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Studies on the use of locally grown field beans and red clover in dairy cow diets

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CONTENTS

High quality protein plays a crucial role in dairy cow diets. Historically bypass protein has been provided principally by soya beans and rapeseed meal. These protein sources have to be imported and can be subject to significant price fluctuations. In addition, there is increasing pressure to reduce the use of soya beans for environmental reasons.

It was with this in mind that AgriSearch with co-funding from DAERA commissioned research at AFBI to investigate the potential role for home-grown proteins in dairy cow systems. The results of this research are documented in this booklet.

The results of the research indicate that home grown field beans have the potential to replace up to half of the imported soya in typical dairy cow diets. This has the additional benefit of significantly reducing the cost of dairy cow rations.

The importance of food security and shorter food supply chains has been highlighted by the current Covid-19 pandemic. Imported protein supplements are expensive and subject to price volatility.

In addition, the long-term supply of non-genetically modified protein into Europe cannot be guaranteed. Reducing imports would both increase resilience in the sector and improve the carbon footprint and environmental sustainability of local dairy systems.

Thomas Steele
Chairman - Dairy Advisory Committee

"The importance of food security and shorter food supply chains has been highlighted by the current Covid-19 pandemic."

Disclaimer

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- Only a small proportion of high protein crops required for livestock feeds are grown within the European Union. To address this, there is interest in growing protein crops locally.

- A number of studies were conducted to examine options for partially replacing imported protein feedstuffs in dairy cow diets with locally grown 'protein crops'.

- Three of these studies involved locally grown field beans. Field beans have a lower protein content than soya-bean meal (approx. 28% crude protein on a dry matter basis) but a relatively high starch content (approx. 40% starch on a dry matter basis).

- In Experiment 1, cow performance was unaffected when either moist rolled beans treated with propionic acid, or dried beans were offered. This has demonstrated that if beans are grown on local farms, they can be preserved moist on the farm using acid treatment, without the need to take them to a drying plant.

- Field bean inclusion levels in dairy cow diets is normally low. In Experiment 2 field beans were included in the diet at up to 4.7 kg per cow per day with no reduction in cow performance. In this study the beans partially replaced the conventional protein components in the diet.

- In Experiment 3, which involved early lactation cows, fat plus protein yield was reduced when cows were offered 8.4 kg field beans per day. There was also a hint that fertility may have been negatively affected. Consequently, it is recommended that field bean inclusion levels for dairy cows should not exceed 4.0 – 5.0 kg per cow per day.

- Due to their high phosphorus content (approximately 9 g/kg dry matter), rations containing higher levels of beans will need to be carefully balanced to avoid phosphorus levels becoming excessively high.

- The cost of field beans varies considerably from year to year, and the cost of beans relative to other feed ingredients is also extremely variable. There are years when it may make economic sense to feed field beans, while there are other years when alternative protein sources may be more cost effective. •

- Red clover is a protein forage which is of interest within livestock systems in Northern Ireland. Pure red clover swards can produce yields of 18 t dry matter during the first year following sowing, without fertiliser nitrogen. However, red clover levels in swards (and as such, yields) tend to decrease over a 3 – 5 year period following sowing.

- Red clover typically has a crude protein content of between 18 – 22%, substantially higher than that of grass at the same growth stage. When offered to dairy cows, intakes of red clover silage are generally higher than intakes of grass silage. However, the milk production response of cows to red clover inclusion in the diet is variable.

- In Experiment 4, grass silage and red clover silage were mixed at four different ratios (0, 30, 50 and 70% red clover on a dry matter basis). While total silage dry matter intake increased with higher inclusion levels of red clover in the diet, milk yield, milk fat and protein content, and fat + protein yield were unaffected.

- In Experiment 5, three cuts of silage from a pure grass sward were compared with three cuts of silage from a mixed grass/red clover sward. While responses were extremely variable between harvests, when the mean performance across all three harvests is examined, intakes were higher with the silage produced from the grass/clover swards, although milk production was not affected. The value of milk produced per hectare was lower with the grass/red clover silage. This was not compensated for by the lower fertiliser nitrogen input with this treatment.

- The results of Experiments 4 and 5 showed no overall benefit from including red clover in dairy cow diets.

As the UK livestock sector has expanded and intensified, the demand for concentrate feeds has increased, as illustrated in the figure below. This increase in concentrate use has led to an increased demand for 'high protein' feedstuffs such as soya-bean meal and rapeseed meal. However, the European Union (EU) currently grows only 30% of the 'high protein' feeds required for its livestock sector, with the remaining 70% imported from non-EU countries. This reliance on imported protein feeds has left the livestock sector vulnerable to price volatility and instability of supply, while EU legislation places restrictions on the importation of genetically modified protein feedstuffs.

To overcome these issues, there is increasing interest in growing protein crops locally. In addition, the use of locally grown protein crops may bring wider benefits, including their low reliance on fertiliser nitrogen (compared to grassland), diversification of crop rotations, improved biodiversity, changes in weed, pest and disease pressures, improved soil fertility, and potentially lower greenhouse gas emissions.

This research programme was established to examine options for partially replacing imported protein feedstuffs in dairy cow diets with locally grown 'protein crops'. The programme focused on two crops, namely field beans (a 'grain' legume) and red clover (a 'forage' legume).

> "The use of locally grown protein crops may bring wider benefits"

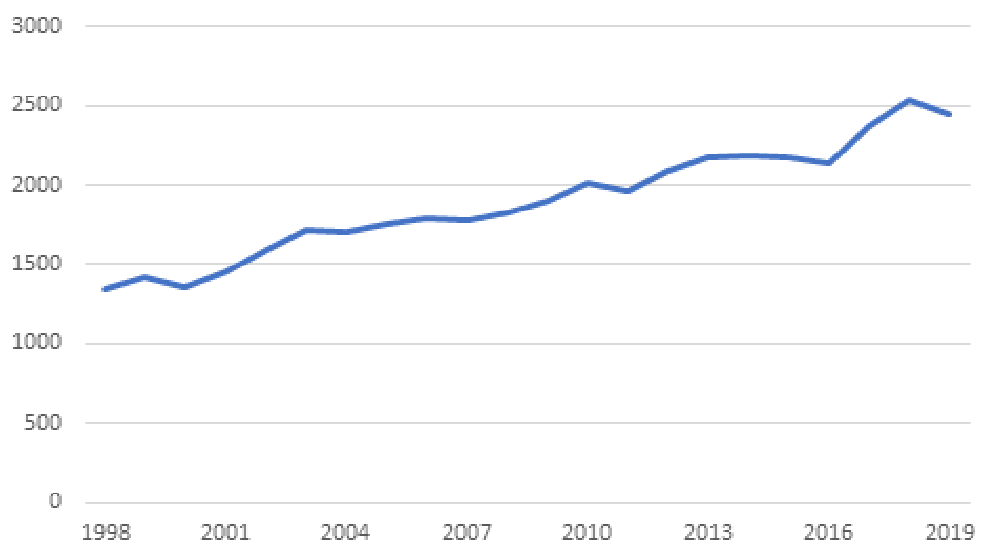


Figure A Total Quantity of Compound Feedstuffs Purchased in Northern Ireland ('000 tonnes)

Figures taken from DAERA NI

*Provisional figures for 2019.

Background

Field bean (Vicia Faba) is a grain legume which is often used as a break crop in cereal rotations. The crop is well suited to the cooler moist summers found in western parts of the United Kingdom and in Ireland, and can be grown on heavier wetter soils. On lighter soils it can be susceptible to drought. The crop can be planted in both the spring and autumn, although spring planting is more common in Ireland. Spring sowing normally takes place from late February to mid-April, and beans are normally sown at 30 – 35 seeds/m2, and to depth of at least 7.5 cm, to avoid crow damage. As the crop is a legume, it can 'fix' its own nitrogen from the atmosphere, thus eliminating the need for expensive fertiliser nitrogen. However, the crop has a requirements for phosphorus and potash, and rates will be determined by soil nutrient status.

Field bean competes poorly with weeds post emergence due to the open nature of the crop, and attention to weed control is required. Pest control (e.g. for bean weevil) and disease control (e.g. for chocolate spot and downy mildew) are likely to be required. Harvesting takes place from mid-September onwards, with the crop normally 'burn-off' prior to harvest. Late harvesting can be a problem, making it difficult to sow the following crop on time. Field beans can leave substantial amounts of residual nitrogen in the soil, and this can reduce the need to apply nitrogen to the following crop.

Field bean yields of 4.5 – 7.5 tonnes/ha have been reported in Ireland. While the crude protein content of field beans is lower (approx. 28%, DM basis) than that of soya-bean meal (approx. 50%, DM basis), beans have a relatively high starch content (approx. 40%, DM basis), and as such might appear to be ideal in ruminant diets. Nevertheless, the inclusion of field beans in ruminant diets is normally restricted due to the perceived risk associated with 'anti-nutritional substances' that have the potential to reduce intakes and digestibility, and oestrogenic compounds that could adversely impact fertility. However, there is limited information on the optimum level of inclusion of field beans in dairy cow diets.

Downy mildew on field beans

Field beans can be grown either alone for conventional harvest, or grown with cereals and ensiled as a whole crop. In addition, beans can be combined moist and crimped. A number of studies in the Republic of Ireland have examined these options. However, AFBI studies have focused on incorporating dry field beans into dairy concentrates as a partial or complete replacement for conventional protein sources.

AFBI studies

Three studies were conducted within this project. Experiment 1 examined the impact of three different post-harvest processing treatments for field bean on dairy cow performance. In Experiment 2, mid-lactation dairy cows were offered diets containing moderate levels of field beans. The third experiment (Experiment 3) examined the impact of including higher levels of field beans in the diets of early lactation dairy cows.

The effect of degree of milling of dry field beans, and acid preservation of moist field beans, on dairy cow performance

Background

In the more northerly parts of the UK beans are frequently harvested with a high moisture content, and treatment is then required to prevent mould growth and loss of quality. Moist beans are frequently dried, and the dried beans then physically processed to break the hard seed coat to facilitate digestion. However, there is little information available on the impact of degree of physical processing of dried beans on subsequent performance. This is an important issue given the high starch content of beans. In addition, beans can be preserved moist using acid treatment, and this approach has been adopted on some local farms. However, the impact of acid treatment on cow performance is unknown. This study was designed to examine the effect of physical treatment of dried field beans, and of moist preservation of field beans using propionic acid, on dairy cow performance.

The Study

The field bean crop used in the experiment (Variety Boxer) was harvested at a moisture content of approximately 25%. Three post-harvest treatments were examined as shown in the photographs displayed to the right. The treated beans were then offered to mid-lactation dairy cows in a short experiment. Cows on all treatments consumed approximately 3.5 kg beans per day.

"there is little information available on the impact of degree of physical processing of dried beans on subsequent performance"

Dried beans, coarsely rolled: The beans were dried to a moisture content of 16% and then coarsely rolled.

Dried beans, finely milled: The beans were dried to a moisture content of 16% and then finely milled.

Moist beans, acid treated: The moist beans were coarsely rolled and then treated with propionic acid at a rate of 20 litres/ton fresh beans.

Outcomes and Implications

The results of Experiment 1 are summarised in Table 1, and clearly demonstrate that offering either coarsely rolled or finely milled beans had no effect on either intakes or milk production. Thus at the levels used in this study, bean particle size was not important. Similarly, there was no difference in performance when either dried beans, or moist beans which had been preserved using acid, were offered. Thus if beans are grown on local farms, they can be preserved moist on the farm using acid treatment, without the need to take them to a drying plant.

Table 1 The effects of post-harvest treatment of field beans on cow performance

	Dried beans, coarsely rolled	Dried beans, finely milled	Moist beans, acid treated
Silage intake (kg DM/day)	13.0	13.2	13.4
Total intake (kg DM/day)	22.6	22.9	22.3
Milk yield (kg/day)	33.5	33.3	32.0
Milk fat (%)	4.19	4.15	4.22
Milk protein (%)	3.37	3.39	3.39
Milk fat + protein yield (kg/day)	2.50	2.47	2.33
Body condition score at end of study	2.6	2.6	2.6

The impact of including 'low' levels of field beans in the diet of mid lactation dairy cows

Background

While Experiment 1 has demonstrated that moist field beans can be included in dairy cow diets, the use of dried beans is likely to be more common, especially if beans are grown in 'arable areas' and then sold on to feed mills or livestock farms. Nevertheless, few studies have examined the impact of including field beans in dairy cow diets, and most of these have involved low inclusion levels, normally between 1 – 2 kg/cow/day. However, if locally grown beans are to replace significant quantities of imported protein feeds, then higher inclusion rates must be adopted. This study was designed to examine the impact of including moderate levels (0 – 4.7 kg/cow/day) of field beans in the diets of mid-lactation dairy cows, with the beans partially replacing the conventional protein components in the diet.

The Study

The study involved sixty mid lactation dairy cows, with all cows offered grass silage as the basal diet. Cows were offered one of four concentrate types (10.0 kg per day) through an out-of-parlour feeder. These concentrates contained either 0%, 16%, 32% or 47% field beans (Ingredient composition in Appendix 1), and resulted in intakes of beans across the four treatments of 0, 1.6, 3.2 or 4.7 kg per cow each day. In the concentrate containing 47% field beans, the beans replaced approximately 75% of the soya-bean meal and 50% of the rapeseed meal. All four concentrates had the same crude protein and starch content (19.3% and 29.5% on a fresh basis, respectively), and a similar metabolisable energy content. The beans used in the study (variety Fuego) were sourced from a local farm, and had been dried to 16% moisture content, before being milled and incorporated into the concentrates.

Outcomes

The effects on cow performance of including field beans in the concentrate at four different levels is presented in Table 2. The results clearly demonstrate that dairy cows were able to consume up to 4.7 kg beans/day with no adverse effects on either intakes or milk production. However, at the highest bean inclusion level (4.7 kg/day), there was a small reduction in milk protein content, although fat + protein yield was not reduced with this treatment. In general, the results of this experiment demonstrates that field beans can be included in dairy cow diets at higher levels than previously recommended, without having any detrimental effects on performance.

Mature crop of field beans

Table 2 The effects on cow performance of including low levels of field beans in the diet of mid lactation dairy cows,

	Intake of field beans (kg/day)			
	0	1.6	3.2	4.8
Silage intake (kg DM/day)	12.8	12.9	13.1	12.7
Total intake (kg DM/day)	21.7	21.9	21.8	21.5
Milk yield (kg/day)	28.0	29.0	27.4	28.0
Milk fat (%)	4.35	4.46	4.51	4.45
Milk protein (%)	3.49	3.52	3.49	3.41
Milk fat + protein yield (kg/day)	2.05	2.23	2.16	2.16
Average body condition score	2.44	2.44	2.43	2.43

Dried beans

The effect of including high levels of field beans in the diet of early lactation dairy cows

Background

While Experiment 2 demonstrated that field beans can be included in the diets of mid-lactation dairy cows with no adverse effects, Experiment 3 was designed to examine the impact of higher inclusion levels of field beans in dairy cow diets. In addition, this study was designed to include the early lactation period so as to examine possible effects of field beans on fertility performance.

The Study

This three treatment study involved seventy early lactation dairy cows, with the diets offered for the first 20 weeks of lactation. Cows were offered a mixed ration of silage and concentrates (approximately 55% concentrate on a DM basis), with the concentrates containing either 0%, 35% or 70% field beans (Ingredient composition in Appendix 1). These concentrates resulted in daily intakes of beans of 0, 4.2 and 8.4 kg/cow, respectively. In the diet containing 8.4 kg beans, the beans replaced all of the soya-bean meal, rapeseed meal and maize gluten in the concentrate. All four concentrates had the same crude protein content (19.3% on a fresh basis), although starch levels were marginally higher with the 8.4 kg beans treatment. As in Experiment 1, the beans (variety Fuego) were sourced from a local farm, and dried to approximately 14% moisture content, before being milled and incorporated into the concentrates.

Outcomes

The effects of including field beans in dairy cow concentrates are presented in Table 3. The results clearly demonstrate that dairy cows were able to consume the diet which contained 8.4 kg beans/day with no negative effect on intakes. This suggests that the 'anti-nutritional substances' present in beans may not have as large an impact on intakes as previously thought. However, while milk yield was not affected by treatment, both milk fat and milk protein contents were reduced when the diet containing 8.4 kg of beans was offered, and as a consequence, milk fat plus protein yield was also reduced.

The reduction in milk protein content is likely to reflect a shortage of specific amino acids in the diet. For example, field beans are known to contain lower levels of the amino acid methionine than either soya-bean meal of rapeseed meal, and methionine is essential for milk protein synthesis. Thus it is speculated that the reduction in milk protein content might have been avoided if the diet containing 8.4 kg of beans had been supplemented with methionine. While the reduction in milk fat content might be due in part to the slightly higher starch intake with highest bean treatment (8.4 kg beans/cow/day), the type of starch in beans is also very different from that in cereals, and this might also have had an effect on milk fat. Regarding fertility performance, the inclusion of beans in the diet had no effect on days to first oestrus. However, conception rates tended to fall when the diet containing 8.4 kg of field beans was offered. It is impossible to know if this is a genuine effect of beans as very large numbers of cows are needed to measure fertility performance accurately. Nevertheless, the observed trend causes some concern regarding the inclusion of very high levels of beans in the diets of early lactation cows. Consequently, based on the results of this study, in order to manage the potential risks which field beans may present, it is recommended that field bean inclusion levels for dairy cows do not exceed 4.0 – 5.0 kg per cow per day.

Table 3 Effects on cow performance and fertility of including field beans in the diet of early lactation dairy cow

	Intake of field beans (kg/day)		
	0	4.2	8.4
Silage intake (kg DM/day)	9.7	9.6	9.8
Total intake (kg DM/day)	21.9	21.6	22.1
Milk yield (kg/day)	35.7	33.2	33.9
Milk fat (%)	4.28	4.25	4.13
Milk protein (%)	3.38	3.36	3.22
Milk fat + protein yield (kg/day)	2.71	2.49	2.47
Average body condition score	2.5	2.5	2.5
% of cows showing oestrus within 42 days of calving	75	67	79
% of cows pregnant to first plus second service	62	57	50

The use of field beans in dairy cow diets

On many arable farms field beans are grown as a 'break crop' within a cereal rotation, so beans could be adopted as part of a rotation on dairy farms where whole crop cereal or maize silage is grown for cows. Similarly, on grassland farms beans could be grown in fields where reseeding is planned. However, late harvest would normally prevent an autumn reseed, while taking grassland out of production to grow a 'concentrate' crop will affect forage availability, which may create problems on some intensively stocked farms. Growing beans successfully also requires good crop husbandry skills, and grassland farmers may not always have the appropriate skills. Consequently, while a number of dairy farmers may continue to grow beans on their own farms, beans are more likely to be grown on arable farms and then purchased directly by livestock farmers, or by feed compounders for incorporation into their concentrates.

Growing and using field beans may have a number of environmental impacts. Firstly, as a legume, beans are able to fix atmospheric nitrogen and consequently do not have a requirement for fertiliser nitrogen. They also leave a high level of residual nitrogen in the soil for the following crop, although if no crop is planted until the following spring, there is an increased risk of nitrogen losses by leaching over the winter months. If beans are locally grown, their inclusion in the concentrate may reduce the carbon footprint of the milk produced. However, field beans contain relatively high levels of phosphorus (approximately 9 g/kg DM), and their inclusion may increase the overall phosphorus content of the diet, thus contributing to local water quality issues. If not grown on the farm, this may create challenges for dairy farmers operating under a derogation from the Nitrates Directive, who must achieve an annual farm phosphorus surplus of less than 10 kg P/ha. Rations containing higher levels of beans will need to be balanced carefully to avoid phosphorus levels becoming excessively high.

Economics of using field beans

Changes in the cost of beans between 2013 and 2019, relative to the costs of other 'protein' and 'energy' feed ingredients, are presented in Figure 1 and 2, respectively. Firstly, these figures demonstrate that the cost of field beans varies considerably from year to year, and secondly, that the cost of beans relative to other feed ingredients is also extremely variable. This variability will clearly impact on the economics of using field beans in dairy cow diets. To examine this further, the actual costs of individual feedstuffs between 2013 and 2019 (costs from DEFRA) were used to determine what the costs of the concentrates offered in Experiments 2 (Figure 3) and Experiment 3 (Figure 4) would have been over that period of time (standard costs were included for minerals, feed additives, milling and transport). The results clearly demonstrate that there were periods when including field beans in the concentrates would have increased concentrate costs, while at other times, including field beans in the concentrate would have reduced concentrate costs.

Harvesting field beans

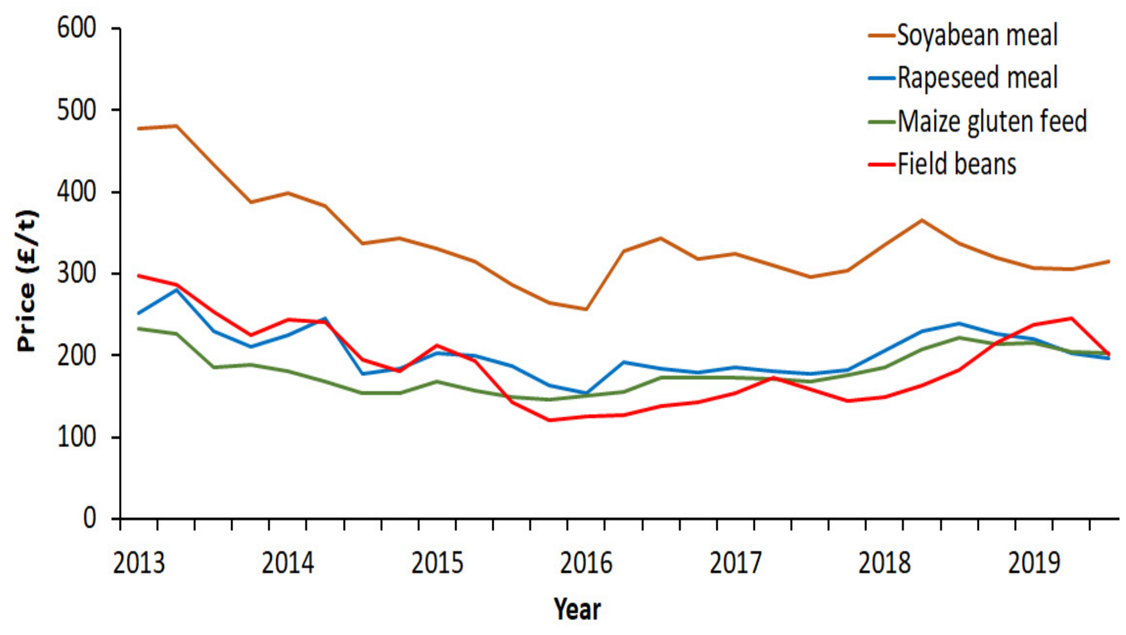
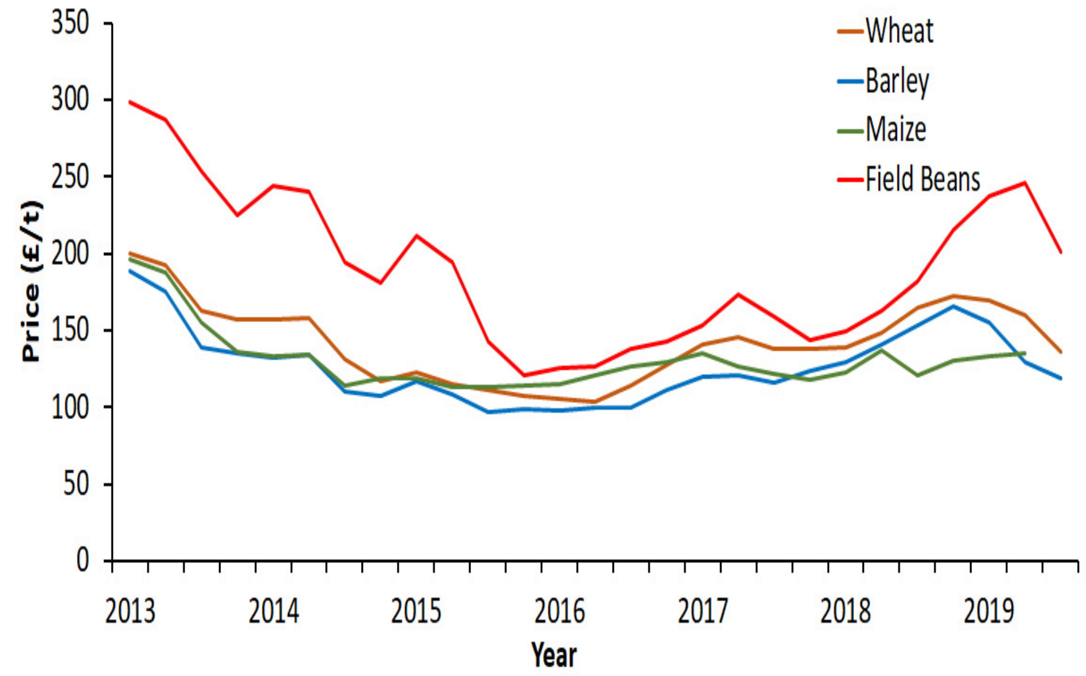


Figure 1 Changes in the cost of field beans, relative to the cost of other protein feeds, between 2013 and 2019 (DEFRA)



Fgure 2 Changes in the cost of field beans, relative to the costs of cereals, between 2013 and 2019 (DEFRA)

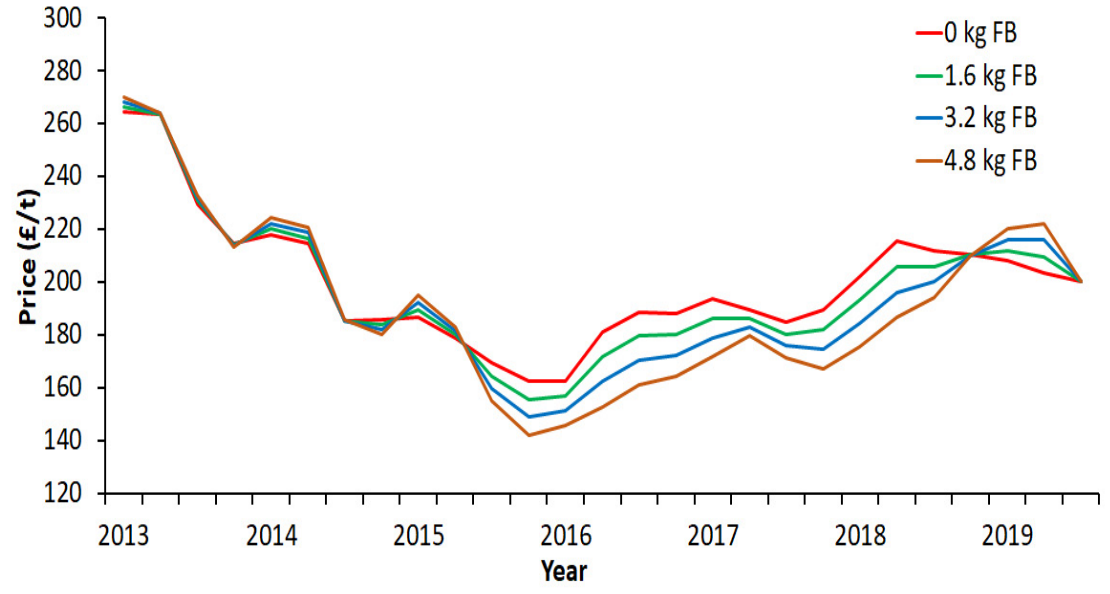


Figure 3 Effect of field bean inclusion level on the cost of concentrates offered in Experiment 2 (based on raw material prices between 2013 and 2019)

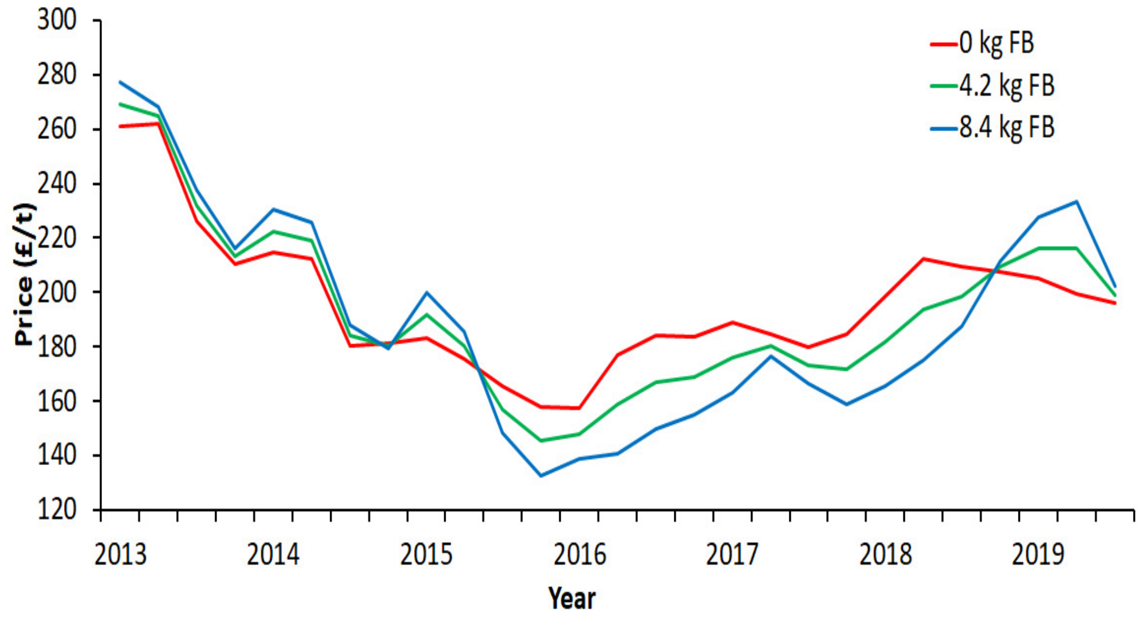


Figure 4 Effect of field bean inclusion level on the costs of concentrates offered in Experiment 3 (based on raw material prices between 2013 and 2019)

Margin-over-feed costs (MOFC)

Margin-over-feed-costs (MOFC) were then calculated for the winter feeding period in each year between 2015 and 2019, based on the actual concentrate costs in Figure 3 and 4. These calculations assumed a milk price of 28 pence per litre (adjusted for standard compositional bonuses), and a silage cost of £100/t DM. Margin-over-feed-costs in Experiment 2 are summarised in Figure 5. In this experiment, cow performance was unaffected by field bean inclusion, so differences in margins are largely due to differences in concentrate costs. In general, MOFC would have been unaffected by field bean inclusion in 2015, while in each of 2016, 2017 and 2018, MOFC would have increased with increasing level of field beans in the diet. However, in 2019 MOFC would have decreased as field bean inclusion level in the diet increased due to the higher costs of beans that year. These results clearly demonstrate that at low inclusion levels of field beans in dairy cow diets, the impact on margins is totally dependent on the cost of beans, relative to other feed ingredients.

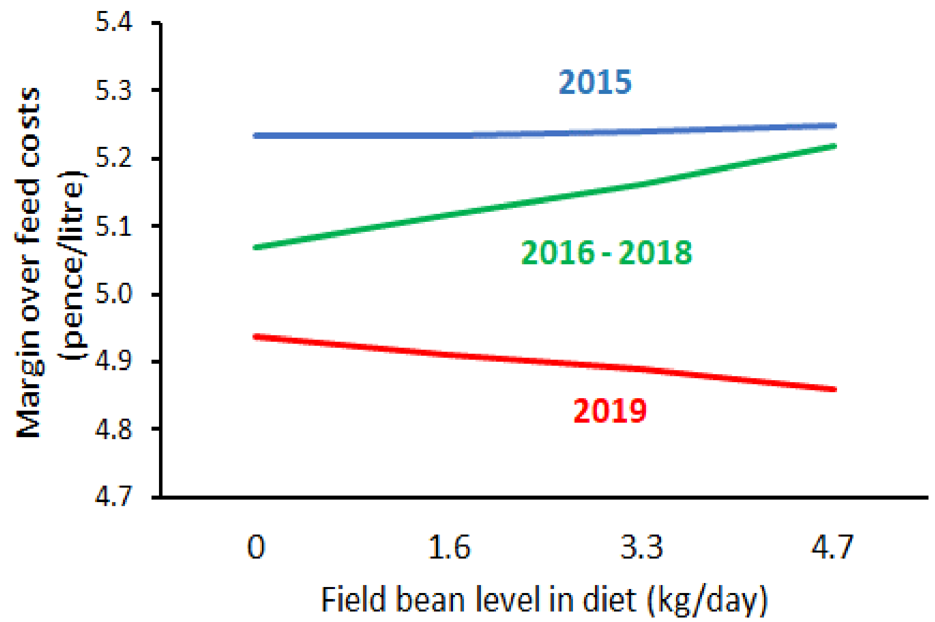


Figure 5 Effect of field bean inclusion levels and concentrate costs, on margin-over-feed-cost in Experiment 2 (based on concentrate prices in 2015, 2016 – 2018, and in 2019).

Background

Prior to the widespread use of inorganic nitrogen fertilizer, red clover was a common constituent of grass seed mixtures within the UK. It had an important role in grassland for hay, increasing the overall protein content of the hay crop, and the hay aftermath. It was also recognised to have a positive effect on soil fertility and structure. However, with the increased use of nitrogen fertilizers, together with the change from hay making to silage production, the importance of clovers, especially red clover, decreased. There is however renewed interest in the use of red clover within livestock systems in Northern Ireland.

Cultivars

In the 1970s tetraploid red clover varieties were bred which, with their larger plants, and resistance to some of the common pests and diseases, produced higher DM yields than diploid varieties at that time. However, the majority of high yielding modern varieties are diploid. Thus the association between ploidy level and production does not now apply. While red clover was traditionally grown as part of a grass clover mix, more recent varieties have been bred with the objective of them being grown on their own. Most red clover varieties available today are early flowering ('double cut') and are generally suited to silage cutting regimes. As red clover is no longer widely used, seeds merchants do not hold a large or varied stock of red clover seed. Thus if a specific variety is desired, the order for seed should be placed well in advance of sowing to ensure that the merchant has time to source it.

Establishment

Clovers require soils at P index 2 and K index 2+, and a pH above 6.0. Due to their small seed sizes, careful attention needs to be paid when sowing clover. Optimal sowing depth is 10 to 15 mm, and if sown deeper than 25 mm, the number of plants establishing will be reduced. If red clover is sown on its own, a sowing rate of 13-15 kg/ha is recommended, whereas if sown with grass, the sowing rate should be reduced to about 8 kg/ha. While red clover can be established successfully using minimum cultivation techniques, control of the previous sward is vital to prevent it outcompeting the young establishing red clover plants. It is advised to sow red clover early to mid-season, as research has shown establishment to be poorer if it is sown in August or September.

As the lifetime of a red clover crop is usually limited, there may be a temptation to reseed red clover into an existing red clover crop. However, there is a risk of attack by stem eelworm (Ditylenchus dipsaci) or the fungus that causes clover rot (Sclerotinia trifoliorum). While modern varieties are relatively resistant to these, they are not completely so. Thus it is recommended that red clover is not re-sown into the same area for a period of 5 to 6 years.

Fertiliser Management

Being a legume, red clover is capable of fixing atmospheric nitrogen in association with a bacterium (Rhizobium trifolii). Nitrogen fixation can supply all of red clover's need for nitrogen, with crops fixing between 200 – 300 kg N/year. When nitrogen fertiliser is applied to a red clover crop, nitrogen fixation is reduced at approximately the same rate as the amount of inorganic fertiliser N applied. Thus the crop derives no benefit from N application. In contrast, when N fertiliser is applied to a grass-red clover sward, grass growth increases and can become competitive towards red clover, so although total DM production increases, the contribution of the red clover declines. As a result, the response of the sward to N fertiliser is lower than it would be if grass had been grown on its own. Some of red clover's nutrients can be supplied by slurry. In a plot trial at Hillsborough in which dairy cow slurry was applied by trailing shoe to red clover growing in a highly fertile soil, a response to slurry was found only when soil reserves of phosphorus and potassium were inadequate to meet red clover's needs during the third and fourth years (Figure 6).

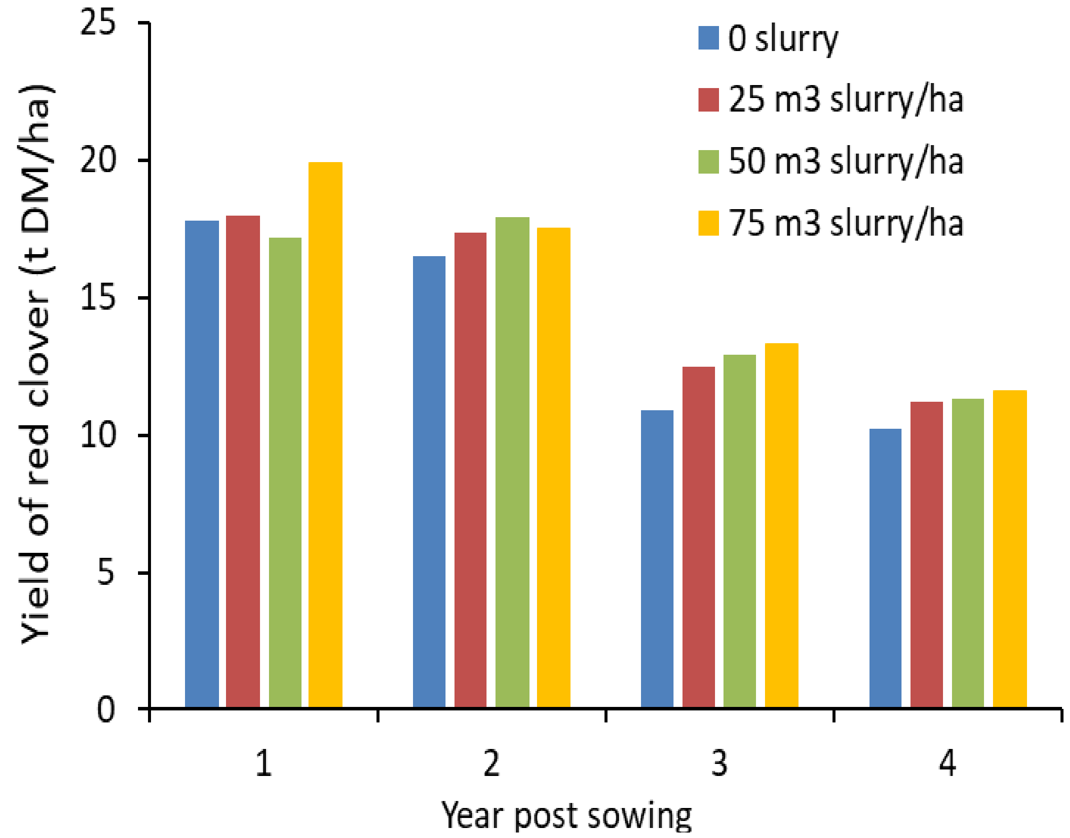


Figure 6 Effect of four levels of slurry application (0, 25, 50 and 75 m^3 per ha per year) on annual DM yields of a pure red clover sward, over a four year period

Yield

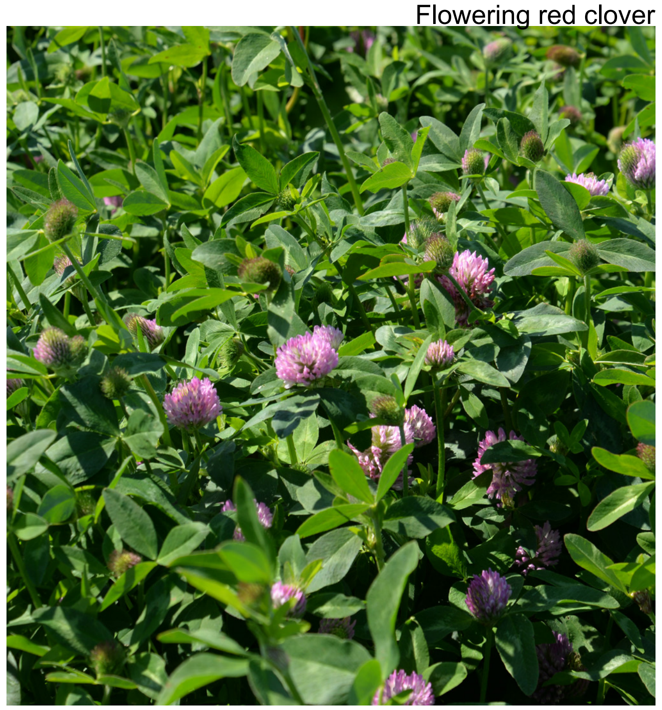
When grown on its own in a plot trial at Hillsborough, red clover produced 18 t DM/ha in the first year, with yields declining considerably during year 3 and 4 (Figure 6). However, when grown on its own under farm conditions, red clover can be expected to produce 12-14 t DM/ha in its first full harvest year without fertiliser nitrogen. More recently there has been a preference among farmers to include hybrid ryegrasses as the companion with red clover. Hybrid ryegrasses produce high yields of dry matter per annum but have a productive lifetime of only about 5 years. When grown with hybrid ryegrass in an environment which is relatively free of pests and disease, and where sward damage is minimal, red clover could remain productive for a similar period as hybrid ryegrass, albeit making a progressively smaller contribution with time, especially after the second year. If the red clover declines markedly earlier than the grass, then additional N fertilizer may have to be applied.

Management

Red clover is principally a forage crop for silage production, and under Northern Ireland conditions it can normally be cut three times in the season. The optimum time for the first cut is when the flower buds are just about to open. However, red clover's higher moisture content and buffering capacity, together with its generally lower sugar content, make it potentially more difficult to manage as a silage crop compared to perennial ryegrass. An alternative management approach involves taking two cuts of silage, and then grazing the aftermath with finishing lambs or by cattle. However, as red clover contains oestrogenic substances, care is required when grazing with breeding livestock, especially ewes around tupping.

One of the major limitations to red clovers longevity in swards is physical 'damage' to the plant. As red clover's shoots grow vertically, the growing point is particularly vulnerable to grazing, and damage by hooves or machinery. This risk appears to have increased as machinery has increased in size. In contrast, white clover stems (stolons) grow horizontally over the soil surface, ensuring that the growing point is protected from damage, or from removal by the grazing animal. While red clover normally has a productive life of 3 - 5 years, under appropriate management white clover can persist indefinitely. Disease and pests represent another significant risk to red clovers longevity. Indeed, much of the breeding effort has been devoted to improving resistance to diseases such as clover rot fungus (that affect leaves, crown and roots), and to root and stem nematodes. While these breeding programmes have been relatively successful, red clover is still a short lived perennial. Nevertheless, there have been exceptions to this. For example, in an AFBI trial comparing varieties of red clover grown on their own and with a range of companion grasses, the red clover continued to make a valuable contribution to the mixed swards for up to six years, albeit that yield declined gradually but progressively after the second year.

Flowering red clover



Animal Production

Red clover typically has a crude protein content of between 18 – 22%, substantially higher than that of grass at the same growth stage. In addition, red clover contains varying contents of an enzyme called polyphenol oxidase, and this enzyme can give some 'protection' to both fats and protein in red clover, limiting their breakdown in the rumen. These can then pass to the small intestine where they can be utilised more efficiently by the cow. When offered to dairy cows, intakes of red clover silages are generally 1.0 – 2.0 kg DM/day higher than intakes of grass silage. This is partly due to the faster rate of breakdown in the rumen of red clover particles, compared to grass silage particles. However, the milk production response of cows to red clover inclusion in the diet is variable, and is one of the key factors examined in the AFBI research programme.

AFBI Research Programme

The current project involved three studies. In the first of these (Experiment 4), silage produced from a pure red clover crop was mixed with grass silage at a number of inclusion rates, and offered to dairy cows. In Experiment 5, silages produced from a mixed red clover/grass silage sward were compared with silage produced from a pure grass silage sward, when offered to dairy cows. A further study (Experiment 6) compared wilting rates of red clover swards compared to grass swards following mowing.

> "Red clover is principally a forage crop for silage production, and under Northern Ireland conditions it can normally be cut three times in the season."

Growing red clover crop

Effect of mixing grass silage and red clover silage at four different ratios on cow performance

Background

Red clover can either be grown by itself as a 'pure' sward, or grown alongside grass in a 'mixed' sward. This study used silage produced from a pure sward of red clover. The study was designed to examine how cow performance was affected when red clover silage partially replaced grass silage in dairy cow diets.

The Study

In this short term study dairy cows were offered a diet comprising grass silage alone, or mixtures of grass silage and red clover silage. With the latter treatments the red clover replaced either 30%, 50%, or 70% of the grass silage on a dry matter basis. Each of these diets was supplemented with 12.5 kg concentrate/cow/day, with protein levels varying so that the total protein content of all diets was similar (17% of total DM).

Outcomes

The grass silage offered had a crude protein content of 14%, while the crude protein content of the red clover was 16%. Although the red clover silage had a lower fibre content than the grass silage (44% vs 51%), the grass silage was of good quality and had a metabolisable energy content of 11.2 MJ/kg DM. Both silages were well fermented. Total silage DMI increased with higher inclusion levels of red clover in the diet, as has been observed in many other studies (Table 4). However, replacing grass silage with red clover silage had no effect on milk yield, milk fat and protein content, and on fat + protein yield. The digestibility of the dry matter and fibre within the total diet decreased when grass silage was replaced by red cover silage.

In spite of the higher intakes when red clover was included in the diet, no cow performance benefits were observed in this study. While the red clover appeared to have been harvested at an optimal stage of growth (it had a lower fibre content then the grass silage), red clover inclusion clearly reduced the digestibility of the overall diet. This might reflect the relatively high quality of the grass silage offered, rather than the red clover silage being of a low quality.

Red clover being mown

Table 4. Cow performance when cows were offered either grass silage alone, or when grass silage was replaced by 30, 50 or 70% red clover silage (on a dry matter basis)

		Grass silage plus		
	Grass silage only	30% red clover silage	50% red clover silage	70% red clover silage
Red clover silage intake (kg DM/day)	0	3.3	6.0	8.4
Total silage intake (kg DM/day)	11.8	11.3	12.3	12.6
Total intake (kg DM/day)	22.7	22.2	23.2	23.5
Milk yield (kg/day)	33.5	32.0	32.8	32.9
Milk fat (%)	4.04	4.00	4.14	3.97
Milk protein (%)	3.22	3.20	3.16	3.21
Milk fat-plus-protein yield (kg/d)	2.41	2.29	2.38	2.34
Digestibility of dry matter (%)	77	74	74	73
Digestibility of fibre (%)	70	67	65	62

Milk production potential of silage made from red clover/ grass swards

Background

In mixed grass-clover swards, the red clover proportion in the sward increases as the season progresses. Consequently the red clover content of a first cut silage will be considerably lower than in a third cut silage. This study therefore examined the effects on cow performance of offering silage produced from each of three harvests of a pure grass sward, compared to each of three harvests of a grass/red clover sward.

The Study

Three cuts of silage (harvests 1, 2 and 3) were harvested from either a pure grass sward, or a mixed grass/red clover sward, which had been sown the previous autumn. The grass sward received a total of 248 kg N/ha over the growing season, while no nitrogen was applied to the grass/red clover sward. These silages were then offered to mid-lactation dairy cows with all cows being offered 8.0 kg concentrate per day throughout the experiment.

Outcomes

While the grass silage produced in each of harvests 1, 2 and 3 had a similar crude protein content (Figure 7), the crude protein content of the grass/red clover silage was very low at harvest 1 (9.8%, DM basis), moderate at harvest 2 (14.8%), and increased to 21.6% at harvest 3. This reflects the increasing proportion of red clover in the sward as the season progressed, estimated to be approximately 20% at harvest 1, 40% at harvest 2 and 60% at harvest 3. The metaboliable energy content of the silages produced were similar at each of harvests 1 and 2, but lower with the grass/red clover silage at harvest 3. Silage DM intakes, milk yields and fat plus protein yields for the grass silage and grass/red clover silage at harvests 1, 2 and 3, are presented in Figure 8. These figures highlight the highly variable responses between harvests. For example, silage DM intakes were higher with the grass/red clover silages at harvests 1 and 2, but not at harvest 3.

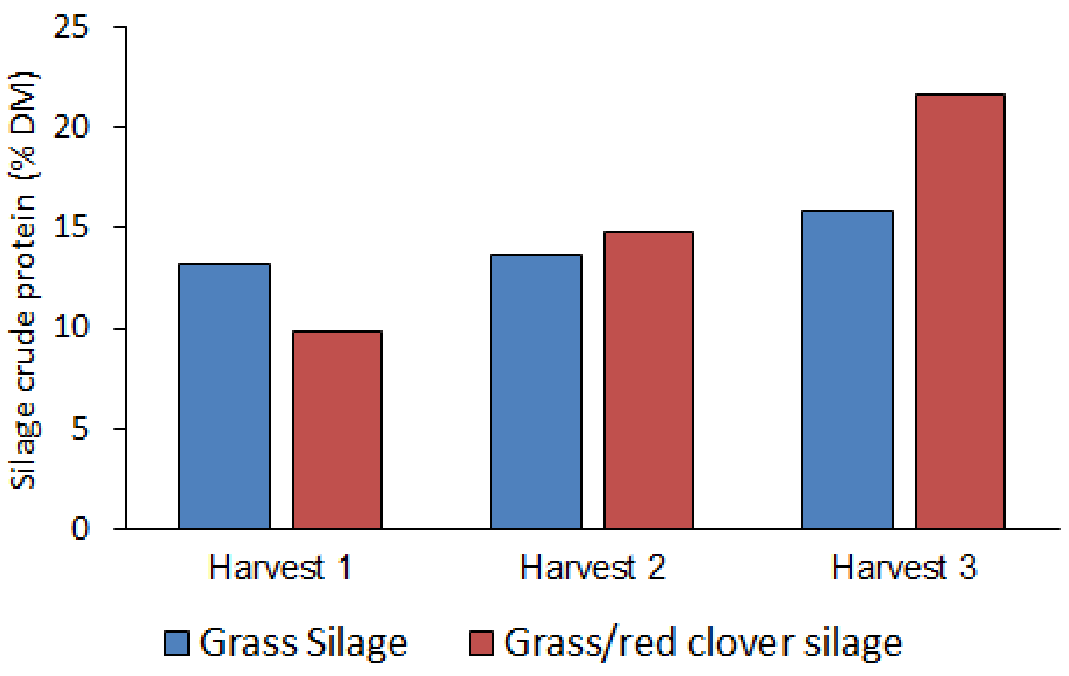


Figure 7 Crude protein content of the grass silage and red clover/grass silage produced from each of harvests 1, 2 and 3

Table 5 Mean performance of cows offered silages produced from the 1st, 2nd and 3rd harvest of either a grass sward or a grass/clover sward

	Grass silage	Grass/red clover silage
Silage intake (kg DM/day)	9.5	11.1
Total intake (kg DM/day)	16.7	18.3
Milk yield (kg/day)	23.4	24.4
Milk fat (%)	4.68	4.58
Milk protein (%)	3.23	3.15
Fat + protein yield (kg/day)	2.62	2.56
Body condition score at end of study	2.52	2.56

However, milk yield was unaffected by silage type at harvests 1 and 2, while being higher with the grass/red clover silage at harvest 3. Fat + protein yield was not affected by silage type at any harvest. However, when the mean performance across all three harvests is examined (Table 5) with the exception of silage DM intake, which was higher with the grass/ red clover silage, none of the other measures differed between treatments. The study has clearly demonstrated the very different cow performance responses to red clover inclusion which can arise between individual harvests within a season, especially during the first full season following establishment, when the relative proportions of the two species changed considerably over the season. The variability in silage composition between harvests also creates very practical challenges. For example, the very different forage crude protein levels with the grass/red clover mix creates real practical difficulties in balancing the protein content of the diets offered.

"different forage crude protein levels with the grass/red clover mix creates real practical difficulties in balancing the protein content of the diets offered."

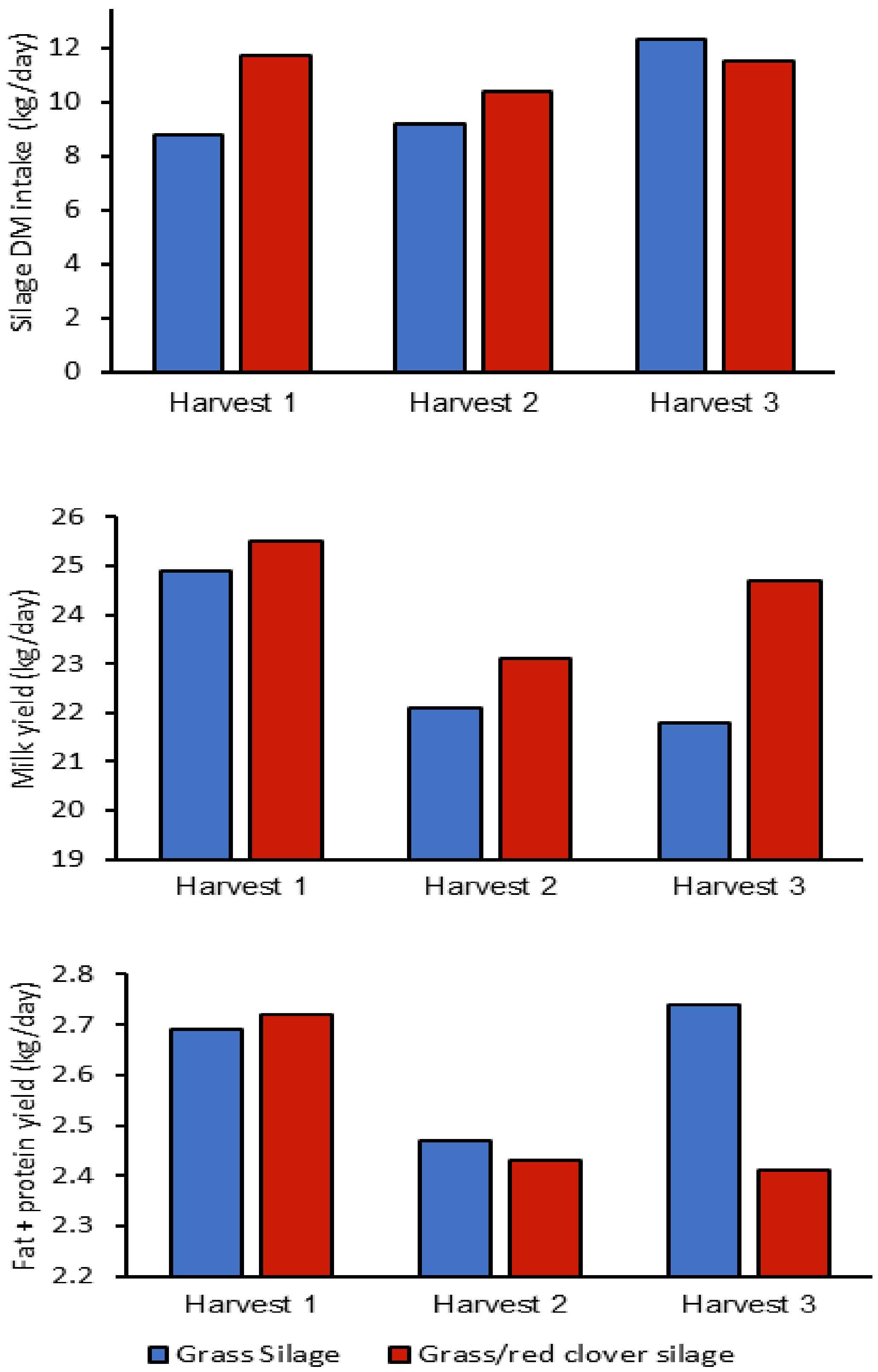


Figure 8 Silage DM intake, milk yield and fat plus protein yield of dairy cows offered silages produced from either a grass sward or a grass/red clover sward (for each of harvests 1, 2 and 3)

Overall Systems Effect

The total yield of DM over the three harvests was 10.4 t/ha with the grass sward and 9.9 t/ha with the grass/red clover sward (Table 6). Using these herbage yields (in-silo losses assumed as 10% of DM ensiled), and the mean silage intakes across the experimental period, one hectare of the grass sward was able to produce sufficient silage for 985 'cow feeding days', while one hectare of the grass/red clover sward was able to provide sufficient silage for 803 'cow feeding days' (Table 6). Given that the value of milk produced per cow/day was £7.02 with the grass silage and £7.20 with the grass/red clover silage (milk at 28 pence per litre, plus standard compositional bonuses) the total value of milk per hectare was £6917 and £5779 with the grass silage and grass/red clover silage, respectively. Thus, even considering the saving in fertiliser use with the grass/red clover silage system (approximately £220/ha), this did not compensate for the loss in the value of milk produced. Furthermore, limits to red clover persistence also need to be taken into account, with reseeding of red clover swards normally required every 3 – 4 years. In addition, the saving in fertiliser nitrogen creates another potential dilemma, in that red clover swards still have a requirement for phosphorus and potassium. Thus if these nutrients are to be supplied from slurry, the crop will likely be oversupplied in nitrogen, and the nitrogen fixing potential of the red clover will not be realised.

Conclusions

In this study, which involved crops harvested in the first full season of growth following establishment, cow performance was extremely variable between harvests. However, the higher total DM intakes with the grass/red clover crop, combined with the lower yield of herbage grown, resulted in a lower value of milk produced per hectare with the grass/red clover silages.

Mixed grass/red clover sward

Table 6 Effect of sward type of herbage production, number of 'cow feeding days' per hectare, and the value of milk produced per cow and per hectare (milk at 28 pence/litre)

	Grass	Grass/red clover
Forage yield (t DM/ha)	10.4	9.9
'Cow feeding days' (per ha)	985	803
Value of milk produced per cow per day (£)	7.02	7.20
Value of milk produced per ha (£)	6917	5779*

*While fertiliser savings of approximately £220/ha were achieved with the grass/red clover sward, this sward will likely require more frequent reseeding.

Do red clover swards wilt more slowly than grass swards?

Background

Red clover is often perceived as being a more difficult crop to ensile than grass, with this due in part to its high protein content. Consequently, adequate wilting of the crop is necessary to ensure a good fermentation. However, red clover tends to have a lower DM content than grass, meaning that a more extensive wilt may be required to ensure good fermentation. In contrast, under good drying conditions its leaves can be easily lost by shattering during field operations, and as red clover leaves are rich in protein this can reduce the protein content of the silage produced. However, it is not known if, despite its lower DM content at harvesting, red clover can lose moisture faster than grass during field drying. A trial was conducted to measure the rate of loss of moisture from red clover compared with perennial ryegrass when the cut crop was left in the swathe or was tedded

The Study

The rates of wilting of a pure red clover crop and a pure grass crop were examined during July and during September at AFBI-Hillsborough. Wilting rates were compared in an undisturbed swathe (covering 75% of the field area) and in a tedded swathe (covering the whole of the field area). Both crops were conditioned at mowing with a mower-conditioner.

Outcomes

Red clover had a lower DM content than grass at mowing during both July and September. During wilting the grass and red clover lost moisture at similar rates, and subsequently increased in DM content by similar amounts (by approximately 8% in July and by 6% in September: Figure 9). Consequently, at the end of the wilting periods the red clover still had a lower DM than the grass, and as such may have been more difficult to ensile that grass. The effect of tedding on herbage DM (average for July and September) is presented in Figure 10. While wilting increased DM content by about 9%, tedding the herbage over the whole area increased DM content by a further 3%. However, both the grass and red clover responded similarly to tedding.

Red clover being wilted

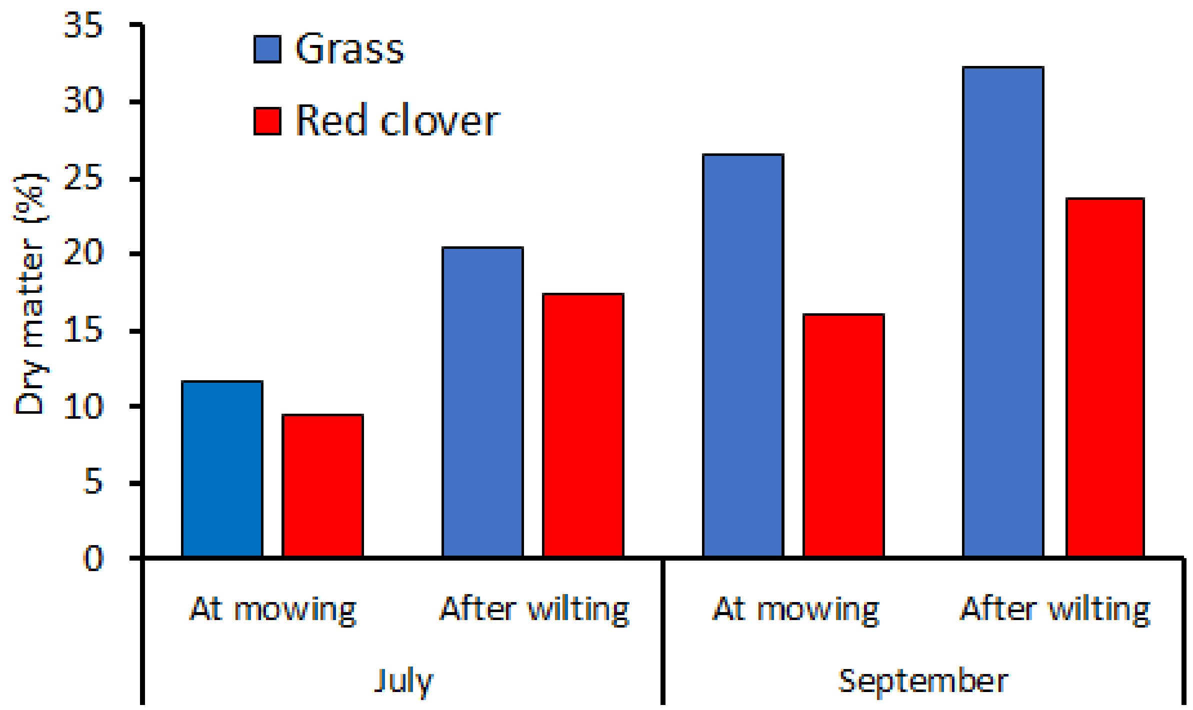


Figure 9 Effect of forage type (grass sward or a red clover sward) on forage dry matter content at mowing and after wilting (measurements undertaken on two occasions: July and September)

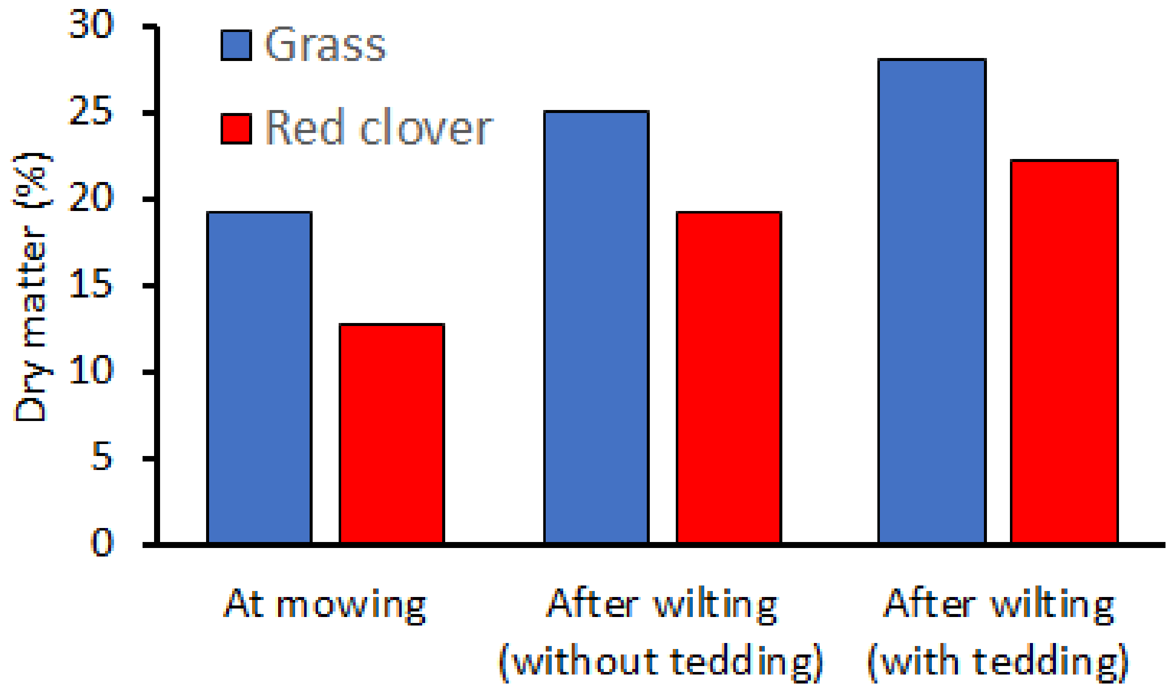


Figure 10 Effect of forage type (grass sward or a red clover sward) on forage dry matter content at mowing and forage dry matter content after wilting (either with or without tedding)

Conclusion

A standing crop of red clover will normally have a lower DM content than perrenial ryegrass under similar conditions. Consequently, red clover will normally need to be wilted to ensure that a good fermentation takes place. Grass and red clover will normally wilt at similar rates, and wilting rates will be enhanced by tedding over the entire area. If tedded, a red clover crop should be able to achieve a DM content of at least 20% DM after two days of wilting. In exceptional weather conditions, caution is required to ensure that the red clover crop does not become excessively dry. If red clover is too dry, in excess of 30% DM, its leaves (the protein rich component) become brittle and can be lost when handled. At a DM content of 23-25% red clover can be handled without danger of losing leaves and valuable protein.

EXPERIMENT 1 CONCENTRATE INGREDIENTS

The ingredient composition (kg/t, fresh weight) of the concentrates offered with 0% and 47% field bean treatments in Experiment 1. The concentrates offered with the 16% and 32% field bean treatments were produced by mixing these two concentrates in the correct proportions.

	Concentrate Type	
	0% Field Beans	47% Field Beans
Field Beans	0	473
Soya Bean Meal	181	48
Rapeseed Meal	102	48
Maize Gluten Feed	71	24
Soya Hulls (Toasted)	142	118
Maize Meal	250	155
Wheat	175	55
Molaferm	40	40
Palm Oil	10	10
Minerals and Vitamins	29	29

EXPERIMENT 2 CONCENTRATE INGREDIENTS

The ingredient composition (kg/t, fresh weight) of the concentrates offered in Experiment 2.

	Concentrate Type		
	0% Field Beans	35% Field Beans	70% Field Beans
Field Beans	0	349	698
Soya Bean Meal	170	85	0
Rapeseed Meal	150	75	0
Mazie Gluten Feed	74	37	0
Maize Meal	245	178	110
Wheat	174	87	0
Soya Hulls (Toasted)	140	139	140
Molaferm	25	25	25
Minerals and Vitamins	23	25	27

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A Comparison Of Confinement And Grazing Systems For Dairy Cows

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