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Influence of grazing different forages on milk production in dairy cows

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1-7-2011

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A research to compare the effects on milk production of dairy cows grazing kikuyu together with
lucerne or oats-ryegrass mix supplemented with silage and concentrate

By

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Camden, New South Wales, Australia
July-2011

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Preface

First of all I would like to thank Ravneet and Ajantha for their continuous support and advise, but above all the warmth and the smiles that always seems to surround them. A very important role has to be recognized to my parents, without their support and their understanding for my drive to go out of the sheets at home and travel over the world, this would never have been possible. I would like to thank Yani as well for offering me to do a project within the FutureDairy project. Not to be forgotten is Yep that gave me the green light to go to Australia to do my graduation project here. Also I would like to thank everybody from MC lab and Costorphine farm, I have had a very pleasant time with everybody.

It certainly has been an interesting story for a farmers-son from the Netherlands to go to Australia and make science. I discovered the practical problems of it but also the charm of learning new things and it's making me hope that I will be learning, next to everything else, all my life.

I like to finish this preface to give special thanks to all my friends from the Nepean Hall but especially Mitch, Helen, Eline and Denise. The four of you made my time on the campus, with everybody's unique and special characteristics, one of the most enjoyable periods of my life and I enjoyed it long time!

Klaas-Willem Nieuwland

July 2011, Camden

Abstract

There has been little research on rotational grazing of a combination of different forages by dairy cows and the potential effect on milk production and quality. The objective of this research was to measure the effects of grazing different forages during the typical period in fall when the quantity and quality of tropical pasture kikuyu, due to the downfall of temperature, starts to decline, and is replaced by the more temperate perennial ryegrass. The period between the downfall of kikuyu quality and quantity and the fully established perennial ryegrass is typically known as the 'feed gap'. During this period supplementation is essential to maintain high milk production. The aim of this research was to asses milk production and quality of cows grazing kikuyu next to the supplementary feeds: lucerne, oats, perennial ryegrass and silage during the feed gap.

Firstly a literature review was conducted to get more insight into different features of the forages used. An important outcome of this review was that quality of kikuyu is not very high compared to the other grasses. Ryegrass had the highest nutritive value compared to the other assessed grasses en therefore most likely to cause higher milk production.

Secondly a trial had been set up that measured the effects of grazing different forages combinations on milk production and quality.

The trial took place at the University of Sydney, Costorphine farm in Camden, NSW. In this trial 14 cows were fed different combinations of forage in 3 different stages:

- Stage 1: Kikuyu, lucerne and silage (pasture), 7 February until 20 February.
- Stage 2: Kikuyu and lucerne, 1 April until 14 April.
- Stage 3: Oats (70%)/ryegrass (30%) mix, kikuyu and (maize) silage, 25 April until 8 May.

Cows were fed a concentrate (commercial cereal-based dairy pellets) between 8 and 10 kg/day. This concentrate was available twice a day during milking. The herd was grazed rotationally. The more extensive experimental design is outlined in chapter 2.

Results showed that mean milk production was 23.7, 24.2 and 24.3 kg milk/cow.day for stage 1, 2 and 3, respectively. Also a remarkable rising of kikuyu quality through the end of the growth season was indicated, whereas a decline of nutritional value is expected, the value rose. Most likely this is caused trough very in-mature kikuyu. The addition in stage 3 of the high quality oats-ryegrass mix caused a rise in milk production and quality. Even though cows were further in lactation they produced more milk. It was concluded that supplementation is necessary for optimal milk production when kikuyu is mature; and from all the different forages the oat-ryegrass combination had the most positive influence on milk production.

With results of this trial Australian dairy farmers can get a better understanding of the nutritive values of the used forages during the transition period of grasses in Autumn, and the effect on milk production and quality.

List of abbreviations

ME	Metabolic Energy
CP	Crude Protein
NDF	Neutral Detergent Fibre
ADF	Acid Detergent Fibre
ADL	Acid Detergent Lignin
WSC	Water Soluble Carbohydrates
DM	Dry Matter
DM%	Dry matter percentage
DMD	Dry Matter Digestibility
IVDMD	In Vitro Dry Matter Digestibility
Kg	Kilogram
MJ	Mega Joule
N	Nitrogen
Ca	Calcium
Mg	Magnesium
Na	Sodium
K	Potassium
P	Phosphorus
FCP	Fat Corrected Milk

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Introduction

Australia is known for its long summers in which it can be exceptionally warm and there can be a shortage of water. Dairy farmers are grazing their cows on kikuyu (*Pennisetum clandestinum*) grass during these warm periods. When maximum temperatures drops below 21 degrees, the regrowth of kikuyu declines (Ivory., 1976) and availability and quality of kikuyu is no longer sufficient to support high milk production. Therefore cows grazing kikuyu need supplementation.

The farmers using kikuyu are situated on the east coast of Australia, north of Sydney and under irrigation in south west of Western Australia (Fulkerson[A]., 2007). Kikuyu is a tropical grass, which originated from the kikuyu region of Kenya and it is grazed during the warmer months in Australia. It is probably the second most important pasture species for dairy production in Australia after ryegrass. The water utilization efficiency of kikuyu is twice than that of perennial ryegrass (Neal et al., 2010). Cows grazing well-managed kikuyu pasture can derive up to 14 litre milk/day (Fulkerson et al., 2010).

Kikuyu is grazed during summer period when the temperatures arise above 30 degrees and rainfall is low. When kikuyu matures, the relative amount of leaf decreases and the amount of stem and dead material increases. The digestion of kikuyu plant by rumen microbes decreases because of the lower input of metabolic energy and crude protein, which can lower dry matter intake further and affect the production performance (Fulkerson et al., 2010). Supplementation is required to maintain a high level of milk production with mature kikuyu grass.

Farmers are able to use Lucerne as a high quality feed for livestock throughout the year. The main use of Lucerne in NSW is for grazing (Grain and Graze., 2011). It can also be used as hay, silage or pellets. Lucerne is very drought tolerant because of it's deep root system that makes it possible to get moisture from deeper soil (Marshall et al., 2007)

Oats are used for a range of cattle feed, mostly as cereal, straw, silage and as a grazing forage. Oat fodder productions are mainly used in the southern part of Australia but also in subtropical Queensland, which produces oats for grazing purposes. Oats cultivars are used on large scale as a dual purpose feed. The forage is grazed before stem elongation and then it's harvested as grain (Armstrong et al., 2011). Of all the conserved cereals fed to dairy cows, 75% is from oats (Stubbs., 2000). New South Wales is the largest oats producer in Australia (Armstrong et al., 2011).

Ryegrass is the most used winter pasture for grazing cows in temperate Australia. It is known to have a high nutritive content, good palatability and high digestibility. Ryegrass is not suitable for summer conditions as growth is restricted above 30 degrees and because of its low water use efficiency (Neal et al., 2010). Cows can produce about 20-22 litre milk a day from ryegrass (Fulkerson[B]., 2007).

A common practice of dairy farmers in temperate Australia is to graze cows on kikuyu pasture during the warmer months of the year, while during the colder months ryegrass is being grazed. The transition between these two forages usually accurse during March and April. Typically during this period is a shortage of grass available to be grazed whilst the growth of kikuyu is declining and the ryegrass is not fully established. This occurrence is known as the feed gap and to sustain milk

production supplementation of other forages is necessary. Lucerne (Medicago sativa), oats (Avena sativa L.), ryegrass (Lolium perenne L.) and silage are common supplementary feeds when kikuyu quality and quantity is declining. Various information is available concerning milk production of dairy cows grazing kikuyu during its peak growth, in the summer months and early autumn, with or without concentrate supplementation (Fulkerson et al., 1998, Fulkerson[A]., 2007, Reeves et al[A]., 1996, Reeves et al[B]., 1996, Cross., 1979, Hamilton et al., 1992). However information is lacking during the feed gap in autumn. Therefore a trial has been set up to get a better insight into dairy cow milk production when kikuyu is still being grazed but supplementary forages are offered to overcome the feed gap.

In this project, the main objective is to investigate the impact of rotational grazing a combination of different forages by dairy cows and the potential effect on milk production and quality. The main research question of the project is:

- What is the difference in quantity and quality of milk production in mid-lactating cows grazing 3 different combinations of forages: kikuyu, Lucerne and silage(1), kikuyu and silage(2), oats/ryegrass mix, kikuyu and silage(3)?

Fourteen cows were selected and offered different pasture and forage combinations: kikuyu, lucerne and silage feed (stage 1), kikuyu and Lucerne feed (stage 2), and finally the cows got kikuyu with oats/ryegrass mix together and silage (stage 3). With the results of this research, a bigger insight of the relationship between the different forages and their impact milk yield and quality will be gained. To gain insight into the 'why' and 'how', the dry matter intake and rumen function will also be accounted for.

In chapter 1, a desk study was performed to get an overview about what already is known according to existing literature about the characteristics of the forages in aspects of their growth stages, chemical properties, milk production, rumen function, response to supplementation and milk yield. Chapter 2 contains the experimental trial with details of the materials and methods used. This will be followed by the result of the experiment, given in chapter 3. The discussion is emphasized in chapter 4 followed by the conclusion in chapter 5.

1. Literature

The literature chapter gives more information about what to expect from the experiment according to the existing literature and previous experiments. To give a clear image of the main forage, kikuyu, the following characteristics will be discussed in the literature review:

- Leaf stages
- Regrowth
- Water use efficiency
- Digestibility
- Dry matter intake
- Nutritional value
- Milk production

Because Lucerne, oats-ryegrass mixture and silage are supplementary forages is this experiment, the following properties of these forages will be discussed:

- Digestibility
- Dry matter intake
- Protein content
- Milk production

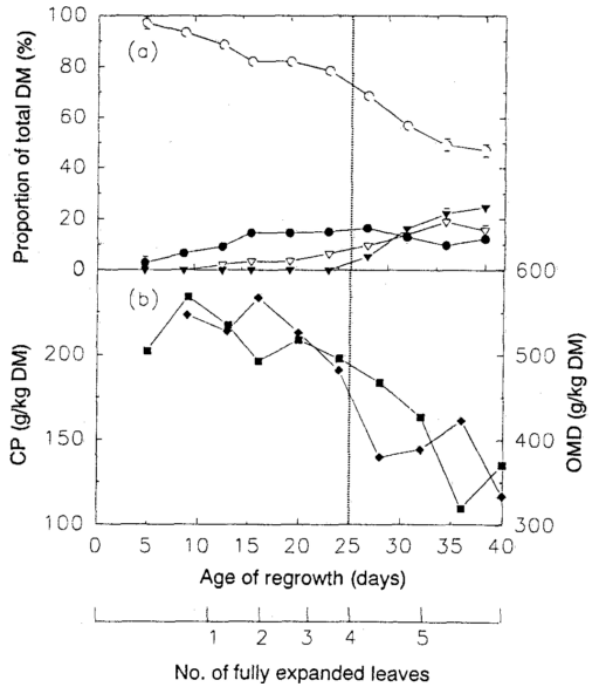
1.1 Kikuyu

1.1.1 Leaf stages

When using the leaf stages principle the following points have to be considered.

1. The first leaf after grazing/mowing is the remnant leaf. This remnant leaf is only partly extended after grazing and can be identified by the tipped end. If the remnant leaf is grown to half of the size or more than a normal leaf, it's counted as the first leaf.
2. The leaf that's next to come will emerge from the sheath before each previous leaf is fully extended.
3. When the fifth leaf is starting to emerge the first leaf is starting to die.

The 4.5 leaf stage is considered as the most ideal grazing stage due the highest proportion of leaf and the highest quality of grass for cow consumption (Fulkerson et al., 2010). The 4.5 leaf stage is reached when the fourth leaf is fully expanded. As the maturity of kikuyu endured the relative amount of leaf blade decreased, while the relative amount of leaf sheath, stem and dead material increased (Reeves[A] et al., 1996).



Changes in (*a*) the proportion (% DM) of leaf blade (○), leaf sheath (●), stem (▽), and dead material (▼); and (*b*) crude protein (CP) (g/kg DM) (■) and organic matter digestibility (OMD) (g/kg DM) (◆) in kikuyu regrowth above 5 cm stubble over 40 days and in relation to the number of fully expanded new leaves present. Vertical line indicates 4·5-leaf stage.

Figure 1 CP and DM on different maturity stages (Reeves[A] et al., 1996)

Cows should not be forced to eat all the stems because it's likely that there won't be enough nutrients consumed to support high milk production. After grazing, a residual of 5-8 cm is left. This needs to be removed mechanically or by hard grazing through dry cows, otherwise relative amount of stem will build up and when grazed next time (even during the 'ideal' leaf stage), the grass will contain lower herbage quality due to relative higher amount of stem.

1.1.2 Regrowth

The day that the kikuyu is mowed or grazed, the leaf regrowth starts again and this day is counted as day zero. There are different data available about the regrowth time of kikuyu. The regrowth depends on the temperature (Ivory & Whiteman., 1978), season (Fulkerson et al., 1998) and fertilizer (Reeves[A] et al., 1996). Research by Fulkerson et al. (1998) indicated that in March the remnant leaf stage was reached after six days, the 4.5 stage after 27 days and the sixth leaf stage after 35 days. Other results (Fulkerson et al, 2010; Fulkerson[A]., 2007; Reeves[A]., 1996) varied in respectively six, fifteen and eleven days regrowth for the remnant stage, and sixteen, thirty-two and twenty-fife days for the 4.5 leaf stage.

When the first four leaves are fully expended the maximum leaf content is reached. As stated previously, the first leaf will die when the fifth leaf is starting to emerge; this causes the amount of available metabolic energy (ME) and crude protein (CP) to decrease.

1.1.3 Water efficiency

As mentioned before, kikuyu is twice as water efficient then ryegrass. Due to the deep root system kikuyu is more suitable when water availability is low. Neal et al. (2010) compared 15 different grasses to get an overview over the water use efficiency. The efficiency was measured by the total yield of the concerning forage, including weeds, divided by the total water used. The experiment was to see which grass was the most efficient under optimal irrigation and which was most water efficient under extreme deficit irrigation. In other words: which grass was able to have the highest yield with the lowest amount of water provided?

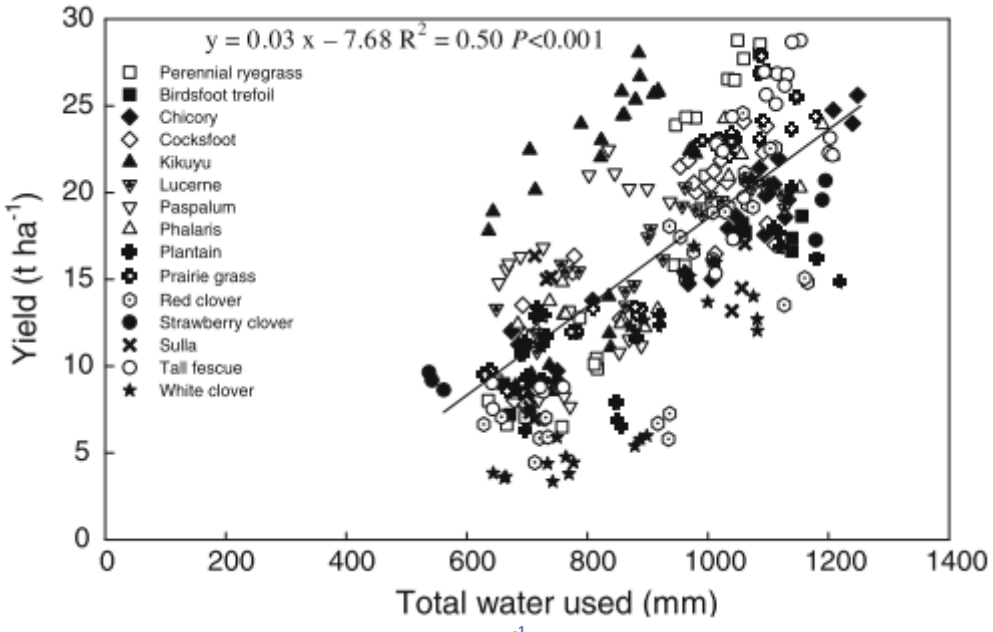


Figure 2 The relationship between annual yield (t ha^{-1}) and annual total water used (mm) over the 3 years of the study for 15 forage species (Neal et al., 2010)

Figure 2 indicates that kikuyu had strong results concerning water efficiency. Once the temperature

arises above 25 degrees, kikuyu has as a C4 grass a higher growth rate because of the more efficient carbon fixing pathway (Neal et al., 2010).
The optimal temperature for kikuyu to grow is 29.4 °C during daytime and 25.6 °C during night-time. (Ivory & Whiteman., 1978). The growth of kikuyu ends when the temperature is below 9 degrees

1.1.4 Digestibility

The amount of NDF can be a limiting factor for the digestibility in the rumen. NDF contains hemicellulose, cellulose and lignin. The NDF can be separated into hemicellulose and ADF. The ADF can be divided into cellulose and lignin (ADL). Lignin gives the plant it's stability, and is considered to be the key element that limits the cell-wall digestibility (Jung & Allen., 1995). Kikuyu, as a tropical plant, had a disadvantage compared to the more temperate plants because the leaves of tropical plants contain more lignin and have a dense mass of cell that resist invasion by micro-organisms (McDonald et al., 2011).

A more mature plant will contain more NDF and will have lower digestibility (McDonald et al., 2011). The minimum of NDF content what should be consumed is 280 g/kg DM (NRC., 1989). Fulkerson[A] (2007) reported NFD contents of kikuyu between 503 and 639 g/kg DM, a lot higher than recommend. In a review conducted by Marais (2001), dry matter digestibility levels (DMD) in kikuyu were found within a range of 450-749 g/kg DM.

The NDF digestibility is an important way to get an indication of the total dry matter digestibility of the plant. A quick plant growth indicates that the plant will have a better cell-wall digestibility then when a slow plant growth. When kikuyu is more mature it consist relatively more stem suggesting a relatively higher amount of lignin, decreasing the cell-wall digestibility and therefore the overall dry matter digestibility. At an immature stage of regrowth the digestibility of the leaf and stem are considered to be equal but as the pasture matures the stem digestibility was much lower (Minson., 1990).

1.1.5 Nutritional value

1.1.5.1 Metabolic energy

Energy is considered to be the first limiting factor for milk production for N-fertilised tropical grass pastures (Royal & Jeffrey., 1972; Davison et al., 1991). According to AFRC (1993), the ME requirement for maintenance of a typical cow of 600 kg, producing 30 kg milk, is 200 MJ/cow/day. The mean metabolic energy changed during the season, 9.5 MJ/cow a day in the winter and 8.5 MJ/cow a day during summer (Fulkerson et al., 1998). The amount of metabolic energy is not enough to sustain high amount of milk production due the high NDF content, which decreases DM intake. As the plant matures the relative amount of leaf decreases, and the amount of stem and dead material increases, which causes the relative amount of ME to decrease.

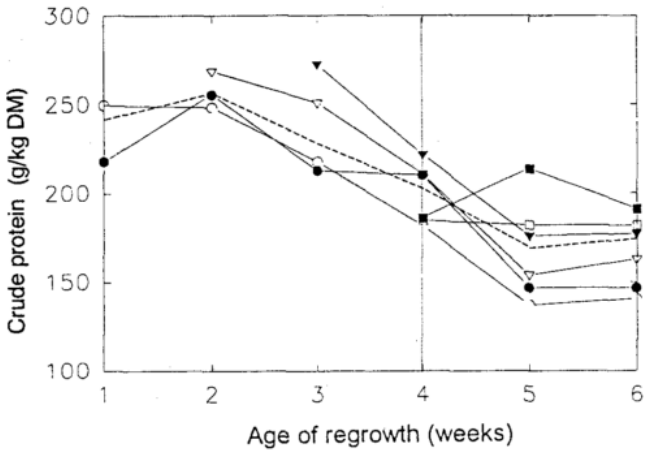
Table 1 Metabolic energy (MJ/kg DM) of leaf, stem and dead material (Fulkerson et al., 2010)

Kikuyu component	Metabolisable energy
	(MJ/kg DM)
Leaf	9.2
Stem	7.4
Dead	6

1.1.5.2 Protein content

The protein content must be sufficient to meet the requirements of the cow and the microbe population in the rumen. The cow protein is obtained either directly from dietary sources (which escaped rumen fermentation), or from microbes that pass from the rumen into the small intestine. The minimum crude protein content for milk production is 15% (Elzinga, personal communication). At the remnant stage kikuyu consisted of 16% CP, it had a downfall to 14% at the three leaves per tiller stage, but it returned to starting level at the sixth leaf a tiller stage (Fulkerson et al., 1998). According to another research (Fulkerson et al., 2010) the CP at the remnant stage is 21%, increased until 22% at the 2 leaf stage. From that point, CP decreased to 20% at 6 leaves per tiller stage.

According to Reeves[B] et al. (1996) the level of CP varied in each leaf, with the mean around 20% at the 4.5 leaf stage. If grazing occurred after 9-10 weeks of regrowth, CP-content of kikuyu declined below 10% as stem and dead material relatively rose compared to leaves (Ware., 1978). In this relationship, CP digestibility also declined if grazed at a mature level, which may be associated with the thickening of cell-wall, under influence of lignin, making it more difficult for microbes to access degrade the material.



Changes in the mean crude protein content of each new leaf (leaf 1 ○, 2 ●, 3 ▽, 4 ▼, 5 □, leaf 6 ■) and the mean (----) for all leaves. Vertical line indicates 4·5 leaf stage.

Figure 3 Time effect on crude protein in kikuyu (Reeves[A] et al., 1996)

1.1.5.3 Minerals

Although Kikuyu is a good pasture to feed in hot and dry months because of efficient use of water, the relative amount of minerals contained by kikuyu is low compared to ryegrass (Reeves[A], 1996). After mowing/grazing kikuyu, the pasture was low in calcium and magnesium. However, the relative amount of these minerals increased when the pasture became more mature (Fulkerson et al., 2010).

Table 2 The mineral content and the requirements for a 600 kg Holstein-Friesian cow producing 20 litres a day (Fulkerson et al. 2010)

Mineral	Kikuyu(% of DM)	Cow needs(% of DM)
Calcium	0.42	0.51
Phosphorus	0.28	0.33
Potassium	2.9	0.9
Magnesium	0.29	0.2
Sodium	0.14	0.18

Calcium (Ca)

Calcium is important for bone and teeth formation, blood clotting and muscle contraction. 99% of calcium is found in the skeleton and teeth (McDonald et al., 2011). If kikuyu is grazed on the ideal leaf stage, it's not enough to meet normal body requirements. Laredo (1974) found that kikuyu leaf contained higher concentrations of Ca then stem (5,6 and 2,5 g/kg DM, respectively). Therefore when the amount of leaf increases, the total amount of Ca becomes higher.

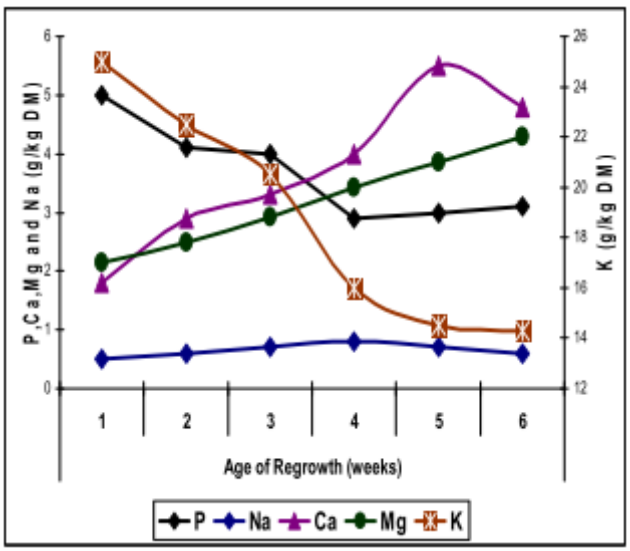


Figure 4 Content (g/kg DM) of Potassium (K), Phosphorus (P), Calcium (Ca) and Sodium (Na) in the leaves of kikuyu (Fulkerson et al., 2010). In this example the 4 leaves a tiller stage is at about 4.5 weeks.

Magnesium (Mg)

Magnesium is an enzyme activator and it plays a role in muscle contraction. It's a constituent of bone. As seen in table 2 the amount of Mg in kikuyu is sufficient to support milk production. Further research on Mg concentrations of kikuyu found a range between 0.9 (Pearson et al., 1985) to 7.4 g/kg DM (Marais et al. 1992), and in half of the reports mean concentration was below recommendations (NRC 1989).

Sodium (Na)

Sodium is important for nerve transmission, muscle contraction, acid-base balance, osmotic pressure and blood pH (McDonald et al., 2011). The concentration of sodium during the remnant leaf stage is too low to match requirements. Around the ideal grazing time, 4.5 leaf stage, sodium is doubled. But as seen in Table 2 the amount is not enough to full fill requirements. Therefore supplementation of Na seems necessary, especially when heat stress occurs that triggers higher excretion of sodium (Suttle., 2010)

Potassium (K)

Potassium influences the maintenance of electrolyte balance, enzyme activator and the muscle/nerve function (McDonald et al., 2011). This mineral ample for milk production solely with kikuyu grass. Kikuyu contains 2.9 g/kg DM of K (Fulkerson et al., 2010). The requirement of a milk producing dairy cow is 0.9 g/kg DM. The higher amount of K in the early leaf stage makes it dangerous for dry cows to graze because K can block the uptake of Mg (Kemp et al., 1961). As shown in Table 3 the amount of K declined rapidly after three weeks of regrowth.

Phosphorus (P)

Phosphorus is involved in energy metabolism, bone and teeth formation, is a part of the DNA and it's rapidly mobilised from the bone during periods of temporarily shortage (McDonald., 2011). In kikuyu pasture P-levels is not sufficient to meet the requirements of a lactating dairy cow (Fulkerson et al., 2010), the demand for a cow producing 20 litre is 0.33% of dry matter intake, while only grazing on kikuyu the intake of P is 0.28% of dry matter intake (Table 2).

1.1.6 Dry matter intake

The dry matter intake is depending on several cow factors; lactation phase, parity, pregnancy status and daily milk yield. Except for cow factors, a key factor is the NDF- content of the forage to predict the voluntary dry matter intake (Waldo., 1986). Oba et al. (1999) conducted an evaluation which compared over fifty studies about the relationship between NDF digestibility and dry matter intake. Results confirmed that a one-unit increase of digestible NDF is associated with 0.17-kg increase of dry matter intake. Dry matter intake decreased when NDF-intake is higher than 1.5% of body weight (Fulkerson et al., 2010), however this theory can be misleading as individual differences in NDF intake seems to be very large (García et al., 2011). In this regard Fulkerson et al. (2006) revealed, that the

cows grazing kikuyu alone had a higher NDF intake which is around 1.6% to 2.2% of body weight. As stated before in paragraph 1.1.2.1 kikuyu containt NDF above the 500 g/kg dry matter, lowering the dry matter intake of dairy cows significantly. This means that a cow of 600 kg grazing kikuyu containing NDF levels of 60% could hypothetically consume 15 kg dry matter. In contrary, Fulkerson et al. (2006) reported intake between 1.6% and 2.2% NDF as a percentage of total body weight. Previous research by Hamilton et al. (1992) and Henning et al. (1995) determined dry matter intake levels of cows to be 12.6 and 14.2 kg DM/cow a day respectively.

1.1.7 Milk production

Maximum milk production of cows grazing kikuyu is about 12-14 litres a day of cows in mid-lactation (Reeves[B] et al., 1996; Henning et al., 1995). Two studies (Cross., 1979 and Hamilton et al., 1992) reported a higher milk yield above 14 litres from kikuyu grass, which was 15.3 and 14.7 litres a day, respectively. The results from Cross (1979) were predicted from the results used in a trial in 1949, and the cows in Hamilton et al. (1992) were earlier in lactation compared to the other experiments.

As stated before, to achieve higher milk production when cows are grazing kikuyu, supplementation is necessary. Reeves[B] at al**.** (1996) supplemented cows that were 6-7 months in lactation with 0, 3 and 6 kg of concentrates. Cows that were given 3 kg produced 18.5 kg of milk. Regarding kikuyu supplementation with concentrates, results of Fulkerson et al. (2006) showed that early lactation cows grazing kikuyu, plus supplemented concentrates, produced around 25 kg milk (mean DIM 54). The amounts of concentrate varied between 2 and 6 kg. The results of this experiment concluded that when amounts of concentration rose, the degradability of the whole diet degreased. For every 9% increase of concentrate intake as a proportion of the whole diet, the pasture digestibility decreased with 8 %. This could be due a decrease in pH level in the rumen, declining digestibility. However partially it could be contributed to micro flora adaption to the more readily fermentable energy source (Mould et al., 1983/84). The study of Fulkerson et al. (2008) indicated that the total dry matter digestibility stayed the same after increasing concentrate levels from 0 kg/cow a day to 6 kg/cow a day, suggesting that there must be a decline in pasture digestibility because of the higher digestibility of concentrate and therefore, the pasture digestibility had to be declined to be on the same whole diet dry matter digestibility. Reeves (1998) showed that a part of the decline in digestibility could be prevented by adding $NaHC0_3$ to the diet, implicating a decline of rumen Ph as an issue.

It can be concluded that milk production from kikuyu is low due the high content of NDF that results into a low dry matter intake. Also the digestibility of the cell-wall is low due the high amount of lignin what makes the dry matter digestibility decrease. To achieve a high milk production, supplementation is necessary.

1.2 Lucerne

Lucerne is a perennial legume and is considered a high quality feed with no requirement for nitrogen fertiliser because its ability to fixated nitrogen from the air (Gault et al., 1995). The Optimum temperature for lucerne to grow is between 25 degrees and 30 degrees (Doorenbos et al., 1977). It is especially fit for long dry periods because of its deep taproot system and its drought tolerance capacity (Marshall et al., 2007), but lucerne can also endure periods of frost (Scheaffer et al., 2009). The taproot system can extend up to 2-3 meters long giving this plant excess to reach nutrients and water from deeper soils, however taproot systems up to 8 meter deep have been reported (Moore et al., 2006). During summer the growth of lucerne still depends on rainfall. During prolonged drought the plant manages to survive by limiting growth, accessing stored soil water and dropping leaves (Moore et al., 2006). Neal et al. (2010) compared water use efficiency of 15 different grasses under optimal and deficit irrigation, lucerne was the only grass that had similar efficiency under both types of irrigation.

The right time to graze Lucerne is considered to be the early flowering or the 10% flowering stage, this is about 35 days after grazing or slashing in summer but longer in the cooler months (McDonald et al, 2003). If it is grazed too early, the cows will remove the apical meri-stems and the regrowth will be delayed. Grazing later will have the disadvantages of lower quality feed and greater chance of leaf drop. It's also important that hungry cows are not put into paddocks which contain high quality lucerne because risk of bloating.

Another feature of Lucerne is that after cutting or grazing it can store the carbohydrate reserves in the main taproot making it possible for the plant to have more energy for its regrowth. For the recovery of the plants carbohydrate reserves, it's important to give the plant time to rebuild its reserves (figure 5).

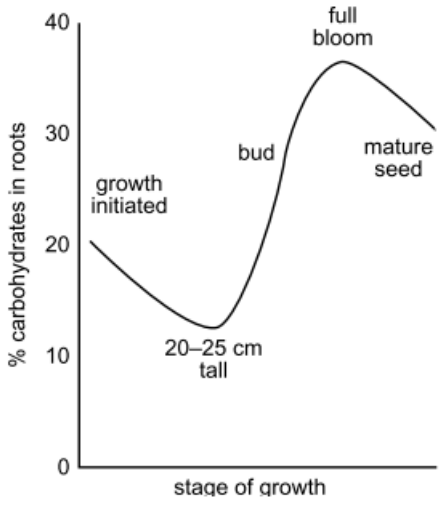


Figure 5 Growth stage Lucerne (Dairylink., 2011)

1.2.1 Digestibility

As with most forage, cows have a preference for the leaves. Danelón et al. (2002) showed that cows had preferences grazing the leaves, as the most digestible fraction, above the stem. Total in vitro DM digestibility before grazing was 743.5 g/kg DM, whereas after grazing the remnant forage had an in vitro digestibility of 649.1 g/kg DM. Figure 6 shows that DM digestibility of lucerne decreased with maturity.

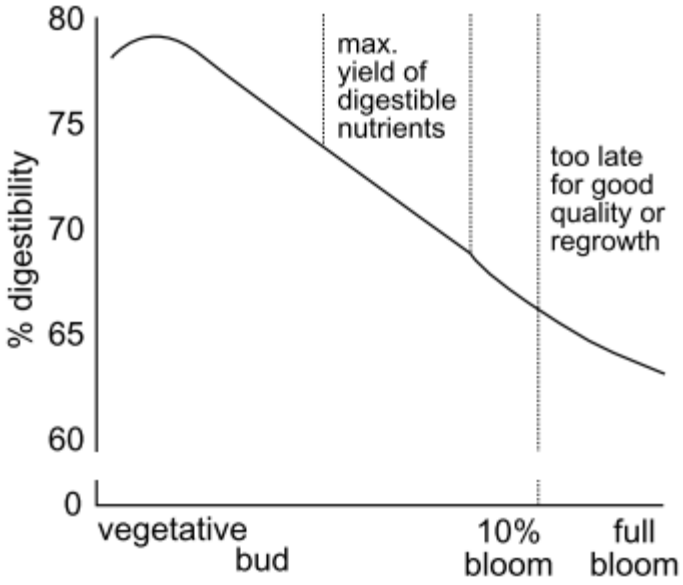


Figure 6 Digestibility Lucerne (Dairylink., 2011)

1.2.2 Protein content

Lucerne usually has a high CP content but decreases with maturity (table 3). When cows were grazing lucerne Danelón et al. (2002) accounted main CP levels between 280 and 298 g/kg DM, on lucerne of 34 days regrowth. The pre-bloom (no more than 10% bloom) CP content was determined by Castillo et al. (2006) on different alfalfa grazing pasture of mean 258.8 g/kg DM, but result differed between a minimum of 228.3 and 308 g/kg DM. Whereas Elizalde et al. (1999) determinded CP-levels levels during the early flower stage on 18.9 g/kg DM(table 3).

Table 3 CP content of lucerne stages (Elizalde et al., 1999)

State	CP(g/kg DM)
Late vegetative	22.6
Early bud	21.2
Early flower	18.9
Late flower	15.8

1.2.3 Dry matter intake

In Australia not much research is done about dairy cows grazing lucerne. However in Argentina, the second largest lucerne producer in the world, grazing cows on lucerne is a common practice. For example Basigalup et al. (2007)reported that 4.7 M hectares of lucerne is grown and in the Pampa region, over 90 % of the lucerne is used for direct feeding to dairy and beef cattle. Danelón et al. (2002) reported DM intake by cows grazing mainly lucerne of 10.52 and 13.11 g/kg DM with respectively direct grazing and sward grazing. The latter grazing can be associated with higher DM intake compared to direct grazing. Higher DM intake is presumably caused by the easiness to obtain a larger bite size of mowed herbage (Allden and Whittaker, 1970; Stobss., 1973). In relation to this, Dougherty et al. (1989) found that animals eating mowed and wilted lucerne (DM 31%) obtained a bite size 5-fold larger than that from grazing but in total DM intake there were no differences. This behaviour in combination with higher DM from mowed and wilted lucerne caused higher DM intake from sward grazing compared to direct grazing (Danelón et al., 2002).

As stated earlier, dairy cows cannot consume more NDF than 1.5% of their body weight (Fulkerson., 2010). Castillo et al. (2006) fed lucerne with mean NDF value of 338.9 g/kg DM to cows with average body weight of 520 and 690 kg. This suggested that maximum intake of 23.0 and 30.5 kg DM a day, respectively, was possible. Whereas in that experiment cows consumed no more than 17.1 (body weight 520 kg) and 18.7 (body weight 690 kg) kg DM a day.

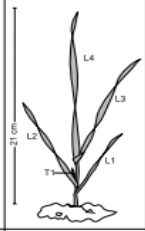
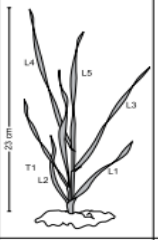
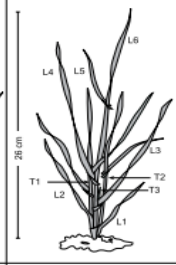
1.2.4 Milk production

High milk production must be based on the right pasture regrowth stage for grazing. On the survey conducted by Castillo et al. (2006) of farmers that mainly grazed cows on lucerne pasture, before the 10% blooming, the average milk yield was 15.1 kg milk cow/day of cows in all lactation stages. Castillo et al.(2006) also conducted an experiment were 4 mid-lactating primiparous cows and 4 late-lactating multiparous cows produced, fed the same fresh cut alfalfa pasture (supplemented by 1 kg ground corn), 19.5 (fat 3.92%, protein 3.09%) and 16.3 (fat 3.9%, protein 3.46%) kg milk a day, respectively.

1.3 Oats

Oats (Avena sativa) is a dual-purpose forage. It can be used for grazing livestock and for human consumption as oatmeal and rolled oats, used for breakfast cereals. It's very reliable feed for dairy farming in Australia because it has higher winter growth then most pastures (Hennessy et al., 2009). As with most cereals oats, growth stages are divided with the help of the Zadoks scale (Zadoks et al., 1974). This divides the cereal crop into a scale from Z10 (first leaf) to Z99 (secondary dormancy lost). When the plant reaches the tillering stage it can be grazed. This is between Zadoks growth stage 21-29 (Hennessy et al., 2009; Jacobs et al., 2009). The growth stages that are important for grazing dairy cows are roughly between the fully tillered stage and the start of jointing (table 4).

Table 4 Growth stages Oats (NSW management guide 2011)

						
Crop growth stage	***2-leaf stage*** Two leaves (L) have unfolded; third leaf present, yet to fully expand.	***Start of tillering*** First tiller (T1) appears from between a lower leaf and the main shoot. Usually 3 or 4 leaves are on the main tiller.	***Tillering stage*** Tillers come from the base where leaves join the stem and continue forming, usually until there are 5 leaves on the main shoot. Secondary roots developing.	***Fully tillered stage*** Usually no more tillers form after the very young head starts forming in the main tiller. Tillering completed when first node detected at base of main stem.	***Start of jointing*** Jointing or node formation starts at the end of tillering. Small swellings – joints – form at the bottom of the main tiller. Heads continue developing and can be seen by dissecting a stem.	***Early boot stage*** The last leaf to form – the flag leaf – appears on top of the extended stem. The developing head can be felt as a swelling in the stem.
Zadoks decimal code	2 leaves unfolded (Z12).	4 leaves unfolded (Z14). Main shoot and 1 tiller (Z21).	5 leaves on main shoot or stem (Z15). Main shoot and 1 tiller (Z21).	6 leaves on the main shoot or stem (Z16). Main shoot and three tillers (Z23).	First node formed at base of main tiller (Z31).	Z35–Z45.
• There is no difference between spring wheat varieties sown on the same day in the rate of appearance of new leaves. • At the early boot stage, the last flowering part – the pollen – is being formed. This occurs earlier in barley than in wheat or triticale.						

Kelman et al. (2009) reported an average growth of 37 kg DM/ha. day, with late seeding date , resulted in a pre-grazing biomass of 2 ton DM/ha. The year after, when sowing took place on normal seeding date, the average growth rate was 24,5 kg DM/ha. day, resulted in a pre-grazing biomass of 2,9 ton DM/ha. Showing that oats reflected a higher dry resistibility than wheat, it makes oats more suitable for Australia's climate. The regrowth after grazing varied between years and depends on the soil moisture (Kelman et al., 2009).

1.3.1 Digestibility

Fulkerson et al. (2008) compared 6 grain crops and 4 herb forages for degradability in the rumen for different seasons (table 5). They demonstrated that the NDF and ADF were changing during the season (table 5).

Table 5 NDF and ADF in oats (Fulkerson et al., 2008)

	NDF(g/kg DM)	**ADF**(g/kg DM)
Spring	608	267
Autumn	411	226
Winter	314	227

Results indicated that oats had a high NDF content in spring, thus digestibility will be low in spring. In autumn and winter the levels were respectably 411 and 314, coming closer to the minimum requirements of 280 g/kg DM (NRC., 1989). Cooler temperatures were also associated with higher forage digestibility (Smith, 1975), the in vitro DM digestibility in winter by Schroeder et al.(2005) was reasonable high with 805 g/kg DM.

1.3.2 Protein content

Results in CP can vary from 121 to 293 g/kg DM (Fulkerson et al., 2008), whilst Schroeder et al. (2005) found CP levels of 195 g/kg DM. The CP content decreased during the grazing season (Elizalde et al., 1996; Fulkerson et al., 2008).

Table 6 CP in oats (Elizalde et al., 1996)

	Crude protein (g/kg DM)
Autumn	293
Winter	262
Spring	121

The CP content was highest in autumn due the higher proportion of leaf in the autumn forage (Minson, 1990).
Seasonal variation of CP can have two causes:

- Differences in light intensity, CP content with a higher light intensity showed a decrease in CP content (Bathurst and Mitchell, 1958; Alberda, 1965)
- CP content decreased with herbage maturity (Ayres et al., 1998; Fulkerson et al., 1998)

Jacobs et al. (2009) presented CP levels between 240 and 320 g/kg DM whereas the CP at the first grazing was significantly higher. Even if CP content looks sufficient, high losses of CP in the rumen can also occur if organic matter digestibility of the oats is insufficient to meet the N levels in the rumen (Elizalde et al., 1996). Garcia et al. (2000) found results that were suggesting that the same amount of N reached the intestines when only feeding high quality fresh oats or with supplementation of corn or barley.

1.3.3 Dry matter intake

Dry matter intake is closely related to NDF in the forage. According to the theory that NDF intake cannot exceed 1.5% of body weight (Fulkerson et al., 2010) hypothetically a cow of 500 kg could consume 25 kg DM a day with NDF levels of 250 g/kg DM. Schroeder et al. (2005) reported dry-matter intake of 15.6 kg with mean NDF levels of 333 g/kg DM. However these cows where grazed below pre pasture biomass values required for maximum pasture intake (Minson., 1990). NDF levels

of 411, 314 and 608 g/kg DM were found in autumn, winter and spring (Fulkerson et al., 2008) allowing DM intake of 14.6, 19.1, and 9,9 kg/DM a day, respectively.

1.3.4 Milk production

High quality winter oats were grazed by mid-lactating dairy cows producing 14.9 kg a day with 3.22% fat and 3.58% protein (Schroeder et al., 2005). The authors suggested that this milk production was low and cows were losing body weight and body condition score, possibly because the cows couldn't get sufficient dry matter as winter oats offered was below ad libitum.

Most trials with winter oats being grazed, involved additional supplementation. Bargo et al. (2001) had cows grazing ad libitum winter oats with protein supplement in concentrate form (6.5 kg a day), different levels of protein had no influence on the amount of milk produced by dairy cows. Average milk yield in this trial was 20.5 kg milk a day.

1.4 Ryegrass

Perennial ryegrass is the most used grass species in the world. It's generally known for its high nutritive value, high productivity, palatability and digestibility. In Australia perennial ryegrass is widely used during the colder periods of the year, since its optimum temperature is 18-20 degrees (Mitchel, 1956). Ryegrass has a low drought tolerance (Boschma et al., 2003).

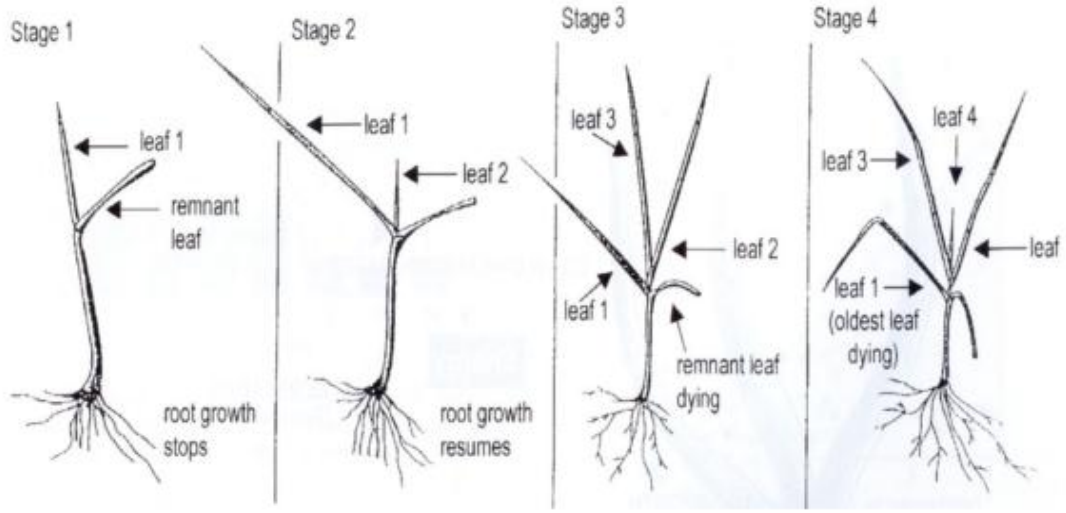


Figure 7 Leaf stage Ryegrass (Fulkerson[B]., 2007)

Perennial ryegrass often gets divided into 4 stages, whereas in stage 4 the first emerging leaf is dying (Fulkerson[B]., 2007). The 3 leaf stage is considered the ideal grazing stage. After cutting the first leaf will emerge after 9 days (Sinclair et al., 2006). It takes the plant around 30 days of regrowth to reach stage 3 (Sinclair et al., 2006). Though this depends greatly on soil, moisture, temperature and fertilizer. For example Smith (2005) determined that the regrowth before grazing was 23 and 29 days in 2002 and 2003, respectively.

1.4.1 Digestibility

Wales et al. (1999) reported differences between leaf and stem in vitro DM digestibility, in stem it was 780 and 784 g/kg DM whereas the digestibility in leaf was 772 and 737 g/kg DM. In the trial by Wales et al. (2001) cows had pre-grazing in vitro digestibility of herbage on offer of 771 g/kg DM but consumed herbage with in vitro digestibility of 833 g/kg DM. In terms of organic matter digestibility perennial ryegrass was reported to be 842 g/kg DM at stage 3 (Reeves et al[A]., 1996). Comparable are the results of O'Neill et al. (2011) with determined organic matter digestibility of 830 g/kg DM.

1.4.2 Protein content

If the CP content drops 100 g per kg DM the estimated content of digestible protein reaching the small intestine decreased to 19 g per kg dry matter (Van Vuuren., 1993). It is not preferable to have a high CP concentrations because of risk that N supply exceeds the supply of energy required for microbial growth in the rumen. Almost 80% of this excess N is excreted in urine (Van Vuuren., 1993). The CP content depends also on the amount of N fertiliser used for growth (Tas et al., 2006).

The CP content is influenced by the relative amount of leaf compared to stem. Wales et al. (1999) determined CP of different samples, 90 and 75 g/kg DM in the stem and 170 and 152 g/kg DM in the

leaves. However, CP concentrations in leaves were also reported to be twice as high then in stems (Stockdale., 1999). Cows have a preference for the higher CP contents of the total herbage (Dalley et al., 1999), cows were consuming grass with 1.32 more CP than the average herbage on offer.

The CP content of perennial ryegrass decreased linearly over time, Sinclair (2006) reported levels of 300 and 250 g/kg DM respectively on day 18 and 30 of regrowth. These figures are well above the recommend concentration of 150 g/kg DM for a 600 kg Friesian cow producing 20L milk/day (NRC, 1989).

1.4.3 Dry matter intake

Dry matter intake is a limiting factor in cow productivity in a pasture based system *(Ulyatt and Waghorn.*, 1993; Muller., 1993), and rarely exceeds 19 kg DM a day, or 3.25% of body weight (Bargo et al., 2003). Dalley et al. (1999) reported that there was a significant increase in intake if cows have higher herbage allowances during grazing. Result indicate that intake was 11.2, 15.4 and 18.7 kg DM/cow. day with respectively 20, 40 and 70 herbage allowances (kg DM/cow.day). Whereas Tas et al. (2006) recorded DM intake between 15.6 and 18.4 with 25 kg DM/cow a day allowance. Also in this experiment was suggested that a higher WSC level could lead to a higher DM intake. Evidence for this positive relationship between WSC concentration and DM intake is confirmed in studies of Moorby et al. (2006) and Miller et al. (2001). However in these studies higher WSC concentration was related to a lower NFD content, which is considered the premium indicator of DM intake (Waldo., 1986; Oba et al., 1999).

The research conducted by Smith (2005) among different perennial ryegrass cultivars for grazing dairy cows determined NDF levels between 470 and 490 g kg/DM. This allows respectively a 600 kg cow to consume 19.1 and 18.4 kg/DM a day, if assumed cows cannot consume more than 1.5% NDF-intake of its body weight (Fulkerson et al., 2010). Recent study by O'Neill (2011), were NDF content was 465 g/kg DM, indicated that DM intake potential is 19.4 kg DM a day.

1.4.4 Milk production

Dairy cows fed a perennial ryegrass pasture only rarely exceed milk yield of 25 kg a day (Van Vuuren., 1993). However if cows are offered an extensive herbage amount early-lactating cows can produce 28.6 and 29.1 kg milk/cow a day with allowance of respectively 50 and 70 kg DM/cow a day (Dalley et al.,1999). Comparable are the results from Wales et al. (2001), in which early lactating cows showed a linear increase of milk yield when herbage allowance was increased.

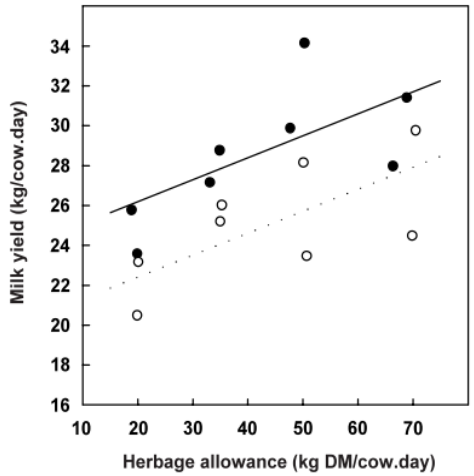


Figure 8 Milk yield witch different herbage allowances (Wales et al., 1999)

Tas et al.(2006) determined that early lactating cows (supplemented with 2.5 kg concentrates a day) were producing between 25.5 and 28.8 kg milk a day. Milk fat differed between 3.79% and 3.92%, whereas milk protein differed between 3.04% and 3.13%. This is in agreement with Taweel (2004), in which cows of similar days in milk (supplemented with 1.5 kg concentrates a day), produced between 25.1 and 27.8 kg milk a day. O'Neill et al. (2011) reported milk production of cows grazing perennial ryegrass pasture produced 21.1 kg milk a day with cows of an average of 64 days in lactation. The milk contained 4.15% milk fat and 3.25% milk protein.

1.5 Literature abstract

Kikuyu
Kikuyu is a tropical grass that is grazed by dairy cows during the warmer months in temperate Australia. The most ideal stage to graze kikuyu is the 4.5 leaf stage. It takes approximately 25 days after slashing or grazing to reach this stage. At this stage the relative amount of leaf is highest, after this stage the relative amount of stem and dead material increases causing:

- lower dry matter intake
- lower dry matter digestibility
- lower metabolic energy
- lower crude protein digestibility

Cows consume les DM when NDF levels are lower. DM intake is an issue with kikuyu due when normally grazed NDF levels reach above 500 g/kg DM. Cows grazing only kikuyu will not reach high levels of milk production. However if supplemented with concentrates early lactation dairy cows are still able to produce 25 kg milk each day.

Lucerne
This legume distinguish itself compared to the other grasses discussed by its ability to fixate nitrogen from the air and het ability to extract water from up to 1 meter into the soil due its deep taproot system. Grazing should take place when 10% of the crop is blooming. Cows are able to consume up to 18.7 kg DM a day. Milk production data of cows grazing lucerne is being founded between 15.1 and 19.5 kg milk a day.

Oats
This cereal crop is grazed during winter because of its high winter growth. Is should be grazed when the plants reaches the tillering stage. Crude protein levels are highest in autumn due the higher proportion of leaves in the forage. Dry matter intake is reported around 15.6 kg DM a day. Unsupplemented mid-lactation cows can produce almost 15 kg milk a day.

Ryegrass
Dairy cows are grazing ryegrass in temperate Australia during the colder periods of the year. The ideal grazing stage is reached between the 23 and the 30 day after mowing or grazing. A factor influencing the DM intake is herbage allowances, when herbage allowance is higher dairy cows will consume more DM. Grazing dairy cows can produce around 25 kg milk a day when fed ryegrass.

During the feed gap when all these forages can be grazed, the literature suggest that if kikuyu is being grazed together with the high quality ryegrass the highest milk production can be reached.

2. Research

2.1 Methods and material

This study was conducted on the University of Sydney Corstorphine farm, Camden, New south Wales, Australia, from March to June 2011. The cows were milked twice a day. The morning milking was at 4.30 am, the afternoon milking was at 1.30 pm.

2.1.1 Experimental design

2.1.1.1 Feed

The experiment consisted of 3 stages:

- **Stage 1:** Kikuyu, lucerne and silage (ryegrass, lucerne), 7 February until 20 February.
- **Stage 2:** Kikuyu and lucerne, 1 April until 14 April.
- **Stage 3:** Oats (70%)/ryegrass (30%) mix, kikuyu and (maize) silage , 25 April until 8 May.

The cows were grazed rotationally, one pasture after the morning milking, the other pasture after the afternoon milking. Cows were offered silage during stage 1 and 3 after the afternoon milking. In stage 1 cows got supplemented with 4.55 kg/DM silage. In stage 3 cows got supplemented 2.96 kg/DM silage.
Between the various stage's cows grazed a combination of all the grasses.
Concentrate: The amount of concentrate fed during the stages was depending on the level of production. Concentrate was available twice a day during milking.

2.1.1.2 Animals

The 14 Friesian-cows which were involved with this trail were part of a bigger herd. Only the data concerning the 14 involved cows was used. The used cows were between 120 and 160 days in milk at the first day of stage 1 (7 February). These 14 cows were closest to the average milk yield of that day (mean 22,1 kg milk). The average body weight is 557 kg and average days in milk was 152 days. These animals were used all 3 stages.

2.1.2 Data collection

Milk production

Milk yield for each cow was recorded daily by Alpro© at a.m.(04.00) and p.m.(13.00) milking's. Milk samples was taken fortnightly at the a.m. and p.m. milking for fat and protein contents of the milk (Dairy Express©).

Rumen function and plant quality

The forages samples were collected once a week in stage 1 and stage 2 . In stage 3 the forage samples were taken every day. All samples were collected between 12.30 and 1.30 pm. The samples were randomly collected by hand plucking, just as the cows graze. The samples went in the oven for 70 hours to determine the dry matter of the pasture. After that they were grinded. Wet chemistry was used to determine the NDF, ADF, CP, nitrogen, nitrate, water soluble carbohydrates (WSC) and lignin.

Dry matter intake

To measure the dry matter intake the following method was used:

By back calculation using the daily body weight of the cows, milk amount, milk quality and the body weight on each fifth day. Body weight is was measured every day during the trial.

Formula: Total DMI (kg/cow/d) = Estimated pasture DMI (1) + silage intake + concentrate intake

(1) Estimated pasture intake = ME of pasture (MJ/cow/d) (2) / ME pasture (MJ/kg DM)

(2) ME pasture (MJ/cow/d) = Total adjusted ME requirements (MJ/cow/d) (3) – (ME supplied by concentrate (MJ/cow/day) + silage in MJ/cow/d) (4)

(3) Total adjusted ME requirements (MJ/cow/d) = (0.65 x weekly body weight change(kg)^0.75) + ((0.376*milk fat% + 0.209*milk protein%) + 0.976/0.625) + body weight contribution (MJ/cow/d)

(4) ME supplied by concentrate (MJ/cow/d) + silage (MJ/cow/d) = ((concentrate intake – refusal (DM/cow/d)) x ME supplied by concentrate) + (silage intake – refusal (DM/cow/d)) x (ME supplied by silage)

These results give a good indication of individual intake but can differ due that general equations are used.

2.1.3 Chemical analysis

All samples were first ground trough a 1-mm sieve.
Nitrogen and crude protein: Total N content of forages were determined by combustion using a Leco® 428 FP-Nitrogen Determinator. Crude protein was then calculated by multiplying the N content by 6.25.
Neutral detergent fibre: Van Soest (1991)
Acid detergent fibre: Van Soest (1991)
Lignin: Van Soest (1991), ADF-ash
Cellulose: ADF- (lignin+ash)
Water soluble carbohydrates: To determine the WSC a modification of the method described by Smith (1969) was used. The 1-mm samples were extracted in a reciprocal shaker for an hour using 0.2% benzoic acid. After 24 hours the resultant solution was subjected to a Technicon® autoanalyser 2. From the sugar concentration the WSC can be calculated.
Organic matter: Feed sample was subjected to combustion using a muffle furnes for 3 hours on 550 degrees.
In vitro dry matter digestibility: A modified method of Tilley and Terry (1963) was used to determine the in vitro dry matter digestibility.
In vitro gas production: The same method was used as descripted in Chaves et al. (2006), only the bottles were made anaerobic by flushing with nitrogen instead of carbon dioxide. Also samples were in duplicates instead of triplicates. Gas measurements were taken after 3, 6, 9, 12, 24 and 48 hours.
Metabolic Energy: The ME was calculated using the following equation (SCA, 1990)
For ME pasture (MJ/kg DM): (%DMD*0,17)-2
For ME maize silage (MJ/kg DM): (%DMD*0,18)-1.8

2.1.4 Data analysis

The DM content, chemical composition and in vitro gas production were stated as mean only and no significant difference was declared. The DM intake, milk yield, milk contents and body weight data were analysed using linear mixed model using REML procedure of Genstat 11 with feed as a fixed term and cows as random term. Level of significance was declared at $P<0.05$ using least significance difference.

2.2 Results

2.2.1 Chemical composition

Understanding table contains all the data concerning the chemical composition of the different feed used.

Table 7 Chemical composition of the feed components (g/kg DM, except where stated)

	Stage 1			Stage 2		Stage 3		
	Kikuyu	Lucerne	Silage	Kikuyu	Lucerne	Kikuyu	Oat-rye	Silage
DM %	16.1	19.7	41.4	16.0	15.8	19.1	14.1	38.5
NDF	597	352	468	597	253	523	426	555
ADF	255	243	342	254	182	222	231	252
Ash	10.3	11.0	11.8	11.3	11.0	10.2	10.7	3.0
CP (%)	20.8	22.4	15.1	20.6	21.9	23.9	24.4	5.4
N	3.3	3.6	2.4	3.4	3.5	3.8	3.9	0.9
ME (MJ/ kg DM)	6.7	9.9	10.0	9.0	12.0	10.6	11.5	8.2
WSC (%)	5.1	5.1	4.0	4.6	7.1	7.5	9.4	8.9
pH	6.21	6.15	6.20	4.09	6.14	5.93	5.88	6.18
NH3	0.75	0.85	0.66	0.89	0.89	0.92	0.89	0.59
IVDMD (%)	51.3	70.2	68.2	64.7	82.1	73.9	79.6	55.3

The chemical composition of the forages at each maturity stage is shown in table 7. Kikuyu NDF for stage 1 and 2 were similar with 597 g/kg DM, but NDF content for kikuyu in stage 3 was lower with 523 g/kg DM. The NFD content of lucerne was determined as 352 and 253 g/kg DM in stage 1 and stage 2, respectively.

Silage CP differed between stage 1 and 3. The CP content in stage 1 was 15.1 g/kg DM whereas in stage 3 the CP was low with 5.4 g/kg DM. The CP content in the other forages were high with CP levels above 20%.

ME values were low for kikuyu in stage 1 and silage in stage 3, which were 6.7 and 8.2 MJ/kg DM respectively. On the other hand the silage in stage 3 was higher in WSC with 8.9 g/kg DM, but the oat-rye WSC content was higher with 9.4 g/kg DM.

Kikuyu had the lowest IVDMD in stage 1 (51.3%) and in stage 2 (64.7%), but kikuyu IVDMD was very high in the last stage (73.9%). The lowest IVDMD in that stage was (maize) silage (55.3%).

2.2.2 Dry matter intake, milk production and quality

Table 8 contains the results of days in milk, dry matter intake and the milk production data. Each measurement is outlined for each separate period.

Table 8 Days in milk, dry matter intake and milk production data (kg/cow/day, except where stated)

	Stage 1	Stage 2	Stage 3	SED	P value
Mean DIM	152	209	233	-	<0.001
DM intake	20.5	20.8	20.0	1.7	0.38
Mean Milk yield	23.7	24.2	24.3	-	-
Fat%	3.5	3.7	3.9	0.08	<0.001
Protein%	3.0	3.3	3.4	0.04	<0.001
Body weight(kg)	567	577	588	36.67	<0.001

The mean DM intake was not significant between the three different stages (mean = 20.1 kg, P>0.38). The mean milk yield in stage 1 and 2 was similar but in the stage 3 it was significantly higher (P<0.001) than stage 2. The percentage of both fat and protein increased with 0.4% over the 3 stages. The average body weight increased over the different stages, in stage 1 mean body weight was 567 kg, in stage 2 it was 577 kg and in stage 3 mean body weight was 588 kg.
Results indicate that the effect of feed on mean DIM, milk yield, fat%, protein% and body weight was significant (P<0.001). A remark had to be made because fat and protein determination was only done fortnightly and therefore might not be very reliable. Furthermore there was not a significant correlation between feed and days in milk on the milk production (0.337).

In table 9 is outlined the difference concerning DM intake during the different stages.

Table 9 Average DM intake of concentrate, pasture and silage

	Concentrate intake	Pasture intake	Silage intake	**Total**
Stage 1	8,06	7,90	4,55	**20,5**
Stage 2	8,00	12,79	-	**20,8**
Stage 3	8,00	8,99	2,96	**20,0**

The DM intake for all 3 stages are high with DM intakes from 20 kg DM and above. Concentrate intakes are stable around the 8 kg DM. Furthermore cows were not offered silage in stage 2 resulting in a higher pasture intake.

The amount gas produced after each measurement is added up with the previous measurements to get an overview of the cumulative gas production of each forage (figure 8). In stage 1 and 2 the kikuyu had the lowest gas production however in stage 3 it was similar to the oats-ryegrass mix and silage.

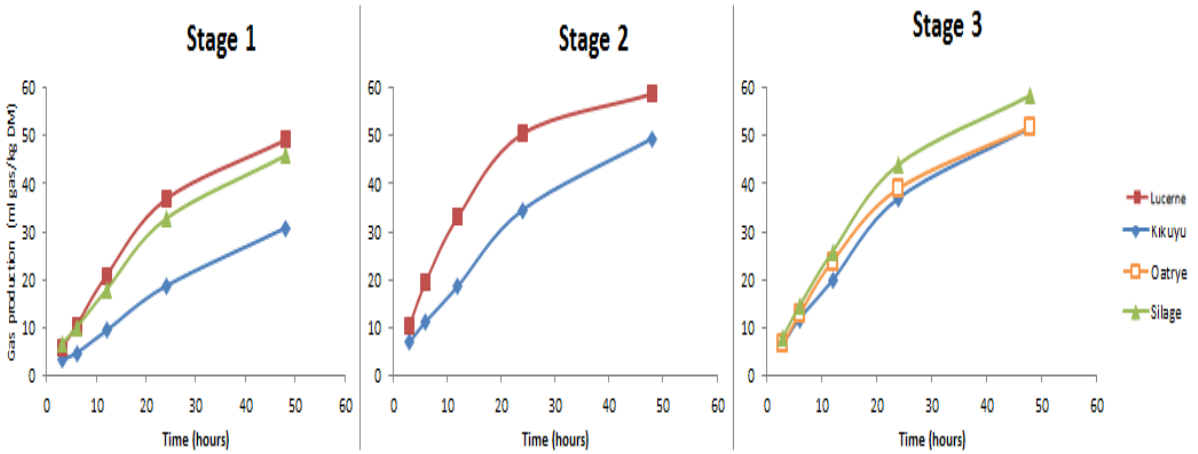


Figure 9 In vitro gas production of lucerne, kikuyu, oat-rye and silage

The amount of gas is an indicator of the digestibility (McDonald et al., 2011; Givens et al., 2000). The gas produced consist of volatile fatty acids, carbon dioxide and methane and are products of the rumen microbes. Lucerne had a high gas production in both stages. In stage 1, where the silage consisted of pasture, the cumulative gas production was lower than the cumulative (maize) silage gas production in stage 3.

3. Discussion

Nutritive value forages

The amount of cell-wall of kikuyu in the form of NDF is considered high with amounts above 500 g/kg DM (Reeves[A] et al., 1996; Fulkerson[A]., 2007). The NDF values of kikuyu during this trial were similar with values of 597 g/kg DM for stage 1 & 2 and 523 g/kg DM for stage 3. NDF values for kikuyu in the first 2 stages were considered normal but the 523 g/kg DM in stage 3 was low for kikuyu according to the time of the year. Fulkerson et al. (1998) determined during the end of April, NDF levels of above 600 g/kg DM. However kikuyu samples taken within stage 3 were immature and not very representative for the kikuyu what the cows normally were grazing during the end of the growing season.

NDF values of lucerne were lower than the NDF values in grasses. Lucerne in the first stage was grazed during a more mature stage than in the second stage, as to be seen in NDF values and DM%. The NDF values of lucerne differed significantly between stage 1 and stage 2 with 352 (19.7 DM%) and 253 (15.8 DM%) g/kg DM, respectively. This matched with the results of Danelón et al. (2002) study, in which DM was 19% and NDF was 332 g/kg DM. The CP content in Danelón et al. (2002) study was 298 g/kg DM, possibly through higher N fertilisation. Even though there was a remarkable difference between NDF values in the first 2 stages, the CP content was similar in our results (both 22.4%). The reason for this fact remains uncertain as CP percentage should decrease with maturity (Elizalde et al., 1999).

NRC (1989) recommends ADF of 210 g/kg DM in the ration of cows producing between 20 and 30 L milk a day. The ADF levels at stage 1 and 3 seemed above recommendation; however, the ADF of lucerne in stage 2 was below recommendation. Low ADF levels can cause milk fat content to decrease (McDonald., 2011), but the milk fat% in stage 2 was with 3.7% normal and thus not influenced by the lower lucerne ADF. The tendency that ADF is not influencing the milk fat% is further stated by the fact that ADF levels in stage 1 were higher than in stage 3, but milk fat differs 0.4 % in favour of the latter.

The quality of kikuyu showed an improvement in stage 3 with higher CP, ME, WSC and IVDMD. This is contrary of the expectation that at the end of the growth season quality of kikuyu declines (Fulkerson et al., 1998). In that study, ME values were 8,5 MJ/kg DM in summer and 9.5 MJ/kg DM in winter. This is in agreement with the result of this trial where the ME values were 6.7, 9.0, and 10.6 MJ/kg DM for stage 1, stage 2 and stage 3, respectively. However, the results in the present study could be confounding due to the fact that kikuyu was too low and samples could have been mixed with ryegrass pasture. Still, it is obvious that kikuyu, in combination with the oat-ryegrass pasture, had the highest pasture quality during this trial.

The CP levels that are required for a 600 kg Friesian cow producing 23 L milk/day is 14.5% (NRC., 1989). For all stages CP levels were well above requirements. The WSC levels depends more on the stage of regrowth rather than the season (Fulkerson et al., 1998). The WSC levels of kikuyu were low in the first 2 stage with 5.1% and 4.6%, respectively. But in stage 3 level of kikuyu WSC was high with 7.5%. Therefore kikuyu samples have been subjected to determination again using the same method

Smith (1969), however this time a Technicon® autoanalyser 3 was used. Results (unpublished) showed the same tendency as when calculated for the first time. The 7.5% WSC content determined in this study was not representative for kikuyu that is normally being grazed, caused by the very immature kikuyu due to the shortage of available pasture that occurred during this time. Fulkerson et al. (1998) indicated that WSC content in the leaf of kikuyu grass was higher for the first 10 days of regrowth indicating that WSC content declines with maturity. They determined the WSC levels between 2-10% during the first 10 days where after the WSC stabilised around 2%. However, the samples used in this trial were hand plucked from the paddock 2 hours later than the samples by Fulkerson et al. (1998). The ideal stage to graze is at the 4.5 leaf stage, around 25 days of regrowth, when WSC was 3.6% of DM (Fulkerson et al., 2010).

For a 600 kg Friesian cow producing 20 L milk/day, only 2% of DM is needed to fulfil WSC requirements (NRC., 1989). When higher levels of WSC are being fed, it's possible that N utilization may improve (Taweel., 2004), but the effect of higher WSC levels on N utilization is still subjected to discussion (Tas et al., 2006). However the elevated WSC content in stage 3 could well have contributed to the increased milk production and the elevated percentage of solids. The question whether the increased WSC content actually contributed to a more efficient use of N, could not be answered because milk urea N was not measured within this trial.

In stage 3 an oat-rye combination was grazed. Limited information is available about the nutritive value of oats and ryegrass in a combination. McCormick et al. (2001) reported the nutritive values of the pasture combination oat-rye. In that study cows grazed pasture consisting of 80% oats and 20% ryegrass whereas in this present study cows grazed pasture containing 70% oats and 30% ryegrass. The present study had comparable contents (table 10). McCormick et al. (2001) studied the effect on pasture intake and lactation performance when cows were given supplementary protein. Results indicated that cows grazing a high quality oat-rye mix pasture did not respond to extra CP supplementation.

Table 10 DM, CP, NDF and ADF of oat-ryegrass mix

	DM (%)	CP (%)	NDF (g /kg DM)	ADF (g/kg DM)
McCormick year 1	15.6	26.8	448	236
McCormick year 2	14.4	23.6	468	272
Present study	14.1	24.4	426	231

IVDMD

A remarkable finding was the amount of gas produced, using the IVDMD method, by the maize silage (Figure 8). The amount of in vitro gas produced is an indicator for digestibility (McDonald et al., 2011; Givens et al., 2000). In this particular case maize silage has a low IVDMD digestibility (table 8) but a high gas production (figure 9). If given the choice rumen bacteria prefer to digest the easily fermentable starch rather than cellulose (McDonald et al., 2011). This could have attributed to the high gas production in combination with a rather low digestibility.

Maize DM digestibility tends to rise until DM reaches 34% where after the DM digestibility declines (Wiersma et al., 1993). The relative high amount of NDF and the low digestibility indicated a high indigestible NDF fraction and is considered undesirable because its limiting DM intake (Jensen et al., 2005; Cone et al., 2006). The ideal maturity stage to harvest is around 32% but the maize silage fed in stage 3 had DM% of 38% with NDF level of 555 g/kg DM. This is matching with the results of De Boever et al. (2005), who reported 38,8% DM with NDF level of 468 g/kg DM. The high DM% was caused by the fact that the maize was harvested later this year because of intensive rainfall in February (personal communication, herd manager). During harvesting maize plant was already dying, an indication of a quality downfall of maize (Cone et al., 2006). Still maize silage in this trial displayed high gas production. This is caused most likely through the high WSC and starch content in maize silage. Microorganisms in the rumen prefer the more readily available nutrients instead of attacking the resistant cellulose and hemicellulose, thus lowering digestibility but increasing gases trough the more absorbable sugars (Schneider et al., 1975).

Moran (1992) reported in his research between maize silage and green-chopped maize IVDMD for silage between 70% and 65,9% for respectively at 104-108 and 119-123 days post emergence. Green-chop had for the same period 65,1% and 64,2% IVDMD for respectively 104-108 and 119-123 days post emerge. This indicates that the fermentation in the silage pit contributes to the IVDMD of the maize. Also it has to be mentioned that the in vitro gas technique is not an indicator for the whole tract digestibility rather an indication of activity of bacteria, protozoa and fungi on the different forages (Givens et al., 2000).

Dry matter intake

The main factor limiting milk production of grazing cows is DM intake (Bargo et al., 2003; Ulyatt and Waghorn., 1993; Muller., 1993). There is no information available on dry matter intake that discusses the used grasses in a combination, most likely due the difficulties to measure DM intake in a grazing situation. This was also the case with the present study. The difficulties were enhanced by the fact that cows were able to graze 2 different forages together with concentrate and silage offered and in stage 1 and stage 3.

Total DM-intake was high with values of 20.5, 20.8 and 20.0 kg DM/cow.day for stage 1, 2 and 3, respectively. The amount of concentrates fed each stage was depending on milk production level. Due that milk production during all 3 stage's was similar, all the cows got 8 kg concentrate throughout all the stage's. Bargo et al. (2003) stated that in a situation where grazing cows are fed supplements, pasture DM-intake usually decreases. In addition, many researchers (table 10) have reported higher total DM intake when cows are being supplemented, which is similar to this present study.

DM intakes in this report were higher compared to Dalley et al. (1999), in which maximum DM intake was 18.7 kg DM in cows fed perennial ryegrass. However, these high amounts of DM intake were only achieved with very high herbage allowance (70 kg DM/cow a day). Although herbage allowance was not measured during in this study, it seems that in stage 3 herbage allowance was in-sufficient

whereas in stage 1 and 2 herbage allowance was considered sufficient on normal practice level. In stage 3 however, cows were regularly not able to graze ad libitum due to insufficient pasture availability through the slow regrowth of kikuyu and the not fully established oat-ryegrass pasture mix. This occurrence seems to be typical for autumn and is known as the feed gap, and supplementation is required. Further, the hand plucked samples during this stage from kikuyu pasture were not very representative of normal kikuyu quality at the end of the growth season. Also in this particular case the question can be raised how much the kikuyu distributed to the total DM intake? It's likely that the main amount of DM intake in stage 3 consisted of oats, ryegrass and maize silage. In regards to the maximum NDF intake of 1.5% of body weight (Fulkerson et al., 2010); it could not be determined how much NDF intake was from the different forages on offer.

Table 11 Effect of different grazing different forager on DM-intake and milk yield

			Results				
Reference	Forage	DIM	DM-intake (kg/DM cow.day)	Milk yield (kg/cow.day)	Fat (%)	Protein (%)	Supplementation (daily)
Reeves[B] et al. 1996	Kikuyu	150-180	12.6[1]	12.5	3.93	3.17	-
Reeves[B] et al. 1996	Kikuyu	150-180	11.6[1]	18.5	3.89	3.38	3 kg crushed barley grain
Fulkerson et al. 2006	Kikuyu	193	15.78[1]	16.75[2]	3.45	3.31	4.1 kg pellets + 2.1 kg lucerne hay
Fulkerson et al. 2006	Kikuyu	57	18.01[1]	26.75[2]	3.66	3.31	2.0 kg pellets + 2.1 kg lucerne hay
Castillo et al. 2006	Lucerne[3]	80	18.7	16.3	3.90	3.46	1 kg ground corn
Bargo et al. 2001	Oats	60	12.06[1]	19.63	3.78	3.61	6.21 kg pellets
Schroeder et al. 2005	Oats	117	15.6	14.9	3.22	3.58	-
Dalley at al. 1999	ryegrass	41	13.2[1&4]	27.1	4.16	3.01	0.5 kg pellets
Wales et al. 2001	ryegrass	49	11.2[1]	20.7	3.80	2.80	-
Wales et al. 2001	ryegrass	49	10.1[1]	25.6	3.73	3.08	7.5 kg DM/day pellets

[1]Pasture intake only [2]Fat corrected milk yield [3]Cows fed freshly cut lucerne [4]Herbage allowance was 30 kg DM

Milk production

There are many studies performed regarding the effect of grazing forages on milk production (Reeves[B] et al., 1996; Castillo et al., 2006; Schroeder et al., 2005; Dalley et al., 1999) but insufficient information is available on milk production while grazing different forages. The milk yield was 23.7, 24.2 and 24.3 kg milk a day for stage 1, 2 and 3, respectively.

Milk production and milk quality was highest in stage 3. This is most likely because of the introduction of the oat-ryegrass mix. As earlier stated these forage combination had the highest nutritional value. The assumption that the oat-rye combination caused the highest milk production

can be reinforced by results in table 10 that indicates milk yields and milk quality from grazing experiments of the different forages is highest with ryegrass. In table 10, results of Dalley et al. (1999) point out that milk production of cows grazing, almost without being allowed additional supplements, that ryegrass had the highest daily milk yield.

Grazing trials with kikuyu had a lower milk yield compared to other trials expect for Fulkerson et al. (2006). But in that trail cows were early in lactation and had high DM intake. If taken into account for stage 1, cows had a mean DIM of 152 days whereas the same cows had at the other 2 stages had DIM of 209 days for stage 2 and 233 days for stage 3. It is remarkable that cows produced more milk when they were in late lactation then in middle lactation. Reeves[B] et al. (1996) had mid lactating cows producing between 12 and 14 kg milk a day. However cows in that study did not had 8 kg of concentrate. Cows on an average produced 23,7 kg milk per day in stage 1. This production is substantially higher than the 17,3 kg milk reported by Reeves[B] et al. (1996) for Friesian cows grazing kikuyu at the 3-4 months of lactation. Also the cows grazed Lucerne which has lower NDF indicating higher digestibility, which was also reflected in the amount of IVDMD 82.1%. This could have attributed to the high milk yield.

In stage 3 cows started grazing high quality oat-ryegrass mix. Even though the cows were late lactating they still managed to produce a higher amount of milk containing higher solids; fat 3.9% and protein 3.4%. This higher milk production is caused by the higher nutritive value of the oat-ryegrass mix and the supplementation of the maize silage.

The increased body weight (table 10) had a significant effect on the milk production (<0.05). Results indicated when the mean body weight increased, milk production increased as well.

4. Conclusion

Dairy cows that grazed oats-perennial ryegrass mix, together with maize silage had the highest milk production, body weight and the highest percentage of fat and protein. Nevertheless the milk production in the first 2 stages were reasonable, furthermore it is obvious that cows grazing kikuyu during this time of the year needed additional supplementation. Also the writer acknowledges that the validity of this research is low due the large amount of confounding (non-fixed) factors. Still this report gives insight of the nutritive value of the used forages and its related milk production and quality during the feed gap.

With the results of this research Australian dairy farmers can get an indication about milk production during the autumn feed gap. It can be stated that milk production is higher with the introduction of the higher quality oats and ryegrass compared to the lower quality kikuyu. However establishments of the forages depends also on the temperature and the water availability.

Further research monitoring the complete autumn feed gap can be useful to get a complete indication of the nutritive values of the different forages during this time. Interesting could also be to research supplementing different levels of concentrates depending on different forages and their respective nutritive contents.

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