To investigate the effects of chicory on grazing beef cattle, on silage quality, and the persistency of chicory when sown in mixtures

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FINAL REPORT

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Executive Summary

Objective 1: To investigate the effects of chicory on grazing beef cattle

The project investigated the effects of chicory compared with ryegrass on the productivity, parasite burdens and carcass quality of a typical UK steer finishing system. In Year 1 (2009), triplicate plots of chicory/ryegrass or ryegrass were established and sward quality was maintained by grazing with sheep. In Year 2 (2010), the focus was to measure the performance of growing steers and to monitor the parasite burdens of these more susceptible animals. In the winter period between Year 2 and 3, steers were housed and fed a standard ryegrass silage plus straw diet. In Year 3 (2011), the focus was on livestock performance, carcass conformation and meat quality.

Field plots (2 ha each) were established with either a chicory / perennial ryegrass mix or a perennial ryegrass control. Forty-eight Belgian Blue - cross steers were used for the experiment but with a core group of 36 animals being recorded from approx. 7 months of age at Day 0 through to finishing. In the first grazing season, an additional 2 animals grazed each plot whilst determining the effects of chicory compared with ryegrass on internal gastro-intestinal (GIT) parasites in steers. Sward herbage availability, chemical composition was determined throughout the grazing period. Individual steers were weighed and body condition scored at the start of the measurement period and every 14 days throughout each grazing period. In Year 2 (2010 grazing season), the parasite levels of the 48 animals was monitored whilst following standard farm practice with regards to gastro-intestinal parasite control. Faecal samples were collected for faecal egg count (FEC) and parasite culture determinations immediately prior to anthelmintic treatment. At the end of grazing in Year 2, a blood sample was taken from each animal to determine *O. ostertagi* antibody and plasma pepsinogen levels. In Year 3, steers was selected-out for slaughter throughout this period as they were deemed as having reached a fat class of 3, with a target conformation of U, and their days to finish was recorded. All carcasses were commercially graded for conformation and fat class. Meat quality was determined in collaboration with Bristol University.

Results showed that chicory plant numbers of 110-131plants per squared metre were recorded during the period from spring 2010 until autumn 2011 (Year 2), when the population declined to 56 plants /m^2. Botanical composition data showed that chicory /ryegrass swards contained 24 and 14 % chicory on a DM basis in Year 2 and 3, respectively. Data on steer performance compared during the first grazing season, winter housing period and then second grazing season showed that there were no differences in the

liveweight gain of steers grazing chicory/ryegrass or ryegrass only swards. The results of the gastro-intestinal parasite data showed there were no differences in FEC, faecal DM or DM-adjusted FEC, parasite antibody or plasma pepsinogen levels of beef steers grazing different swards. Slaughter data showed that there were no differences in carcass or meat quality for days to finish, killing out percentages, fat score, pH, temperature at 2h & 48h, colour, vitamin E, carcass fat colour, fat oxidation, fatty acid concentrations or sensory properties. In conclusion, this study showed that there are no effects of grazing beef steers on chicory /ryegrass pastures on livestock performance, faecal parasite egg counts, carcass characteristics or meat quality when compared with grazing beef steers on ryegrass only swards.

Objective 2. Effects of chicory when ensiled alone or in combination with other forages on fermentation characteristics and silage quality

In the second objective, the effect of ensiling chicory either alone or in combination with perennial ryegrass (*Lolium perenne)* (PRG) or perennial ryegrass with red clover (*Trifolium pratense*) on fermentation and silage quality was investigated. Four replicate plots of chicory (cv. Puna II), perennial ryegrass (cv. Premium) and red clover (cv. Merviot) were established in a randomised block design. Plots were sown at a rate of 35, 16 and 6 kg ha^{-1} for ryegrass, red clover and chicory, respectively. On 17 May 2010, forage from each replicate block was harvested, bulked into one sample, and left to wilt in swaths for 48 h. On 19 May, forages were chopped through a stationary forage harvester, and treated with a silage inoculant. A 500g sub-sample of wilted forage was analysed for dry matter (DM), crude protein (CP) (N x 6.25), water-soluble carbohydrate (WSC), neutral detergent fibre (NDF) and ash. Treatments were: 100 % chicory, 75% chicory & 25% ryegrass, 75 % chicory & 12.5 % ryegrass &12.5 % red clover, 50 % chicory & 50 % ryegrass, 50 % chicory & 25 % ryegrass & 25 % red clover, 25 % chicory & 75 % ryegrass, 25 % chicory & 37.5 % ryegrass & 37.5 % red clover and 100 % ryegrass on a DM basis. The 100 % chicory and 100 % ryegrass treatments were also ensiled without inoculant. After 100 days, silages were opened and analysed for DM content and chemical analysis. Silage DM content concentrations declined with increasing proportions of chicory and were lower when ryegrass was replaced by red clover. Chicory silages had a lower pH and DM, WSC, NDF, ammonia-N, acetate, propionate and butyrate concentrations and higher concentrations of CP, lactate and ethanol than PRG silages. Inoculated silages had a lower pH, lower NDF, ammonia-N and acetate and higher WSC and lactate concentrations. The main effects of using chicory in silages that were observed were due to its low DM content. Despite wilting for 48 h, chicory DM contents were low, increasing the fermentation rate, as shown by

high WSC and low lactate as chicory declined. With 100 % chicory and perennial ryegrass silages, using a silage inoculant improved fermentation, with untreated silages having higher ammonia-N, lower WSC and higher acetate concentrations. In conclusion, chicory can be successfully ensiled when at a vegetative stage in mixtures with perennial ryegrass and red clover. Using an inoculant when ensiling 100 % chicory improved fermentation and silage quality.

Objective 3

This objective determined the effects of sowing chicory in combination with PRG only or PRG with RC on the persistency, agronomic performance and nutritional value of chicory when sown in different sowing mixtures. Red clover was included in the experiment to study its impact on reducing fertiliser inputs and the crude protein concentration of forage from chicory/ryegrass plots. Field plots (10 x 2.5 m) were sown with chicory (cv. Puna II) and perennial ryegrass (cv. Premium) in differing proportions, and either with or without red clover (cv. Merviot), in a replicated randomised block design with four replicate blocks. Forages were sown at rates corresponding to a proportion of their usual monoculture rate, not the total seed rate (i.e. chicory at 6kg ha^{-1}, PRG at 33kg ha^{-1} and PRG / red clover at 22 / 11 kg ha^{-1}). The treatments consisted of chicory sown with PRG alone or a ryegrass / red clover mix consisting of 2 thirds of ryegrass and 1 third red clover, resulting in 10 combinations with chicory included as 0.9, 0.7, 0.5, 0.3 and 0.1. Plant establishment was assessed by measuring chicory and red clover plants within six 360mm x 250mm quadrats placed at random within each plot. Results showed that the highest plant populations for chicory were found when chicory was sown at ninety per cent of the target proportion of the sown sward and this effect was found at establishment through to the spring of the third harvest year. Chicory /ryegrass plots sown with red clover and not receiving artificial nitrogen were found to have lower numbers of chicory plants by spring of the first harvest year and this effect increased further with time. When chicory was sown in combination with ryegrass only, there was a positive effect of increasing chicory in the sward on the DM and crude protein yield during the first and second harvest year. However, when sowing chicory in combinations with PRG and RC, the highest DM, CP and WSC yields were found with increasing and decreasing proportions of red clover and chicory, respectively. Overall, sowing plots with ryegrass only and treating with artificial nitrogen was the best approach to maintain the persistency of chicory within mixed swards as chicory was did not compete well with red clover when sown in combination with ryegrass.

Introduction

The use of chicory for finishing lambs in the UK is increasing due to research showing its benefits to improve liveweight gain and reduce internal parasites compared to ryegrass pastures (Marley *et al*., 2003). However, research has not been conducted to determine the performance of growing or finishing cattle, or cows and calves grazing chicory in the UK.

Including chicory in grass seed mixtures is becoming more popular, as it has the potential to provide high yields of high quality forage for grazing livestock. However, little is known about the effects of chicory when ensiled in combination with other forages on fermentation characteristics and silage quality, which currently limits its use as a year round forage for beef cattle.

Including chicory in grass seed mixtures is becoming more popular, as it offers high yields of very palatable and nutritious fodder for grazing livestock. Research was required to determine the persistency of chicory when sown in these combinations and the impact of different seed combinations on forage quality and nutritive value. Red clover was included in the experiment to study its impact on reducing fertiliser inputs and the crude protein concentration of forage from chicory/ryegrass plots.

The aim of the chicory beef project was to investigate these key issues.

Objectives

There were three main objectives:

1. To investigate the effects of chicory on the productivity, faecal egg counts, carcase characteristics and meat quality of beef steers;

2. To determine the effects of chicory when ensiled in combination with other forages on fermentation characteristics and silage quality.

3. To investigate the agronomic performance of chicory when sown in different combinations with grasses or clover for maximum persistency of chicory, optimal forage quality and nutritional benefits for livestock.

Objective 1. To investigate the effects of chicory on the productivity, parasite burdens, carcass characteristics and meat quality of beef steers

1.1 INTRODUCTION

The project investigated the effects of chicory compared with ryegrass on the productivity, parasite burdens and carcass quality of a typical UK steer finishing system. In Year 1 (2009), replicate plots of chicory or ryegrass were established and sward quality was maintained by grazing with sheep. In Year 2 (2010), the focus was to measure the performance of growing steers and to monitor the parasite burdens of these more susceptible animals. In the winter period between Year 2 and 3, steers were kept as one group and fed a standard ryegrass silage plus straw diet. In Year 3 (2011), the focus of the measurements was on livestock performance and the carcass conformation and meat quality of these steers when finished.

1.2 MATERIAL AND METHODS

1.2.1 Experimental design

The experimental design consisted of using triplicate plots of each treatment, with 6 animals grazing each replicate plot, to provide data on a core group of 36 finishing steers (i.e. 18 steers per treatment) but with an extra 12 animals (i.e. 6 per treatment) to monitor parasites in Year 2. The experiment ran over two consecutive grazing seasons and measured the performance of growing steers, with individual animals remaining on the same forage treatment and replicate plot in Year 2 and 3 of the project.

1.2.2 Treatments

Forage establishment

Triplicate experimental field plots (2 ha each) were established with either a chicory / perennial ryegrass mix or a perennial ryegrass control at Penglais farm, Aberystwyth University 52°25'46"N 4°4'13"W. The experimental area was treated with glyphosate herbicide at 4 litre ha^{-1} before ploughing. Lime, phosphate and potash were applied to correct any soil deficiencies prior to cultivation. Nitrogen was applied at a rate of 67 kg ha^{-1} to the seed bed. The ryegrass plots were sown with perennial ryegrass (cv Premium) at 30kg ha^{-1} and the chicory/ryegrass plots were sown with a mixture of 22.5 kg ha^{-1} perennial ryegrass (cv. Premium) and 7.5 kg ha^{-1} chicory (cv. Puna II) using an Einbock harrow/seeder between the 4 - 5th June 2009. All areas were then rolled with a flat roller. On the 9 July, one grass plot and one chicory plot were topped using a flail mower to reduce the unsown species present at that time in the establishing swards. Slug pellets were applied at a rate of 2.5 kg ha^{-1} to all plots on the 10 July 2009. From 17 July to 11 September 2009, a total of

709 weaned lambs consisting of mixed breeds and gender were introduced to the area to graze the plots and maintain herbage quality during their establishment in Year One. The three replicate plots of each treatment were grazed according to best farm practice (until sward heights of approximately 5 cm were recorded and the weather conditions at that time).

Animals

Forty-eight Belgian Blue - cross steers (approx. 7 months of age at Day 0) were used for the experiment but with a core group of 36 animals being recorded from approximately 7 months of age at Day 0 through to finishing. In the first grazing season (i.e. 2010 only), an additional 2 animals grazed each replicate plot (total extra 12 animals) whilst animals were younger and there was more forage available and to increase the number of animals per replicate whilst determining the effects of chicory compared with ryegrass on internal gastro-intestinal (GIT) parasites in steers. The steers were sourced during February 2010 and were housed and offered first cut ryegrass silage plus 2kg per head of a standard beef fattening concentrate ration. Two weeks prior to turn-out, the amount of concentrates offered was gradually reduced down to allow for rumen adaptation. All steers received two doses of a lungworm vaccine (Huskvac™) treatment prior to turn-out. In Year 2 (2010), four weeks prior to the start of the grazing period (i.e. Day minus 28), steers were placed on an area adjacent to the main grazing plots consisting of a standard ryegrass/white clover permanent pasture. This area had been previously grazed by cattle and provided a 'light' natural infection of GIT parasites, required for the monitoring during the experiment but also to allow these animals to develop a longer-term immunity to GIT parasites as carried out in standard farm practice.

1.2.3 Plot Management

During both grazing years (2010 & 2011), the experimental plots were divided using an electric fence and managed as two separate halves to control grazing quality: Sub-plot A and B (each 1 ha in size). Each half was rotationally-grazed and cut for silage as required to control herbage quality throughout each grazing season. During 2010 (Year 2), sub-plots were also managed so as to ensure an even contamination of parasite eggs across each sub-plot. In 2010, a silage cut was taken from immediately prior to Day 0 of the experimental period (on 18th May). On Day 0 – Day 7, steers grazed Sub-Plot A1 and on Day 7-14, steers grazed Sub-Plot B1 (see Figure 1). On Day 14 – Day 21, steers grazed Sub-Plot A2 and on Day 21-28, steers grazed Sub-Plot B2. A second silage cut was taken from sub-plot A on the 5th July 2010. On Day 28, Sub-Plot B1/2 was closed up for a second silage cut which was taken on 9th August 2010. On Day 28, Sub-Plot B1/2 was closed up for a second silage cut

which was taken on 9th August 2010. During this period, sub-plot A (i.e. A1 and A2) was grazed for 14 day periods. The management of each replicate plot then continued in this way, alternating silage and grazing between Sub-plot A & B so that both halves of each replicate plot had the same number of grazing days or silage cuts by the end of the first grazing season. The data on the forage yields, botanical compositions and quality of forage harvested as silage are presented in Table 1.

Figure 1. Grazing management plan to set-up a 14 day rotation after a first silage cut ensure herbage quality and even parasite contamination during Day 0 - 28.

Sub-plot A1(Day 0-7)	Sub-plot B1 (Day 7-14)
Sub-plot A2 (Day 14-21)	Sub-plot B2 (Day 21-28)

1.3 Measurements

1.3.1 Forages

To determine the persistency of the chicory, the number of chicory plants within a 360mm x 250mm quadrat at 6 random sites across each plot was counted in the spring and autumn of Years 1 (6-8 weeks post-sowing in summer of Year 1) and Year 2 and 3 and the plant population per m^2 determined. The germination index of the seed of each of the forages was determined by placing approximately 200 seeds on dampened tissue in a seed tray at 20°C for 14 days. Sward height was recorded fortnightly throughout the grazing period as a management tool by taking 40 measurements per plot (or from the area available to the steers) of the unextended sward height using a Hill Farm Research Organisation sward stick whilst walking in a 'W' transect across the measurement area (Barthram, 1986). On the areas destined to be ensiled, the herbage yield of each plot was determined using six 0.5 x 1 m quadrats, cut to ground level prior to each silage cut. Herbage availability was determined from six 0.5 x 1 m quadrats, cut to ground level, within each sub-plot at the start and end of grazing each rotationally-grazed area. The fresh weight of each sample was determined and a 400 g sub-sample taken to determine dry matter (DM) content. A second 400 g sub-sample was taken

from each sample, and bulked on a plot basis. This material was thoroughly mixed, and then sub-sampled for botanical separations. The fresh forage was separated when fresh into sown and unsown species (i.e. chicory, sown grass, clover and broad leaf weeds and grass weeds) the separated material dried, and the composition of the sward expressed on a DM basis. A second sub-sample of the bulked material from each sub-plot was freeze dried and submitted for chemical analysis to determine ash, WSC, total nitrogen (TN), and neutral-detergent fibre (NDF) concentrations

1.3.2 Animal measurements

Allocation and Livestock performance

The experiment approach comprised of a standardisation and a measurement period. During the standardisation period of 28 days, the steers were kept as one group and fed on the same standard ryegrass/clover swards. In Year 2 (2010), animals were allocated to their respective treatment on the basis of live weight, body condition score (BCS) and faecal egg counts (FEC) determined 7 days prior to the measurement period (Day minus 7). Liveweight and BCS data determined on Day minus 28, minus 14 and day 0 was used to assess the covariate growth rates of these animals. In 2010, the core 36 animals were balanced across replicate plots as well as the experiment being balanced for the 48 animals to graze the plots that year. On day 0 of the measurement period, steers were placed into treatments x replicate groups, and placed on the experimental plots sown with either a chicory/ryegrass or a ryegrass control. Individual steers were weighed and body condition scored at the start of the measurement period and then every 14 days throughout. Body condition score was determined by the same person on each occasion. The measurement period started on 25 May 2010 (day 0) and continued until herbage availability and weather conditions dictated the end of the grazing season on the 28 September 2010 (Day 126). In Year 3, the steers returned to the experimental plots on 12 April 2011 and remained on the plots until they reached their target slaughter conformation, with the last animals leaving the plots on 11th October 2011 (Day 504).

Parasite control, anthelmintic treatment and monitoring

In Year 2 (2010 grazing season) the parasite levels of the 48 (36 core animals and 12 additional) animals (n = 8 per replicate) animals was monitored whilst following standard farm practice with regards to gastro-intestinal parasite control. All animals were treated with long-acting (6-8 week) anthelmintics (supplied by Merial Animal Health) at 8 and 16 weeks after turnout, and again at housing (i.e. target 24 weeks after turn-out). The anthelmintic treatment on Day 28 of the experiment, which was 8 weeks after their initial turn-out is in line with standard farm practice (4 weeks of which they have rotationally-

grazed ‘parasite-clean’ sub-plots every 7 days on the experimental area). Faecal samples were collected on Day 0, 28, 70, 84 and 126 of the experiment for faecal egg count (FEC) and parasite culture determinations. Faecal samples for FEC were taken immediately prior to anthelmintic treatment (Eprinex Pour-on, 0.5% eprinomectin (Merial Animal Health, Harlow, Essex, UK) at a rate of 1 ml per 10 kg liveweight, given on Day 28, 84 and 126. FEC and culture samples were submitted immediately to the Parasitology Department, VLA Laboratories, Aberystwyth. FEC were determined using a modified McMaster technique (MAFF, 1997), with 1 egg representing 50 eggs g^{-1} of fresh faeces. Faecal cultures of *Trichostrongyle* type eggs to third stage larvae (L3) consisted of a 10 g faecal sample per individual steer, bulked per plot and incubated at 27°C ± 3°C for 7 days. Faecal dry matter (DM) was determined by placing a 15g sample of faeces at 95 C for 48h. On day 126, a blood sample was taken from each animal to determine *O. ostertagi* antibody levels using an enzyme-linked immuno-assay (ELISA), with results expressed as an optical density ratio (ODR) (Charlier *et al*. 2005) and plasma pepsinogen levels using a colorimetric method, with enzyme activity expressed as units (U) of tyrosine. The blood samples was taken into vacutainers without Heparin and the blood was left to clot (approx. 30 mins) before samples were centrifuged at 1300 RCF (G) for 10 min. The serum of each sample was then separately placed in a new eppendorf tube and stored frozen at -20ºC prior to analysis.

Winter housing period (Autumn 2010 – Spring 2011)

During the winter housing period, all animals was housed as one group and offered first cut clamp grass silage *ad libitum* mixed with the inclusion of 0.5 kg barley straw (fresh weight) offered per head per day. The feeding value of the silage to be offered was checked for quality (see Table 3 in results) prior to feeding, with the same clamp silage being fed to all animals over the winter period. The live weight of the steers was checked at 4 week intervals during housing. At the end of the winter housing period, animals returned to their respective replicate grazing plots and their performance was recorded fortnightly, as during the first grazing season.

Carcass characteristics and meat quality

In Year 3, steers was selected-out for slaughter as they were deemed as having reached a fat class of 3, with a target conformation of U, throughout the grazing period and their days to finish was recorded. All carcasses were commercially graded for conformation (EUROP classification) and fat class. Live weight and cold carcass weight was used to determine killing-out percentages. Meat quality (colour, shelf life, sensory properties, fatty acids and total lipids) was determined in collaboration with Bristol University.

Steers were transported from IBERS at Aberystwyth, Wales, to the University of Bristol, UK. Animals were housed overnight prior to slaughter. Muscle pH was checked at 2 and 48 h post-slaughter in the *M. longissimus* between the 10 and 11th rib, using a Testo 230 pH direct probe. After dressing, the carcasses were stored at 2 C. A 250 mm-long section of the hindloin joint containing the *M. longissimus lumborum* muscle was removed from the left side of the carcass, posterior to the 10th rib, and deboned. A 20 mm-thick steak was cut and the muscle dissected free of subcutaneous adipose tissue. The muscle sample was vacuum packed and frozen at 20 C for subsequent analysis of vitamin E, a further steak being retained for fatty acid analysis. The remaining section of the loin was vacuum-packed and conditioned at 1ºC to 14 days from slaughter. After this, three 20 mm-thick steaks were cut and packed individually in modified atmosphere packs (MAP, O_2:CO_2; 75:25) and subjected to simulated retail display (4 ºC, 700 lux for 16 h out of 24 h). The remaining section of the conditioned loin was frozen and stored at 20 C prior to sensory analysis.

Meat colour (L*a*b*) coordinates (CIE, 1986) were measured daily on two of the MAP packed steaks for 14 days on the surface of the steaks through the film lid using a Minolta Chromameter CR200 (Minolta Camera Company, Milton Keynes, UK). The chromameter was standardised against a white tile (L* = 97.78, a* = 0.19, b* = 1.84) covered in the MA top web film and checked against a red plate (L* = 23.0, a* = 24.3, b* = 11.5). Colour saturation (chroma), which is a measure of the intensity of the red colour, was calculated from the formula $[(a^*)^2 + (b^*)^{2,0.5}$ and hue, a measure of overall colour, was calculated from arctangent(b*/a*).

The other MAP steak was taken at Day 10, trimmed of excess visible fat around the edges, homogenised and subsampled, for analysis of lipid oxidation as thiobarbituric acid reacting substances (TBARS) by the method of Tarladgis *et al*. (1960) modified by the use of a Buchi 321 distillation unit. Vitamin E was analysed by the method of Arnold *et al*. (1993) using 5,7-dimethyl-tocol as internal standard.

Fatty acids analysis was carried out by direct saponification as described in detail by Teye *et al.* (2006). Samples were hydrolysed with 2M KOH in water:methanol (1:1) and the FAs extracted into petroleum spirit, methylated using diazomethane and analysed by gas liquid chromatography. Samples were injected in the split mode, 70:1, onto a CP Sil 88, 50 m $\times$ 0.25 mm fatty acid methyl esters (FAME) column (Chrompack UK Ltd, London) with helium as the carrier gas. The output from the flame ionization detector was quantified using a computing integrator (Spectra Physics 4270) and linearity of the system was tested using saturated (FAME4) and monounsaturated

(FAME5) methyl ester quantitative standards (Thames Restek UK Ltd, Windsor, UK). Total IMF content was calculated gravimetrically as total weight of FA extracted.

1.4 RESULTS

1.4.1 Forages

Germination percentages and chicory plant populations

The results of the germination test showed that the chicory and ryegrass seed had a germination success of 89 and 95 %, respectively. Plant population data showed that chicory established well in all three replicate plots. Chicory plant numbers of 110-131plants per square metre were recorded during the period from spring 2010 until autumn 2011 (Year 2), when the population declined to 56 plants /m^2.

Beef steers grazing ryegrass only swards during Year One (2010)

Herbage offtake as silage

The results of the mean DM yield, botanical composition and chemical composition of these silage cuts are presented in Table 1. Overall, the forage DM and crude protein yield from the chicory / ryegrass plots were numerically

higher than from ryegrass only plots in Cut 1 and 2 but not in Cut 3. The proportion of chicory in the cuts changed in each Cut, with the highest levels present during Cut 2 taken early July although at Cut 2, the inclusion of chicory did not result in differences in crude protein concentrations of the forage. Weed grasses, white clover and broad leaf weeds only contributed to a relatively low proportion of the forage harvested.

Table 1. Mean dry matter (DM) yield (kg DM/ha), botanical composition (kg DM/ha), chemical composition (g/kg DM) and chemical composition yield (kg/ha), of silage cuts taken during the first grazing season (2010).

	Cut 1		Cut 2		Cut 3	
	Grass	Chicory	Grass	Chicory	Grass	Chicory
Forage Yield	3861	4950	1745	2333	2421	2126
Comprising:-						
PRG	3815	4054	1691	1015	2404	1384
Chicory	1	814	0	1272	0	731
Weed Grass	42	23	22	31	1	8
White Clover	3	1	8	0	11	1
B. leaf weeds	1	58	24	15	4	4
Chicory %	0	16	0	55	0	34
Chemical composition						
CP	121	130	111	111	152	175
WSC	288	275	238	172	166	126
NDF	407	378	470	432	508	424
Ash	62	73	61	70	71	95
CP Yield	468	642	194	259	367	373
WSC Yield	1114	1360	415	402	402	267

Sward composition

Botanical composition data showed that chicory /ryegrass swards contained 24 and 14 % chicory on a DM basis in Year 2 and 3, respectively (Table 2a). The ryegrass plots had a higher forage biomass available to steers in Year 1 and Year 2, when presented on a DM basis. The amount of perennial ryegrass present in the chicory swards was consistent between years, and changes observed in botanical composition were due to a reduction in the chicory yield and an increase in introgressed weed grasses, white clover and other broadleaf weeds. Despite, the sward heights of the treatment plots being maintained at the same height, there was a higher biomass of available forage on ryegrass plots in Year 1 (P<0.05) but not in Year 2. Ryegrass only swards were found to have a higher water-soluble carbohydrate concentration in Year 1 but also higher fibre concentrations in Year 2 (Table 2b). These differences

between years are probably due to changes in the percentage of chicory present in the swards and its effects on sward density. The dry matter of forage on ryegrass plots was significantly higher in both Year 1 (P<0.05) and Year 2 (P<0.01). However, overall, the data showed that forage availability would not have restricted the voluntary intake capacity of the steers during this study.

Table 2a. Mean forage biomass, botanical composition and sward height of grazed plots within each grazing season (2010 and 2011).

i) 2010

	Grass	Chicory/RG	sed	Prob
Forage biomass (kg DM/ha)	1631	1313	71.8	*
PRG (kg DM/ha)	1602	971	126.4	**
Chicory (kg DM/ha)	-	324	-	-
Weed Grass (kg DM/ha)	14.0	7.5	23.8	ns
White Clover (kg DM/ha)	3.2	2.3	5.0	ns
B. leaf weeds (kg DM/ha)	11.5	7.5	5.7	ns
Chicory %	-	24	-	-
Sward Height (cm)	13.4	12.7	0.39	ns

ii) 2011

	Grass	Chicory/RG	sed	Prob
Forage biomass (kg DM/ha)	1388	1280	86.5	ns
PRG (kg DM/ha)	1261	1007	101.2	ns
Chicory (kg DM/ha)	-	174		
Weed Grass (kg DM/ha)	47.8	29.2	22.6	ns
White Clover (kg DM/ha)	9.7	8.4	3.39	ns
B. leaf weeds (kg DM/ha)	31.6	30.7	19.7	ns
Chicory %	-	14		
Sward height (cm)	12.1	11.7	0.47	ns

ns, not significant (P>0.05).

Table 2b. Mean forage dry matter and chemical composition of grazed plots throughout each grazing season (2010 and 2011).

i) 2010

	Grass	Chicory/RG	sed	Prob
DM (g/kg fresh matter)	209	184	5.4	*
CP (g/kg DM)	157	168	5.3	ns
WSC (g/kg DM)	128	107	7.7	*
NDF (g/kg DM)	531	471	25.2	ns
Ash (g/kg DM)	96	123	17.0	ns

ii) 2011

	Grass	Chicory/RG	sed	Prob
DM (g/kg fresh matter)	229	209	2.71	**
CP (g/kg DM)	148	157	5.34	ns
WSC (g/kg DM)	169	154	6.43	ns
NDF (g/kg DM)	525	495	9.92	*
Ash (g/kg DM)	80	89	4.35	ns

The quality of the ryegrass silage offered during the winter housing period had a high dry matter and ME content and a moderate crude protein concentration compared to a typical ryegrass silage produced in the UK.

Table 3. Silage composition of standard ryegrass clamp silage offered to steers during winter housing period (winter 2010-2011)

Chemical Composition	g/kg DM (unless otherwise stated)
Dry Matter (g/kg fresh weight)	448
pH	4.4
Ammonia N (g/kg total N)	44
Crude Protein	135
NDF	435
ME (MJ/kg DM)	11.4
Lactic Acid	40.6
Volatile Fatty Acids	20.2
Ash	7.7

1.4.2 Animals

Performance

The liveweight data showed that there were no differences between grazing treatments in the performance of beef steers during either the first or second grazing season and this was reflected in the number of days to slaughter (Table 4).

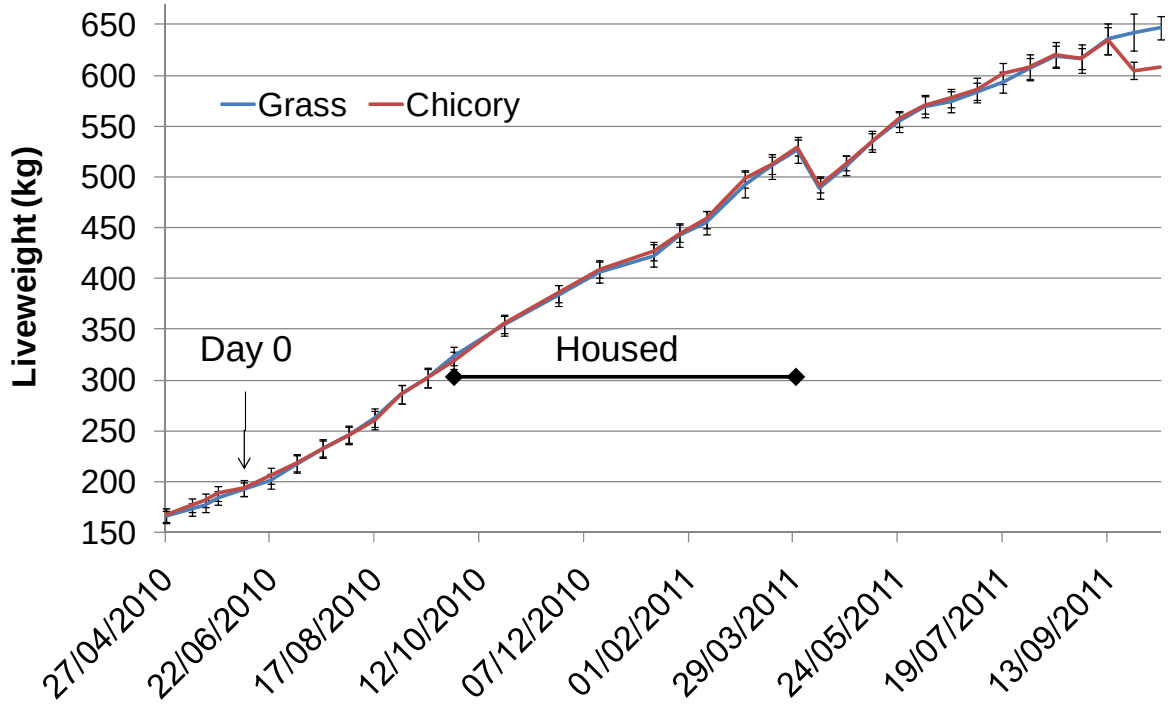
Table 4. Performance of beef steers grazing either chicory/ryegrass or ryegrass only swards during their first (Year 1) and second (Year 2) grazing season and during the winter period between whilst housed.

	Ryegrass	Chicory/ryegrass	sed	Prob
Live-weight gain (kg/day)				
Year 1	1.15	1.09	0.052	ns
Winter period	1.08	1.11	0.049	ns
Year 2	1.07	1.00	0.135	ns
Days to slaughter[a]	137	136	12.7	ns

[a], number of days from turnout in Year 2 to slaughter.

Data on steer performance comparing the first grazing season, winter housing period and then second grazing season showed that there were no differences in the daily liveweight gain of steers grazing chicory/ryegrass or ryegrass only swards in this experiment and averaged 1.04 kg /day. As expected, there was a slight decline in liveweight following turn out in Year 2. It should be noted that the decline observed for the last two measurements is a reflection of there only being 6 and 2 animals being left on the ryegrass and chicory/ryegrass plots, respectively on 27 September and then only 2 and 1 animal being left on the ryegrass and chicory/ryegrass plots, respectively, by 11 October 2011.

Figure 2. Mean and SEM liveweight (kg) of beef steers over the two year production period.



Parasite status

The results of the gastro-intestinal parasite data are shown in Table 5. These data showed that the steers experienced a moderate challenge of parasitic nematodes over the grazing season. Faecal cultures indicated that *Ostertagia ostertagi* and *Cooperia* spp. were the main parasite species present in the steers. There were no differences in faecal egg count (FEC), faecal DM or DM-adjusted FEC, *O. ostertagi* antibody or plasma pepsinogen levels of beef steers grazing either chicory/ryegrass swards or ryegrass only swards.

Table 5. Square root transformed FEC (g/DM), *O. ostertagi* antibody (ODR) or plasma pepsinogen (U) levels of grazing beef steers

	Ryegrass	Chicory/ryegrass	sed	Prob
FEC				
Day 0	51.7	51.4	4.25	ns
Day 28	65.0	65.2	7.40	ns
Day 70	25.9	31.2	2.70	ns
Day 84	37.2	45.6	3.94	ns
Day 126	20.8	23.1	7.64	ns
O.ostertagi antibody	0.72	0.70	0.06	ns
Plasma Pepsinogen	2.15	2.07	0.197	ns

Carcass characteristics and meat quality

Carcass slaughter grades were convered to numeric score as shown in Table 6a. The conformation, fat grade, killing out proportion and carcass weight of beef steers grazing ryegrass or ryegrass/chicory swards were not found to differ in this study (Table 6b). The carcass and fat grades in Table 6 are equivalent to R3, fat class as targeted and a better conformation.

Table 6a Carcass grading numeric scores

Fat	Numeric	Conformation	Numeric
1	20	E	155
2	45	U+	140
3	65	U-	115
4L	90	R	85
4H	105	O+	55
5L	125	O-	30
5H	145	P+	20
		P	15
		P-	10

Table 6b. Carcass characteristics of grazing beef steers

	Ryegrass	Chicory/ryegrass	SED	Probability
Conformation	85.0	92.8	8.74	ns
Fat grade	52.8	61.2	6.57	ns
Slaughter weight	638	632	12.3	ns
Killing out	0.55	0.56	0.004	ns
Carcass Weight				
Right side hot	178.1	176.8	3.21	ns
Right side cold	174.1	175.6	3.23	ns
Total cold	350.9	353.7	6.44	ns

Meat colour, vitamin E content, stability and eating quality

Measurements on the colour of the meat and the vitamin E concentration and oxidative stability of showed that there were no effects of including chicory in the diet of grazing beef steers. Figure 3 shows the differences in muscle colour over a 14 day period, when the colour finally turned brown. A chroma of 18 can be taken as the point at which a consumer will reject the product because of discolouration. A period of 14 days is much longer than the 7-8 days specified by retailers and is a reflection of the high vitamin E concentrations, which has been shown to stabilise meat colour. However, statistical analysis of colour at 24 h, (the time point at which the greatest visual difference between treatments was apparent) showed no difference between treatments (Table 7). Figure 4 shows there were no differences in the levels of fatty acid oxidation and vitamin E levels in the *M. longissimus* steaks taken from beef steers grazing chicory/ryegrass or ryegrass only swards. There were also no differences found in the eating quality of the steaks from the two treatments (Table 8).

Figure 3. *M. longissimus* colour during a 14 day period from beef steers grazing chicory/ryegrass or ryegrass only swards.

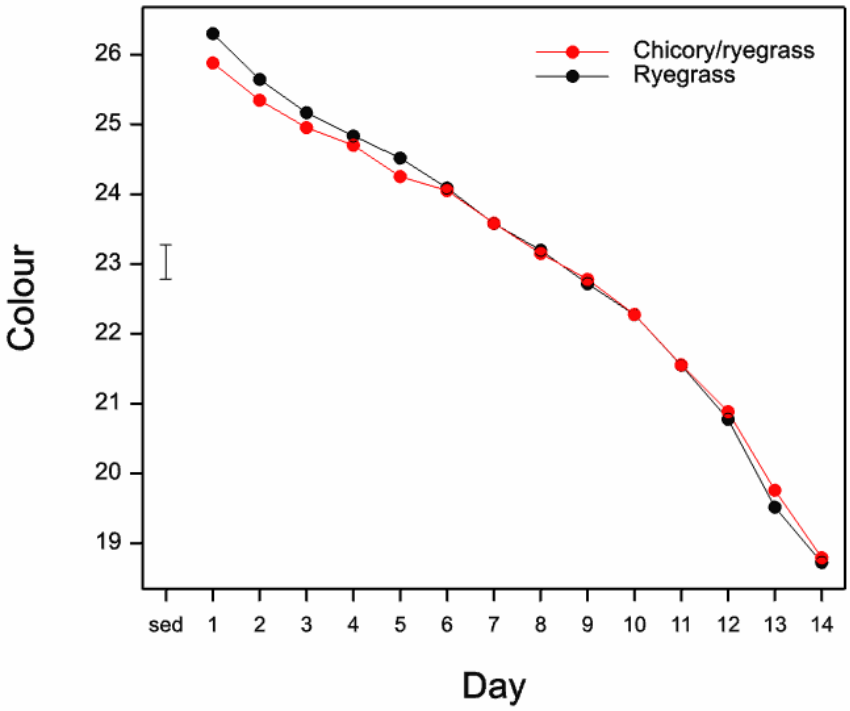


Table 7. *M. longissimus* pH, colour and stability after boning from beef steers grazing chicory/ryegrass or ryegrass only swards.

	Ryegrass	Chicory/ryegrass	sed	Prob
pH				
At 2h	6.18	6.26	0.100	ns
At 48h	5.59	5.71	0.053	ns
Temperature				
At 2h	33.9	34.4	0.59	ns
At 48h	2.56	2.43	0.369	ns
Colour at 24h	26.3	25.9	0.72	ns
L* (Lightness)	67.1	67.3	1.05	ns
a* (Redness)	3.24	3.83	0.935	ns
b* (Yellowness)	17.2	20.7	2.99	ns
Chroma	17.6	21.2	3.10	ns
Hue	79.6	78.9	1.56	ns
Vitamin E (µg/g)	3.97	4.30	0.306	ns
Oxidation (TBars (ug/g))	1.10	0.87	0.056[a]	ns

[a], sed values shown are $\log_{10}$ as data was transformed to normalise prior to statistical analysis.

Figure 4. Fatty Acid Oxidation (TBARS) (µg/100g) and Vitamin E (µg/100g) of *M. longissimus* steaks taken from beef steers grazing either chicory/ryegrass or ryegrass only swards.

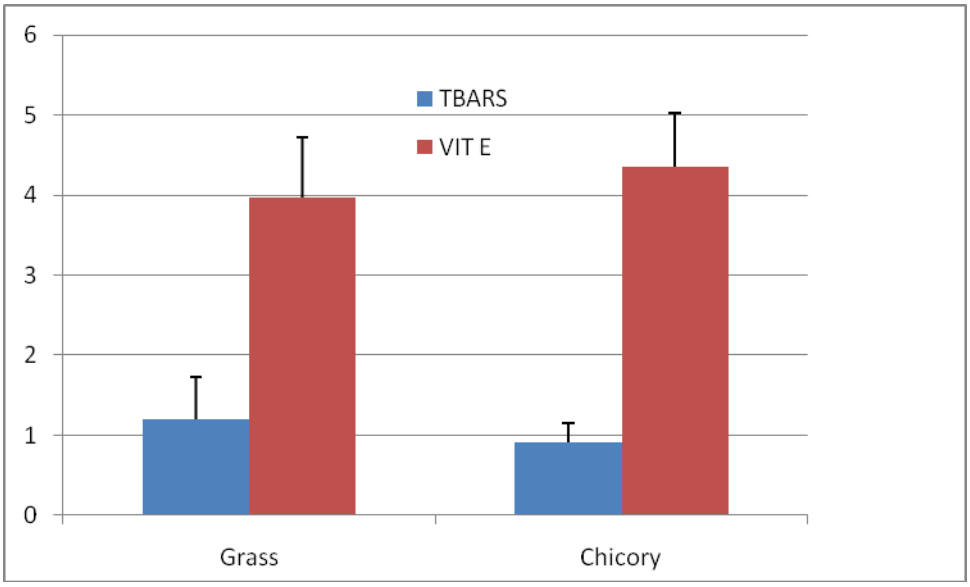


Table 8. Effects of pasture type on eating quality of beef steaks from steers that grazed either chicory/ryegrass or ryegrass only swards.

Attribute	Ryegrass	Chicory/ryegrass	SED	Significance
8 point category scale				
Texture	4.5	4.6	0.15	ns
Juiciness	5.1	5.1	0.12	ns
Beef	4.2	4.3	0.18	ns
Abnormal	2.2	2.1	0.6	ns
100mm line scale				
Greasy	9.2	8.5	1.73	ns
Bloody	12.8	12.6	2.72	ns
Livery	11	10.9	2.93	ns
Metallic	17.7	15.4	3.19	ns
Bitter	6.7	5.1	1.07	ns
Sweet	15.2	16.6	2.6	ns
Rancid	0.7	0.3	0.23	ns
Fishy	0.5	0.4	0.17	ns
Acid	7.3	5.7	1.07	ns
Cardboard	14.1	14.5	2.37	ns
Vegetable/Grass	15.9	13.9	2.79	ns
Dairy	13.7	14.71	2.52	ns
Hedonic				
Overall liking	48.6	50.73	2.1	ns

Tables 9 -10 show there were no differences in the levels of the total or selected individual fatty acids in the *M. longissimus* steaks taken from beef steers grazing chicory/ryegrass or ryegrass only swards.

Table 9. Effects of pasture type on the total fatty acids and selected fatty acid composition (mg/100g tissue) of the *M. Longissimus* muscle of from steers that grazed either chicory/ryegrass or ryegrass only swards.

	Ryegrass	Chicory/ryegrass	sed	Prob
14:0	64.6	59.9	8.31	ns
16:0	621	586	64.2	ns
16:1	102.2	96.9	12.12	ns
18:0	329.7	347.6	32.05	ns
18:1*trans*[a]	49.4	49.7	10.17	ns
18:1*cis*-9	866	849	102.5	ns
18:1n-7	29.4	29.3	2.69	ns
18:2n-6	62.1	63.2	1.38	ns
18:3n-3	39.0	38.9	0.91	ns
CLA[b]	10.8	10.1	2.34	ns
C20:3n-6	5.88	5.67	0.240	ns
C20:4n-6	20.9	20.7	0.94	ns
C20:4n-3	5.79	5.68	0.157	ns
C20:5n-3	17.13	17.39	0.716	ns
C22:4n-6	1.14	1.21	0.126	ns
C22:5n-3	21.8	22.1	0.33	ns
C22:6n-3	2.30	2.23	0.126	ns
Total	2496	2455	249	ns

[a]Combination of all isomers (sum of18:1trans4–16); [b]Conjugated linoleic acid, 18:2*cis*-9, *trans*-11.

Table 10. Total fatty acid composition (mg/100g tissue) and ratios of the *M. Longissimus* muscle from steers that grazed either chicory/ryegrass or ryegrass only swards.

	Ryegrass	Chicory/ryegrass	SED	Sig	P
Total SFA	1017	994	100.8		ns
Total MUFA	1050	1029	126.0		ns
Total PUFA	176	177	2.4		ns
Total n-6	90.0	90.8	1.66		ns
Total n-3	86.0	86.3	1.20		ns

SFA, Saturated fatty acids (sum of 12:0, C14:0, C15:0, C16:0, C17:0, C18:0, C19:0, C20:0);
MUFA, Monounsaturated fatty acids (sum of 16:1, C18:1, C20:1);
PUFA, Polyunsaturated fatty acids (sum of 18:2, C18:3, C20:3, C20:4, C20:5, C22:4, C22:5,C22:6);
n-3,sum of C20:4, C20:5, C22:5, C22:6;
n-6, sum of 18:2, C20:3, C20:4, C22:4;
P:S, (18:2n-6 + 18:3n-3)/(14:0 + 16:0 + 18:0).

Conclusion

In conclusion, the results of this experiment show that the inclusion of chicory in the diet of grazing beef steers did not alter their performance, faecal egg counts, blood indicators of parasite burdens, carcass characteristics, meat quality or meat sensory properties when compared with beef steers grazing ryegrass only swards.

Objective 2. Effects of chicory when ensiled alone or in combination with other forages on fermentation characteristics and silage quality

2.1 INTRODUCTION

Whilst there have been some anecdotal reports from industry that farmers are ensiling swards with chicory due to forage peaks during mid-season pasture growth, little is known about the effects of chicory when ensiled, which has limited its use as a year-round forage. In this objective, the effect of ensiling chicory either alone or in combination with perennial ryegrass (*Lolium perenne)* (PRG) or perennial ryegrass with red clover (*Trifolium pratense*) on fermentation and silage quality was investigated.

2.2 MATERIAL AND METHODS

Four replicate plots (7.5 m x 10 m) of chicory (cv. Puna II), perennial ryegrass (cv. Premium) and red clover (cv. Merviot) were established in a randomised block design on 29 June 2009. Plots were sown using a Fiona seed drill at the rate of 35, 16 and 6 kg ha^{-1} for ryegrass, red clover and chicory, respectively. On 23 March 2010, ammonium nitrate (34.5 % N) was applied at 77 kg N ha^{-1} to the chicory and ryegrass plots. On 17 May 2010, forage from each replicate block was harvested, bulked into one sample, and left to wilt in swaths for 48 h. On 19 May, forages were chopped through a stationary forage harvester, and treated with a silage inoculant (Powerstart Instant, Genus plc, UK) at the recommended rate. A 500g sub-sample of wilted forage was analysed for dry matter (DM), crude protein (CP) (N x 6.25), water-soluble carbohydrate (WSC), neutral detergent fibre (NDF) and ash. Triplicate 1.5 L mini-silos for each treatment were prepared. Prior to ensiling, forage DMs were estimated by heating 100 g in a microwave oven until a constant weight was achieved. Treatments were: 100% chicory, 75% chicory/25% ryegrass, 75% chicory/12.5% ryegrass/12.5% red clover, 50% chicory/50% ryegrass, 50% chicory/25% ryegrass/25% red clover, 25% chicory/75% ryegrass, 25% chicory/37.5% ryegrass/37.5% red clover and 100% ryegrass on a DM basis. The 100% chicory and 100% ryegrass treatments were also ensiled without inoculant. After 100 days, silages were opened and analysed for DM content and chemical analysis.

2.3 RESULTS

Forage yield (± SEM) of chicory, red clover and ryegrass at harvest was 3000 (± 273) kg DM ha^{-1}, 3462 (± 482) and 5142 (± 319), respectively. Prior to ensiling, numerically, wilted chicory had a lower DM content than ryegrass and red clover, a higher and lower CP concentration than ryegrass and red clover, respectively and a higher WSC than red clover (Table 1).

Table 1. Mean (± SEM) dry matter content and composition of wilted forages at ensiling (g kg DM^{-1})

	Chicory	Red Clover	Perennial Ryegrass
Dry Matter (g kg^{-1})	158 ± 2.7	254 ± 1.8	329 ± 1.4
Crude Protein	161 ± 3.0	253 ± 1.8	126 ± 1.7
WSC	277 ± 8.1	114 ± 2.6	265 ± 2.5
NDF	191 ± 5.0	256 ± 2.9	463 ± 2.4
Ash	77 ± 0.9	76 ± 0.2	48 ± 1.5

Silage DM contents declined with increasing proportions of chicory and were lower when ryegrass was replaced by red clover (Table 2). Silages containing red clover had a higher CP concentration than other silages but there was no effect of forage ratios on CP. WSC concentrations increased with increasing ryegrass but when red clover was included, forage ratio did not affect WSC. There was a forage x ratio interaction on silage pH: decreasing with increasing chicory inclusion. NDF concentrations decreased in silages with increasing chicory inclusion, with lower NDF concentrations in silages which contained red clover. Lactate concentrations increased as chicory ratios increased. Acetate concentrations were higher in the 75% chicory/25% ryegrass silage and all red clover silages compared to others. Ethanol concentrations increased in silages with increasing chicory inclusion, and silage with red clover had lower ethanol concentrations than those with ryegrass only.

Chicory silages had a lower pH and DM, WSC, NDF, ammonia-N, acetate, propionate and butyrate concentrations and higher concentrations of CP, lactate and ethanol than PRG silages (Table 3). Inoculated silages had a lower pH, lower NDF, ammonia-N and acetate and higher WSC and lactate concentrations.

Table 2. Chemical composition of 90 day silage consisting of differing ratios of chicory (C), perennial ryegrass (PRG) and red clover (RC) (g kg DM^{-1})

	PRG			PRG/RC			sed	F	R	FxR
Chicory (C)	25	50	75	25	50	75				
DM (g kg $fresh^{-1}$)	271	231	181	245	221	176	7.4	**	***	ns
Crude Protein	168	158	165	206	199	190	10.0	***	ns	ns
WSC	166	147	101	84	107	91	14.4	***	*	*
NDF	440	409	348	369	338	308	13.3	***	***	ns
pH	3.55	3.50	3.47	3.61	3.56	3.48	0.008	***	***	**
NH_3N (g kg N^{-1})	44	48	42	43	40	39	4.3	ns	ns	ns
Lactate	118	141	149	130	140	157	7.9	ns	***	ns
Acetate	5.1	5.1	7.3	7.2	7.0	7.0	0.78	*	ns	ns
Ethanol	35	42	55	30	23	34	5.3	***	**	ns

*F, effect of including red clover; R, effect of different ratios of chicory; ns, P>0.05; *, P< 0.05; **, P<0.01; and, P<0.001.*

Table 3. Chemical composition of 100% chicory and perennial ryegrass silage when ensiled either with or without an inoculant.

	Chicory		PRG					
g kg DM^{-1}	Inoc	Not inoc	Inoc	Not inoc	sed	F	Inoc	F x I
DM (g kg $fresh^{-1}$)	139	144	326	303	2.7	***	**	***
Crude Protein	188	176	149	163	4.8	***	ns	**
WSC	60	33	213	130	11.7	***	***	*
NDF	206	211	447	475	4.8	***	**	**
pH	3.37	3.60	3.62	4.55	0.014	***	***	***
NH_3N (g kg N^{-1})	39	75	47	98	4.1	***	***	*
Lactate	164	133	101	36	3.8	***	***	***
Acetate	6.0	28.7	4.3	8.5	1.36	***	***	***
Butyrate	0	0	0	23.8	0.64	***	***	***
Propionate	0	0	0	8.0	0.45	***	***	***
Ethanol	67	29	15	30	3.3	***	**	***

F; Forage effect; Inoc; inoculant effect; F x I; forage x inoculants effect. *ns, P>0.05; *, P< 0.05; **, P<0.01; and ***, P<0.001.*

2.4 CONCLUSIONS

The main effects of using chicory in silages that were observed were due to its low DM content. Despite wilting for 48 h, chicory DM contents were low, increasing the fermentation rate, as shown by high WSC and low lactate as chicory declined. Silages containing red clover have been shown to have an

increased buffering capacity, resulting in high pH as shown here. Despite red clover silages being higher in crude protein, ammonia-N did not differ when ensiled with chicory indicating a good fermentation with low protein breakdown. With 100 % chicory and perennial ryegrass silages, using a silage inoculant improved fermentation, with untreated silages having higher ammonia-N, lower WSC and higher acetate concentrations. Overall, chicory can be successfully ensiled when at a vegetative stage in mixtures with perennial ryegrass and red clover. Using an inoculant when ensiling 100 % chicory improved fermentation and silage quality.

Objective 3. Persistency, agronomic performance and nutritional value of chicory when sown in mixtures

3.1 INTRODUCTION

Including chicory in grass seed mixtures is becoming more popular, as it offers high yields of very palatable and nutritious fodder for grazing livestock. Research has previously found that, typically, crude protein (CP) and water-soluble carbohydrates (WSC) concentrations of chicory are higher than perennial ryegrass (PRG) (*Lolium perenne)* but crude protein concentrations are lower than red clover (RC) (*Trifolium pratense*) (Li and Kemp, 2005). However, little is know about the persistency of chicory when sown in combination with these other species and the impact of different seed combinations on forage quality and nutritive value.

This objective determined the effects of sowing chicory in combination with PRG only or PRG with RC on the persistency, agronomic performance and nutritional value of chicory when sown in different sowing mixtures. Red clover was included in the experiment to study its impact on reducing fertiliser inputs and the crude protein concentration of forage from chicory/ryegrass plots.

3.2 MATERIAL AND METHODS

Field plots (10 x 2.5 m) were sown with chicory (cv. Puna II) and perennial ryegrass (cv. Premium) in differing proportions, and either with or without red clover (cv. Merviot), in a replicated randomised block design with four replicate blocks. Forages were sown on 25 June 2009 at rates corresponding to a proportion of their usual monoculture rate, not the total seed rate (i.e. chicory at 6 kg ha^{-1}, PRG at 33 kg ha^{-1} and PRG / red clover at 22 / 11 kg ha^{-1}). The treatments consisted of chicory sown with PRG alone or a ryegrass / red clover mix consisting of 2 thirds of ryegrass and 1 third red clover, resulting in 10 combinations with chicory included as 0.9, 0.7, 0.5, 0.3 and 0.1 (Table 1). The experimental area was treated with glyphosate herbicide before ploughing. Lime, phosphate and potash were applied to correct any soil deficiencies prior to cultivation. Each plot was sown using an Oyjord experimental plot drill before the area was harrowed using an Einbock harrow and rolled. Slug pellets were applied at 2.5kg/ha on the 10 July. Plant establishment was assessed on the 6 August by measuring chicory and red clover plants within six 360mm x 250mm quadrats placed at random within each plot.

Table 1. The target proportion of chicory, ryegrass or ryegrass/red clover mix in the sward.

Treatment	Chicory	Ryegrass	Ryegrass/red clover mix	
1	90	10	0	90% Chic +PRG
2	90	0	10	90% Chic +RC
3	70	30	0	70% Chic +PRG
4	70	0	30	70% Chic +RC
5	50	50	0	50% Chic +PRG
6	50	0	50	50% Chic +RC
7	30	70	0	30% Chic +PRG
8	30	0	70	30% Chic +RC
9	10	90	0	10% Chic +PRG
10	10	0	90	10% Chic +RC

Table 2. Sowing rates (kg ha^{-1}) to reach target proportion of chicory, ryegrass or ryegrass/red clover mix in the sward, as given in Table 1 (assumes a 100 % chicory sward would be sown at 6.0 kg ha^{-1} and a 100% ryegrass sward would be sown at 33 kg ha^{-1} and that a ryegrass/ red clover seed mix would be 2/3 ryegrass and 1/3 red clover seed per kg).

Treatment	Chicory (kg ha^{-1})	Ryegrass (kg ha^{-1})	Red Clover (kg ha^{-1})	Total (kg ha^{-1})
1	5.4	3.3		8.7
2	5.4	2.2	1.1	8.7
3	4.2	9.9		14.1
4	4.2	6.6	3.3	14.1
5	3.0	16.5		19.5
6	3.0	11.0	5.5	19.5
7	1.8	23.1		24.9
8	1.8	15.4	7.7	24.9
9	0.6	29.7		30.3
10	0.6	19.8	9.9	30.3

All plots received 60kg ha^{-1} P_2O_5 and 60 kg ha^{-1} K_20 in the seed bed. The PRG/chicory plots received 50kg N ha^{-1} during establishment. During the establishment year, plots were mechanically harvested using a Haldrup plot harvester on the 14 September and the 19 October. During the first harvest year (2010), plots were mechanically harvested at 4 week intervals, on the 21 May, 17 June, 12 July, 10 August and 17 September. The PRG/chicory plots received inorganic N on 4 occasions, 77kg N on 23 March, 61kg on 26 May, 30kg on 22 June and 28kg on the 22 July 2010. During the second harvest year (2011), plots were mechanically harvested at approximately 4 week intervals, on the 4 May, 6 June, 27 June, 27 July, 2 Sept and 7th November 2011. The PRG/chicory plots received inorganic N on 4 occasions, 80kg N on 18 March, 31kg on 11 May, 31kg on 8 June and 32kg on the 11 July 2010.

Replicate experimental plots of chicory sown in differing ratios with ryegrass and either with or without red clover at Gogerddan, Aberystwyth.

To determine the persistency of the mixtures, the number of chicory (and, where applicable red clover) plants within a 0.15 m x 0.15 m quadrat at 6 random sites within each plot were counted in the spring and autumn of Years 1 (6-8 weeks post-sowing in spring of Year 1) and again in Year 2 and 3 and the plant population per m^2 determined.

Total yield was determined by weighing the material cut from an area of 10 m x 1.5 m within each plot. A sub-sample of the bulked material from each plot was submitted for chemical analysis to determine dry matter (DM), CP (total nitrogen x 6.25), WSC and neutral-detergent fibre (NDF) concentrations. Data were analysed using Genstat® 11.1 by polynomial contrast analysis to determine the effects of sowing ratios.

3.3 RESULTS

Figure 1 shows the number of chicory plant /m^2 present in plots sown without red clover but with ryegrass only in differing ratios and how the chicory persisted over time. The largest decline in chicory plant populations was found to relate to the highest sowing rate. However, there was a positive linear effect of the sowing ratio on the number of chicory plants found ($P < 0.01$) during the establishment year and these differences were still significant by the spring of the third harvest year (Table 3). Therefore, by spring of the third harvest year the chicory population was still 25 plants /m^2 when chicory was sown at 10 % of its usual monoculture sowing rate with ryegrass but without red clover.

Figure 2 shows the number of chicory plant /m^2 present in plots sown with ryegrass and red clover in differing ratios and how the chicory persisted over time. Plots not receiving artificial nitrogen but sown with red clover were found to reduce the number of chicory plants that persisted by spring of the first harvest year ($P < 0.05$), and this effect increased further with time ($P < 0.001$) (Table 3). Therefore, by autumn of the first harvest year the chicory population of these plots was found to be below 25 plants /m^2 when chicory was sown at 10 % of its usual monoculture sowing rate.

Figure 1. Plant populations of chicory (plants/m^2) when chicory is sown in combination with perennial ryegrass without red clover from establishment through to spring of the third harvest year.

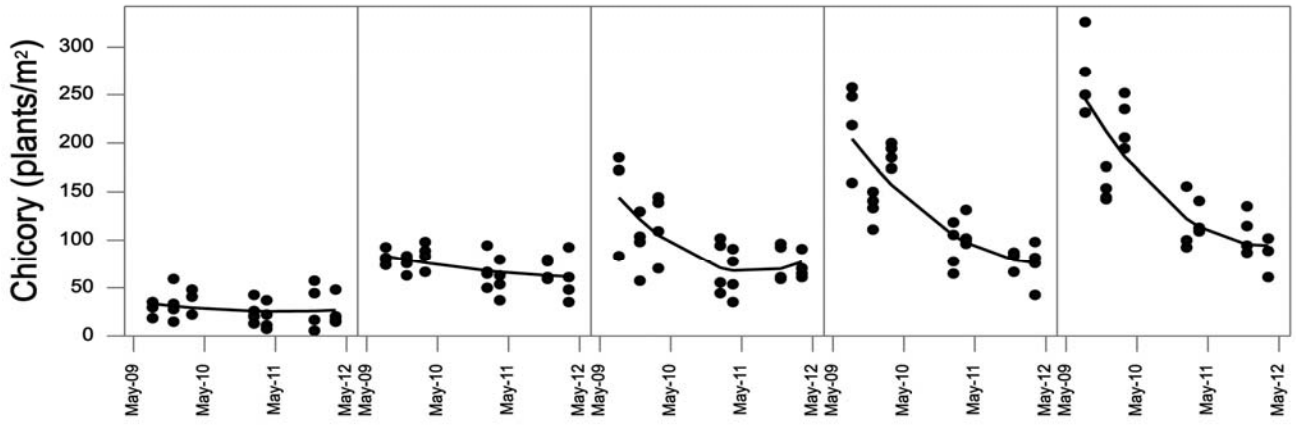


Figure 2. Plant populations of chicory (plants /m^2) when chicory is sown in combination with perennial ryegrass with red clover from establishment through to spring of the third harvest year.

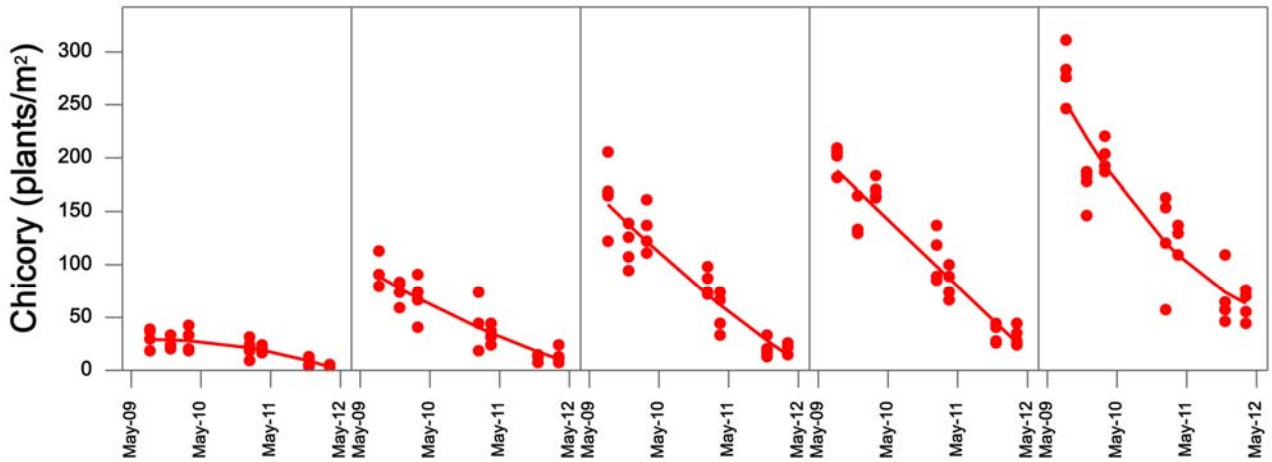


Table 3. Mean plant populations of chicory (plants/m^2) when chicory is sown in combination with perennial ryegrass, either with or without red clover (RC), during the establishment through to spring of the third harvest year.

	RC	Chicory Sowing Ratio (R)					sed	Prob	
		0.1	0.3	0.5	0.7	0.9		RC	R
Estab 2009	-	30	82	157	221	270	20.4	ns	***
	+	31	91	165	200	280			
Autumn 2009	-	34	76	97	134	154	12.7	ns	***
	+	26	75	117	140	174			
Spring 2010	-	33	84	116	188	222	12.7	ns	***
	+	29	68	133	170	201			
Autumn 2010	-	26	69	74	92	112	15.4	ns	***
	+	21	45	83	107	124			
Spring 2011	-	19	58	64	107	119	10.9	*	***
	+	21	34	55	82	121			
Autumn 2011	-	31	69	77	81	108	11.9	***	***
	+	8	12	21	35	69			
Spring 2012	-	25	59	72	75	85	11.0	***	***
	+	3	14	19	33	62			

ns, $P>0.05$; * $P<0.05$; *** $P<0.001$.

There was a positive linear relationship between the number of red clover plants and the sowing ratio of red clover seed when sown in combination with chicory and perennial ryegrass from establishment through to spring of the third harvest year (Table 4).

Table 4. Mean plant populations of red clover (plants/m^2) when sown in combination with chicory and perennial ryegrass during the establishment through to spring of the third harvest year.

	Chicory Sowing Ratio					sed	Prob
	0.1	0.3	0.5	0.7	0.9		
Establishment 2010	283	219	180	78	29	30.2	***
Autumn 2009	182	155	137	88	30	22.3	***
Spring 2010	103	90	87	67	27	10.1	***
Autumn 2010	74	63	64	52	38	10.4	*
Spring 2011	77	73	66	62	29	8.2	***
Autumn 2011	83	83	67	53	38	7.5	***
Spring 2012	61	49	49	42	31	7.0	*

* $P<0.05$; ** $P<0.01$; *** $P<0.001$.

The effects of the different sowing ratios and nitrogen treatments on the yields and nutritive value of yields during the first harvest year are shown in Table 5a. During the first harvest year, there was a linear increase ($P<0.001$) in the dry matter (DM) content and the DM yield of the harvested forage as the proportion of chicory sown was decreased but there was no effect of including red clover in the sown sward. There was a linear increase ($P<0.001$) in the yield of perennial ryegrass as the ratio of ryegrass sown increased in plots treated with inorganic N or sown with red clover and receiving no inorganic N. The yield of chicory was lower when chicory was sown in combination with perennial ryegrass and red clover and not treated with artificial N but there was a linear increase ($P<0.001$) in chicory yield as the sowing ratio of chicory increased. There was an interaction between the inclusion of red clover and the sowing ratio on the total forage protein yield. When chicory was sown with ryegrass only and treated with inorganic N, there was a positive linear increase in the forage protein yield as the proportion of chicory sown was increased. In contrast, when chicory was sown in combination with ryegrass and red clover and not treated with inorganic N, the highest forage protein yield was when chicory was sown at 10 % of its usual monoculture sowing rate. Sowing ratio was found to change the WSC yield, with a linear ($P<0.05$) and quadratic effect ($P<0.05$) on WSC of increasing the proportion of chicory sown with ryegrass. Although including red clover in chicory/ryegrass swards was found to reduce the overall WSC yield, the most linear response of the effects of differing sowing ratios on WSC yields was found in plots where red clover was present ($P<0.01$) (Table 5a).

The effects of the different sowing ratios and nitrogen treatments on the yields and nutritive value of yields during the second harvest year are shown in Table 5b. In the second harvest year, the inclusion of red clover had a significant effect on all yield and nutritional parameters whereas sowing ratios in contrast, did not alter the DM yield or WSC yield. Similar to the first harvest year, the yield of chicory was lower when chicory was sown in combination with perennial ryegrass and red clover and not treated with artificial N and there was a linear and quadratic increase ($P<0.001$) in chicory yield as the sowing ratio of chicory increased. There was also an interaction between the inclusion of red clover and the sowing ratio on the total chicory and the total forage protein yield. In the first and second harvest year, when chicory was sown in combination with ryegrass and red clover and not treated with inorganic N, the highest forage protein yield was when chicory was sown at 10 % of its usual monoculture sowing rate.

However, of note is the finding that the percentage of chicory found in the sward did not continues to increase with increasing sowing ratios, with percentage in plots of chicory was sown at 30 % of its usual monoculture rate being similar to plots at 90 %. This is despite plant population data showing that there are still differences in plant numbers. In contrast, when chicory/ryegrass were sown with red clover and not treated with inorganic N, the percentage of chicory was found to increase quadratically ($P<0.01$) by increasing the sowing ratio the percentage of chicory. Data for the second harvest year was therefore also compared by regression analysis to determine the effects of the actual percentage of chicory present on the nutritive value of the harvested forage. Results found that increasing the actual percentage of chicory in the sward had an effect on the crude protein ($P<0.001$) but not the WSC yield ($P=0.07$) of the harvested forage (Table 5b).

Table 5. Effects of sowing chicory in differing ratios with ryegrass and either with or without red clover (RC) on the DM content and chemical composition and total nutritional value of the harvested forages

a) First harvest year.

	RC	Chicory sowing ratio (R)					sed	Prob		
		0.1	0.3	0.5	0.7	0.9		RC	R	RCxR
DM content	-	187.9	165.5	163.0	151.7	147.1	7.85	NS	***	NS
g kg^{-1}	+	173.5	170.7	163.8	161.5	160.5				
DM	-	7001	8363	7579	8336	7611	668.6	NS	*	**
kg ha^{-1}	+	9438	8568	8459	7546	6006				
PRG	-	5623	5667	5201	4228	3086	572.7	***	***	NS
kg DM ha^{-1}	+	2084	1132	1468	1122	950				
Chicory	-	1220	2542	2172	3881	3705	519.6	***	***	NS
kg DM ha^{-1}	+	864	1348	2100	2294	2287				
Chicory	-	17.1	30.0	29.6	46.5	48.2	5.64	***	***	NS
%	+	8.9	15.4	24.3	30.4	37.8				
Protein	-	1011	1149	1122	1153	1223	119.3	***	**	***
kg ha^{-1}	+	1887	1646	1615	1286	994				
WSC	-	1610	1926	1681	1889	1613	136.5	***	*	NS
kg ha^{-1}	+	1442	1344	1340	1268	1009				

b) Second harvest year.

	RC	Chicory sowing ratio (R) 0.1	0.3	0.5	0.7	0.9	sed	Prob RC	R	RCxR
DM content g kg^{-1}	-	202.2	173.3	183.7	176.9	174.2	6.99	***	**	ns
	+	168.6	166.7	164.5	161.3	160.1				
DM kg ha^{-1}	-	6877	7308	7769	7639	7559	373.9	***	ns	ns
	+	11588	11420	11898	11592	10616				
PRG kg DM ha^{-1}	-	6113	4882	5246	5192	5161	347.4	***	*	ns
	+	1867	1517	1416	2131	1373				
Chicory kg DM ha^{-1}	-	352	1512	1578	1436	1303	182.8	***	***	**
	+	224	500	590	614	801				
Chicory %	-	5.1	20.7	20.7	18.7	17.3	2.39	***	***	**
	+	2.0	4.4	5.0	5.2	7.5				
Protein kg ha^{-1}	-	1034	1121	1151	1120	1147	81.2	***	*	**
	+	2600	2591	2581	2509	2234				
WSC kg ha^{-1}	-	1639	1640	1743	1701	1681	75.1	*	ns	ns
	+	1569	1588	1654	1581	1542				

ns, not significant; * P<0.05; ** P<0.01; *** P<0.001; RC, red clover effect; R, sowing ratio effect.

CONCLUSIONS

The highest plant populations for chicory were found when chicory was sown at ninety per cent of the target proportion of the sown sward and this effect was found at establishment through to the spring of the third harvest year. Chicory/ryegrass plots sown with red clover and not receiving artificial nitrogen were found to have lower numbers of chicory plants by spring of the first harvest year and this effect increased further with time. When chicory was sown in combination with ryegrass only, there was a positive effect of increasing chicory in the sward on the DM and crude protein yield during the first and second harvest year. However, when sowing chicory in combinations with PRG and RC, the highest DM, CP and WSC yields were found with increasing and decreasing proportions of red clover and chicory, respectively. Overall, sowing plots with ryegrass only and treating with artificial nitrogen was the best approach to maintain the persistency of chicory within mixed swards as chicory did not compete well with red clover when sown in combination with ryegrass.

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Project Publications to date

Marley, C.L., Fychan, R., Davies J.W., Sanderson, R. Genever, E., Forbes, A.B.(2011) Effects of chicory / perennial ryegrass swards compared with perennial ryegrass swards on the faecal egg counts of grazing beef steers. Proceedings of the ASF/AVTRW/BSAS/WPSA Annual Conference: Food Security – Challenges and Opportunities for Animal Science, Nottingham, 4-6th April 2011. In: Advances in Animal Biosciences, April 2011, Volume 2 (1), Cambridge University Press, pp.180.

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