain between D15 and D44 were greater in the high than the low sward height treatment (Table 2).

**Table 3:** Mean (±SEM) carcass weight (kg) at the start and end (predicted from regression equations) of the main study period and dressing out percentage (DO %) of all lambs on high and low grazing height treatments of plantain, and final carcass weight (kg) and total carcass weight (kg/ha) for two stocking rates of lambs on plantain.

| Treatment | Predicted carcass weight | | Final carcass weight | | Dressing out percentage |
|---|---|---|---|---|---|
| | n | | n | | |
| | Study one | | | | |
| | | D16 | | D45 | |
| **High (11 cm)** | 75 | 15.3±0.2 | 70 | 17.9±0.2[a] | 44.7±0.4 |
| **Low (6 cm)** | 75 | 15.1±0.1 | 75 | 16.2±0.3[b] | 44.2±0.7 |
| | Study two | | | | |
| | | D15 | | D44 | |
| **High (8 cm)** | 60 | 15.01±0.15 | 48 | 15.94±0.22 | 40.70±0.58 |
| **Low (5 cm)** | 60 | 15.27±0.08 | 54 | 15.82±0.21 | 40.65±0.53 |
| | Study three | | | | |
| | | | | D36 | Total carcass weight (kg/ha) |
| **19 lambs/ha** | | Na | 42 | 16.8±0.2 | 313±3.8[a] |
| **24 lambs/ha** | | Na | 53 | 17.0±0.2 | 408±4.8[b] |

Different superscripts within columns denote significant differences (P=<0.001)

***Carcass weights*** At D15, the predicted carcass weight did not differ between treatments. At D44 treatment had no effect on carcass weight or dressing-out percentage (Table 3).

***Herbage measurements*** Pre-grazing herbage masses were greater (P<0.05) in the high than low treatment during D15-21, 22-28 and D36-43 (Table 6). Post-grazing herbage masses were greater (P<0.05) in the high than and low treatments at D15-21, D29-35, and D36-43. Pre and post grazing sward heights did not differ (P>0.05) between the treatments during D15-21 (Table 6). However, during D22-28, D29-35 and D36-43 both the pre and post grazing heights were greater (P<0.05) in the high than the low treatment (Table 6).

Table 7 shows the average nutritive value of the high (8 cm) and low (5 cm) treatments over the experiment. Values were similar for both treatment heights and were relatively low for crude protein, digestibility and metabolisable energy, and relatively high for fibre and lignin.

***Study three***

***Live weight*** The live weight of the lambs at the two stocking rates of 19 and 24 lambs/ha were similar at D15 and D50 when grazing on plantain in summer (Table 2). The average daily weight gains were similar for the two stocking rates suggesting forage on offer was similar in the two treatments (Table 2). This was reinforced by the mean pre and post sward heights over the course of study three for the two treatments being similar (Table 8). Mean pre- and post-grazing sward heights were 7.0±0.17 cm and 4.9±0.17 cm for 19 lambs/ha, and 6.4±0.24 cm and 4.8±0.14 cm for 24 lambs/ha (Table 8).

***Carcass weights*** The carcass weights for the two stocking rates were similar at D36, with a mean of 16.9 kg/lamb for the experiment (Table 3). Consequently, the total carcass weight/ha was 30 % greater for 24 lambs/ha than for 19 lambs/ha (Table 3).

***Herbage measurements*** The pre-grazing herbage mass was higher for the 19 than the 24 lambs/ha stocking rate for the periods D8-D21 and D22-D36, but the post-grazing herbage masses were similar (Table 8). The nutritive values of the plantain in both stocking rates were similar, but the crude protein concentration was lower at the start of the experiment (D1) than at completion (D35) with means of 175 and 236 g/kg DM for D1 and D35, respectively (Table 9).

**Table 4** Mean (±SE) sward height (cm) for high (11cm) and low (6cm) grazing height treatments of plantain, and average pre and post grazing sward height (cm) during study one (D16-45).

| Treatment | D16-45 Average sward height | D16-D45 Average pre-grazing height | Average post-grazing height |
|---|---|---|---|
| **High** | 11.03±0.47[a] | 13.44±1.04[a] | 8.45±0.21[a] |
| **Low** | 5.90±0.3[b] | 7.77±0.37[b] | 4.89±0.47[b] |

**Table 5:** Mean (±SE) herbage mass (kg DM $ha^{-1}$) for high (11cm) and low (6cm) grazing height treatments of plantain during study one (D16-45).

| Treatment | D16 | D30 | D45 |
|---|---|---|---|
| **High** | 2356±320 | 2154±89[a] | 2164±203[a] |
| **Low** | 1630±370 | 1037±46[b] | 1005±40[b] |

Different superscripts within columns denote significant differences (P=<0.005)

greater than 200 g/day for lambs grazing plantain in summer require either high summer rainfall or irrigation (Moorhead *et al.*, 2002), and a post- grazing sward height no lower than 5 cm. By comparison, the ADG for lambs in summer on un-irrigated pastures over a number of years was 154 g/day (range: 56 – 226) for perennial ryegrass and white clover pasture, and was regularly greater than 275 g/day for both chicory and red clover (Kemp *et al.*, 2010). Overall, the results from the three years of experiments presented here support Tonic plantain being effective forage for lambs in summer and a productive and persistent pasture for at least three years. However, these experiments also demonstrate that lamb growth on pure plantain in summer is diminished more during periods of soil moisture stress than has been observed for some alternative species such as chicory, red clover and lucerne (Kemp et al. 2010).

**Table 6** Mean (±SE) sward heights (cm) and pre and post grazing herbage masses (kgDM/ha) of high (8 cm) and low (5 cm) grazing height treatments of plantain at D 15-21, 22-28, 29-35 and 36-43 for study two.

| | D15-21 | | D22-28 | | D29-35 | | D36-43 | |
|---|---|---|---|---|---|---|---|---|
| **Treatment** | **Pre** | **Post** | **Pre** | **Post** | **Pre** | **Post** | **Pre** | **Post** |
| **Height** | | | | | | | | |
| **High** | 9.6±0.5 | 8±0 | 9.3±1.9[b] | 7.4±0.9[b] | 8.3±0.7[b] | 5.6±0.5[b] | 6.5±0.8[b] | n/r |
| **Low** | 7.9±1.2 | 7±1.1 | 6.1±0.3[a] | 3.9±0.6[a] | 5.0±1.0[a] | 3.8±0.7[a] | 4.1±0.2[a] | 3.5±0.5 |
| **Mass** | | | | | | | | |
| **High** | 2473±112.0[b] | 1507±118.9[b] | 1835±150.4[b] | 1146±66.8 | 1296±164.3 | 1003±68.1[b] | 969±125.0[b] | 979±165.7[b] |
| **Low** | 1072±139.3[a] | 921±125.4[a] | 856±116.7[a] | 769±202.0 | 1038±313.5 | 446±56.7[a] | 498±44.8[a] | 444±101.2[a] |

n/r =not recorded
Different superscripts within columns denote significant differences (p=<0.005)

## Discussion

The ADG for lambs grazing plantain in summer ranged from 81 to 219 g/day for a range of treatments over three years. The highest ADG occurred in a summer with above average rainfall and when the post-grazing sward height was above 8.5 cm, and the lowest ADG occurred when there was a severe soil moisture deficit and the post-grazing sward height was mainly less than 4 cm. It is suggested that ADGs

The crude protein concentration of Tonic plantain was lower when the pasture was water stressed throughout most of study two and at the beginning of study three. Similarly, Corkran (2009) found crude protein in Tonic plantain was 129 g/kg DM when water stressed in March and 175 g/kg DM in May when soil moisture was readily available. The low crude protein concentration is a reminder that addition of a legume species such as either red or white clover will provide nitrogen fixation, as well as increasing the nutritive value of the pasture on offer to lambs (Golding et al. 2011). Alternatively, an application of nitrogen fertilizer in early summer to ensure an adequate crude protein concentration appears to be a practical approach to managing pure plantain.

**Table 7:** Average nutritive value [in vitro digestibility (DMD), neutral detergent fibre (NDF), acid detergent fibre (AD), crude protein (CP), metabolisable energy (ME) and lignin] of plantain from the start (D15) to the end (D44) of study two for the high (8cm) and low (5cm) treatment heights. Values are the average of one randomly selected replicate at each of the three measurement periods.

| Nutritive measure | Average value of treatments | | |
|---|---|---|---|
| | High | Low | SEM (±) |
| DMD (g/kg) | 663 | 675 | 13.9 |
| NDF (g/kg) | 485 | 471 | 22.2 |
| ADF (g/kg) | 310 | 290 | 23.8 |
| Crude protein (g/kg) | 155 | 157 | 17.0 |
| ME (MJ ME/kgDM) | 9.8 | 9.9 | 0.20 |
| Lignin (g/kg) | 119 | 123 | 13.2 |

**Table 8:** The effect of stocking rate of 19 lambs/ha vs. 24 lambs/ha on sward height (cm) and herbage mass (kg DM $ha^{-1}$) of plantain during D1 to D7, D8 to D16, D17 to D24, D25-D36 (mean ±SE) in study three.

| Lambs/ha | D1-7 | | D8-21 | | D22-36 | | Overall mean | |
|---|---|---|---|---|---|---|---|---|
| | Pre | Post | Pre | Post | Pre | Post | Pre | Post |
| 18 | 6.9±0.30 | 4.5±0.43 | 7.1±0.48 | 4.6±0.27 | 7.0±0.15 | 5.2±0.22 | 7.0±0.17 | 4.9±0.17 |
| 24 | 6.5±0.54 | 4.4±0.28 | 6.5±0.42 | 4.8±0.21 | 6.2±0.23 | 4.9±0.21 | 6.4±0.24 | 4.8±0.14 |
| | D1-7 | | D8-16 | | D17-24 | | D25-36 | |
| | Pre | Post | Pre | Post | Pre | Post | Pre | Post |
| 18 | 2573±131.1$^{c}$ | 1959±195.0$^{b}$ | 2494±291.0$^{bc2}$ | 1547±167.2$^{a}$ | 1657±83.7$^{a2}$ | 1468±103.2$^{a2}$ | 1951±114.6$^{ab}$ | 1654±90.8$^{a}$ |
| 24 | 2517±182.1$^{b}$ | 1946±156.4$^{b}$ | 1618±115.8$^{ab1}$ | 1486±103.4$^{a,b}$ | 1417±99.3$^{a1}$ | 1156±90.5$^{a1}$ | 1792±197.6$^{b}$ | 1389±98.5$^{a}$ |

Means with differing superscripts ($^{a,b,c,d}$) are significantly different across the row ($p<0.05$)
Means with differing superscripts ($^{1,2}$) are significantly different within columns ($p<0.05$)

The nutritive value of the plantain was relatively high in study three (Hodgson & Brooke, 1999), with ME above 11.5 MJ/kg DM and NDF below 300 g/kg DM, and after it rained the crude protein level recovered from a mean of 175 to 236 g/kg DM. Yet, despite the post-grazing herbage residual being approximately 5 cm and 1500 kg DM/ha for both stocking rates throughout the experiment, the ADG of the lambs was no better than 205 g/day. That the higher stocking rate of 24 lambs/ha produced similar ADGs to the lower stocking rate of 19 lambs/ha, with the consequence that a greater carcass weight per ha was produced at the higher stocking rate, suggests that the ADG of the lambs in the lower stocking was not limited by intake, but rather the feeding value of the plantain. This result adds to the conclusion that ADG of lambs on plantain in summer is not as high as it is for high feeding value herbs and legumes such as chicory, red clover, lucerne and white clover, but is likely to be greater than that from summer pastures of perennial ryegrass and white clover (Moorhead et al. 2002; Kemp et al. 2010).

**Table 9** The neutral detergent fibre (NDF, g/kg DM), crude protein (CP, g/kg DM) and metabolisable energy (ME, MJ ME/kg DM) of plantain in summer for the two lamb stocking rates at the start and end of study three.

| Lambs/ha | D1 | D35 | SEM(±) |
|---|---|---|---|
| NDF18 | 256 | 255 | 13.9 |
| NDF24 | 301 | 231 | 13.9 |
| CP 18 | 180$^{a}$ | 232$^{b}$ | 12.4 |
| CP 24 | 169$^{a}$ | 240$^{b}$ | 12.4 |
| ME 18 | 11.8 | 11.7 | 0.05 |
| ME 24 | 11.5 | 11.8 | 0.05 |

An objective of these experiments was to better define the pre- and post-grazing sward height and herbage mass for lambs being grazed *ad libitum* on Tonic plantain in summer. Although the highest ADG was when pre- and post-grazing heights ranged from 11 to 8.5 cm, this management has practical disadvantages. These disadvantages include poor utilization of pasture and poor control of seedheads, as well as a risk that the forage will become too mature for high intakes (Moorhead et al. 2002). In two out of the three years of experiments, grazing management was affected by periods of soil moisture deficit, but lamb ADG, and therefore intake, appeared to be decreased at swards heights below 5 cm. It is proposed that pre- and post-grazing heights of 8 cm and 5 cm would result in both high lamb ADG and high utilization of the plantain under most environmental conditions. These heights approximately equate to herbage masses of 2000 and 1500 kg DM/ha, respectively. An average pre- and post-grazing herbage mass of 2000 and 1000 kg DM/ha, respectively, was reported by Moorhead et al. (2002) when they achieved an ADG of 222g/day. However, the results of the studies reported here suggest that grazing below an average sward height of 1200-1400kg DM/ha reduces ADG of lambs, probably through limiting daily intake potential.

In conclusion, Tonic plantain can support reasonable stocking rates of lambs over summer with ADGs over 200 g/day provided lambs are fed *ad libitum* with a post grazing height of at least 5 cm and the plants are not water stressed. To avoid potentially low crude protein concentrations in dry conditions, it is recommended that either a clover species is included with plantain, or nitrogen fertilizer is applied before the onset of a soil moisture deficit in summer.

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