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Published by
Agri Connect (Pty) Ltd
2013

Limited print run of 1 000 copies.

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www.elsenburg.com
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Reproduction	Agri Connect (Pty) Ltd PO Box 1284 Pretoria, 0001 South Africa www.agriconnect.co.za
Managing Director	Erika Alberts
Publisher	Leza Putter
Executive editor	Pavarni Jorgensen
Sub-editor	Dr David Barraclough
Layout design	Michélle van der Walt

ISBN: 978-0-9922220-0-0

Printed and bound by Digital Action, South Africa

Foreword

The impact of our research team at Outeniqua Research Farm is continuously growing – both in terms of outputs and cutting-edge technology. This group heads one of the flagships of the Western Cape Department of Agriculture. It is the only pasture and dairy research group of its kind in the country – resulting in Outeniqua being a centre of excellence for pastures-for-dairy research.

Despite the overwhelming challenges facing dairy farmers, our research remains focussed on minimising input cost – while optimising yield. In addition to this, sustainability and resource conservation are part of our portfolio of research projects. We have embarked on a pilot study to generate electricity for the dairy with a biogas digester – using manure from the dairy. If this proves to be efficient, the pilot might be expanded to a bigger plant – to attempt to make the Research Farm more energy efficient.

The other new research area is soil biological research. In all our production systems, we have been using minimum- and no-till practices for years. In both the traditional small-grain cropping systems, and the planted-pasture systems in the southern Cape, we have initiated research projects to investigate and determine soil biological indicators. This research area has always been seen as an imperative part of our programme. However, capacity and funding remains a big challenge – particularly as there is no industry directly linked to soils or the sustainability of our natural resources, to help carry the burden of funding such research projects.

Outeniqua has also become a hub where postgraduate students are mentored while executing research projects for our Department – with Professor Robin Meeske and Dr Philip Botha leading their respective research teams. The outputs of the group have since multiplied at an impressive rate – strengthening our research effort and service delivery to dairy producers – in the Western Cape, in particular.

Since 2011, we have presented both Afrikaans and English Pasture Courses for Beginners, as well as an Intermediate and Advanced Pasture Course. The group has also been involved in training smallholder farmers from Mozambique over the last few years. We also integrate and communicate with those producers and advisors who want to communicate with us at a scientific level.

Despite the current situation where research in general is facing a multitude of challenges internationally – we have been able to expand our capacity within the Department's "Research and Technology Development Services" programme for the future, both in terms of budget and personnel. This demonstrates our continuous commitment to service delivery to all producers in the Western Cape.

This compilation is a summary of research completed by the team over the past few years. Research results are presented at scientific congresses in the form of poster presentations – which enable readers to see a considerable amount of research information on one concise page. Producers do not, however, tend to attend scientific congresses, and this compilation is a way to inform them at a more scientific level. The team also publish extensively in popular media.

Contents

Contents

1.

The influence of tillage practice on compaction, soil organic matter and pasture performance

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Introduction

Dairy farming in the southern Cape region of South Africa requires irrigated pastures, and large areas have been cultivated for the planting of such pastures (Memiaghe, 2008). These cultivated pastures are established or reinforced with various implements – which may cause severe or no soil disturbance.

The dominant pastures are perennial ryegrass (*Lolium perenne*), which is over-sown into kikuyu (*Pennisetum clandestinum*) in a no-till pasture system – with kikuyu as the pasture base. Soil disturbance is minimal when these pastures are reinforced during autumn with annual, winter-growing ryegrass (*L. multiflorum*) varieties, using a mulcher and no-till planter. Other popular annual, winter-growing pastures – normally established after eradication of weeds with herbicides, or after soils are conventionally tilled with various implements causing severe soil disturbance and inversion – are annual ryegrass with oats (Avena sativa) or triticale (*Triticosecale*) mixtures (Botha, 2009).

The tillage or no-tillage practices may have substantial effects on the chemical, physical (Karlen *et al.*, 1999) and biological (Mills *et al.*, 2012) processes within soil – which are essentially processes sustaining soil quality. While it is known that soil quality is a reflection of how well the soil is functioning (Mausbach, 1998), the effects of tillage practice on physical, chemical and biological properties of soil, are unknown. The aim of this study was therefore to evaluate the impact that tillage method has on soil compaction, soil organic matter, and pasture productivity.

Materials and Methods

Soil samples were collected on a regional basis from the Van Stadens River in the Eastern Cape Province – to Stormsvlei in the Western Cape Province (ca. 30 000 km^2). The dominant soil textures are sandy or sandy-loams in the top 200 mm, but form part of diverse soil groups with great variability. Soil samples were collected from 142 pastures. Samples consisted of at least 20 subsamples (0–100 mm deep). The clay content median was 17.0% and all data were split into a high clay content (>17%) class, and a low clay content (≤17%) class. Data were divided up by the different tillage methods, which served as treatments:

1. Pure kikuyu pasture and no soil disturbance (Pure kik).
2. Kikuyu-based pasture over-sown annually with ryegrass, using a no-till planter (Kik-Rye).
3. Herbicide treatment to eradicate weeds before establishing a pure ryegrass pasture (Herb).
4. Establishing kikuyu or ryegrass pasture annually with shallow tillage (<15 cm depth) (Shallow).
5. Establishing kikuyu or ryegrass pasture annually with deep tillage (>15 cm depth) (Deep).

Bulk density was measured using a double cylinder, hammer-driven sampler, and penetration resistance was measured using a microprocessor-based hand penetrometer.

Soil organic C (Allison, 1965), total soil organic matter (Broadbent, 1965), active C (Weil *et al.*, 2003), and total N (Bremner, 1960), were measured on each sample.

Part of the study was also undertaken at the Outeniqua Research Farm near George, where pasture performance was measured for each of the treatments (tillage practices). Herbage production of the cultivated pasture was measured monthly by cutting herbage within the border of 3 x 0.25 m^2 quadrants, per plot, to a height of 30 mm above ground level. This herbage was dried at 60 °C for 72 hours (van der Colf, 2011).

GLM analysis was used to test for differences between treatment effects, with gamma distribution for positively-skewed data and log-link function, testing at 5% level. A repeated measures linear model was used to test for significant differences in herbage production through time.

Results and Discussion

Soil compaction

Bulk density and penetration resistance are indicators of soil compaction. Bulk density was a more sensitive indicator – with less variation when one considers the coefficients of variation (15% for bulk density and 34% for penetration resistance). Pure kikuyu pasture had the lowest) bulk density ($P<0.05$ (Figure 1), followed by no-till kikuyu-ryegrass pasture, no-till annual pasture after herbicide treatment, shallow tillage, and finally deep tillage with the highest bulk density.

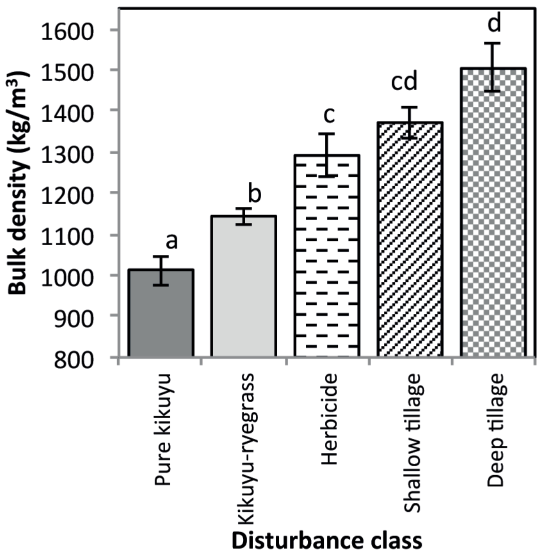


Figure 1:
Bulk density of disturbance classes of 0–100 mm soil depth, of commercial dairy farms in the southern Cape region. Error bars indicate SEM. Similar letters indicate no significant difference (P=0.05).

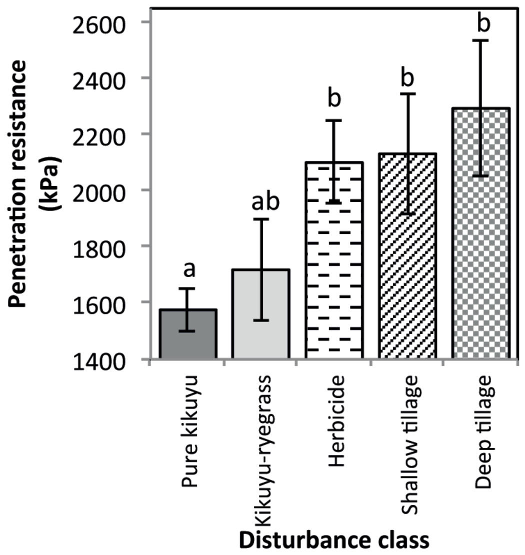


Figure 2:
Penetration resistance of disturbance classes of 0–100 mm soil depth of commercial dairy farms in the southern Cape region. Error bars indicate SEM. Similar letters indicate no significant difference (P=0.05).

The same pattern was evident with penetration resistance (Figure 2). Pure kikuyu and no-till kikuyu-ryegrass pasture had similarly the lowest ($P<0.05$) penetration resistance, while herbicide-treated pasture, shallow tillage, and deep tillage had similarly the highest ($P<0.05$) values.

It could be reasoned that less disturbance of soil promotes lower bulk densities or loose soil. Soil disturbance – as with shallow or deep tillage – breaks down soil and rapidly introduces large amounts of air into the soil, and available carbon can be metabolised by microbes until low or depleted. Therefore, the highest bulk densities and penetration resistance were observed in the shallow and deep tillage treatments. On the other hand, when soil is left undisturbed, bulk density was lower. Kikuyu – characteristically with dense stolons and rhizomes – builds up a matt and introduces a large volume of soil organic matter into the surface layers of the soil when roots die-off, when senescent or after grazing. The spaces where there were once rhizomes could fill with air and decrease the soil density. The aerobic conditions in the porous 10 cm from the surface are beneficial for microbial metabolism, and carbon could efficiently be broken down.

Even though the annual pasture (herbicide treated) was also under a no-till regime, and soil disturbance was minimal, it was more compact than kikuyu-ryegrass pastures. A permanent groundcover prevents crusting and surface compaction, and when a groundcover is absent and soil is left bare, carbon is not added to the soil and a net breakdown of soil organic matter results. The lowered soil organic matter content leads to soil compaction. The threshold value for root penetration is reported to be 2000 kPa under conventional tillage, and 3 000–5 000 kPa under conservation tillage (Mendoza *et al.*, 2008). The higher threshold value under minimum-till practices is due to the preservation of bio-channels. Conventional tillage had penetration resistance values in the 100–200 mm – much higher than that of the thresholds, and root penetration could be severely impaired. Threshold values could vary between soils and thresholds for the sandy soils of the southern Cape region may be higher.

Sandy soil (<17% clay) and clay-soils (>17% clay) showed no differences in compaction, and clay content had no influence on bulk density or penetration resistance.

Soil organic matter-related indicators

These indicators performed differently in soils with high clay content (>17% clay) compared to sandy soils (<17% clay). Clay particles provide an active surface for microbes to adhere to for proper functioning. Soils with higher clay content contain fewer pores, and are therefore less aerated. When clay particles are present, soil organic matter is physically protected against oxidation or degradation by microbes (Six *et al.*, 2002), and it is clear from Figures 3 and 4 that there were higher levels of soil organic matter or soil organic C in clay soils – due to the slower turnover of C in the heavier soil. When the treatment effects are examined, it is clear that pure kikuyu pastures with no disturbance

Figure 3: Tillage effects on soil organic matter content of sandy and clay soils in the southern Cape region.

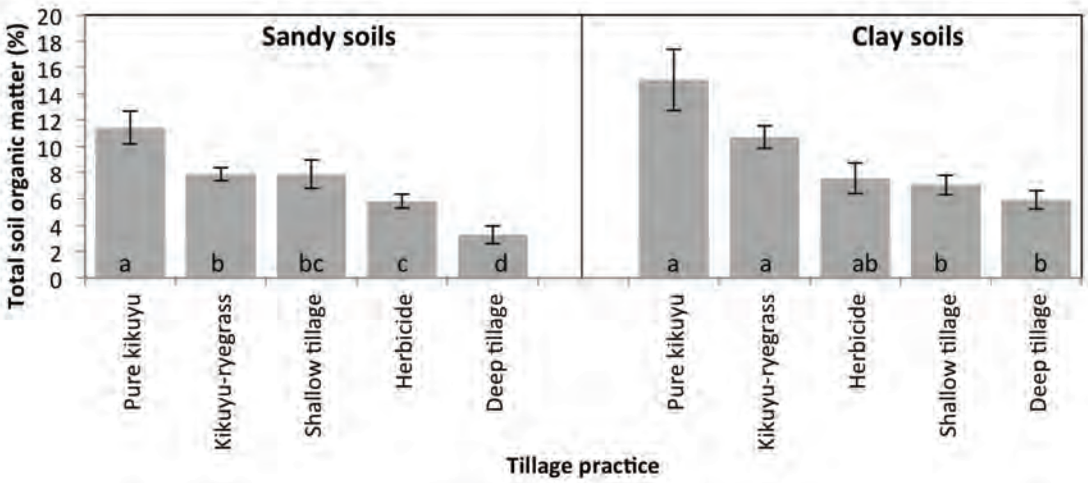
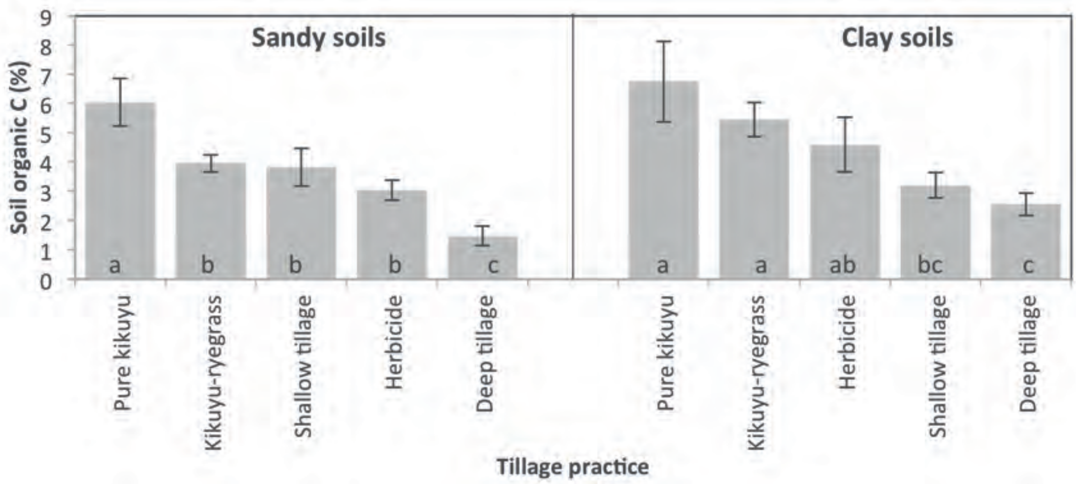


Figure 4: Tillage effects on soil organic carbon content of sandy and clay soils in the southern Cape region.



had the most positive effect on soil organic matter build-up. Kikuyu, over-sown with ryegrass, was similar to pure kikuyu pastures in clay soils, but not in sandy soils. More intense disturbance was less favourable to enrichment with soil organic matter. Annual pastures (herbicide treated) resulted in lower organic matter contents in sandy soil than in clay soil, when compared with other treatments.

Total N was highly correlated with soil organic C (Pearson's correlation coefficient R2=0.91; P≤0.05) – concurrent with the findings of Swanepoel and Botha (2013). This was also evident from the similar form of the total N content in sandy and clay soils (Figure 5) – to that of soil organic C (Figure 4). Pure kikuyu and kikuyu-ryegrass pastures had the highest total N contents, and therefore were the most beneficial.

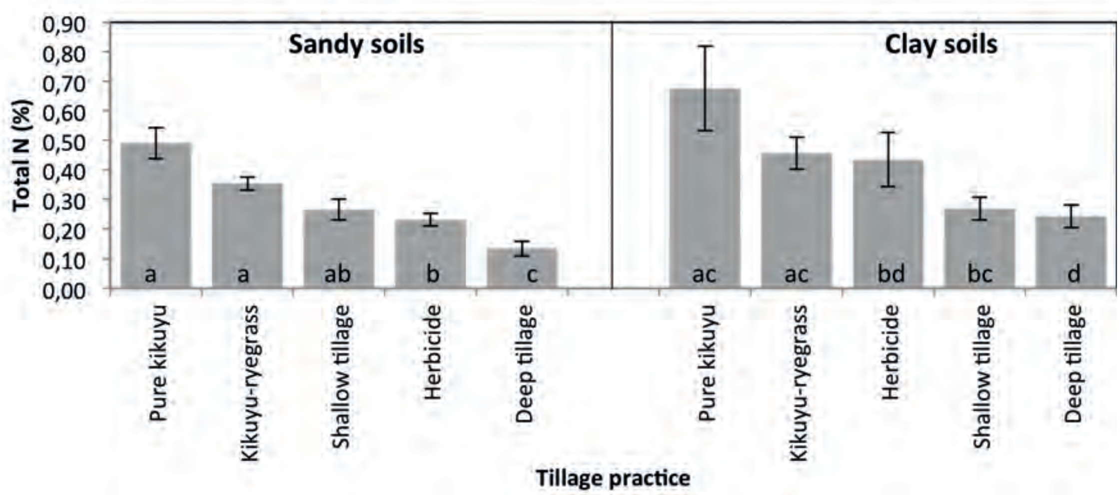


Figure 5: Tillage effects on total N content of sandy and clay soils in the southern Cape region.

Data further showed that the annual N application rate had no influence (P>0.05) on total N stocks in soil. Irrigation and supplementary irrigation led to higher (P>0.05) stocks of N than dryland in the 0–100 mm depth – in both high and low clay content soils. This is likely due to the higher (P≤0.05) total soil organic-matter content in irrigated pastures – even though observed only in the high clay content soils.

The highly labile proportion of SOM – namely active C – is shown in Figure 6.

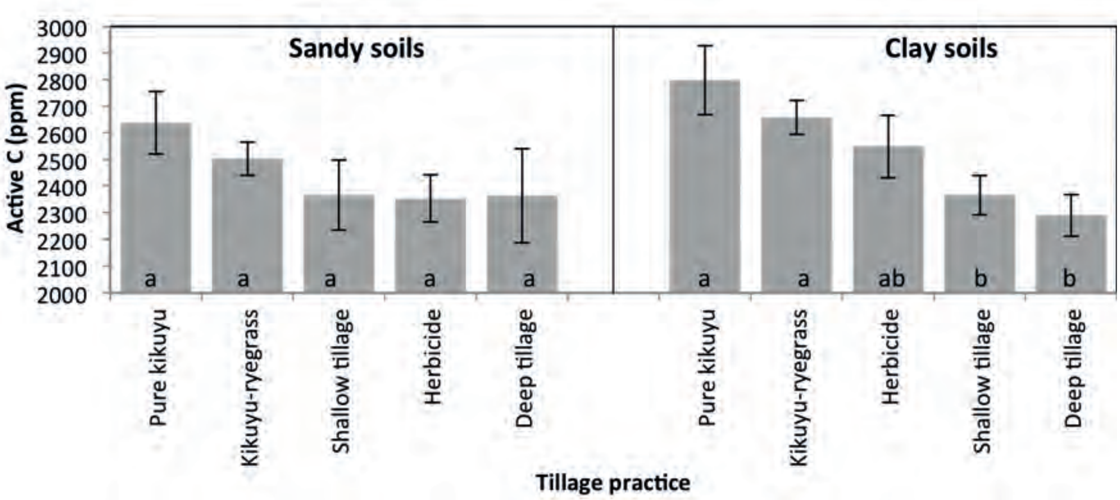


Figure 6: Tillage effects on active C content of sandy and clay soils in the southern Cape region.

There were no significant differences between active C content of a sandy soil – but in clay soils, there was a higher active C content in pure kikuyu and kikuyu-ryegrass pasture, and annual pasture (herbicide treated) was similar to those.

Active C comprised only 3.1% of SOM, and may be a more useful and sensitive measurement for detecting subtle changes in the SOM pool than SOC concentration (Karlen *et al.*, 1999). The active C concentration in pure kikuyu pasture was 10% higher than in soil that was deeply tilled. This indicates that soil that is disturbed has lower energy content, and microbial activity will therefore be less active and the soil will be lifeless. In intensely grazed dairy pastures, high volumes of labile organic matter are added in forms of manure, moribund forage material, and forage wastage. Active C provided additional information to that of SOC, by proving that less disturbance introduces high volumes of vital energy substrates for microbial metabolism at the surface layer of the soil.

Pasture productivity

Pasture performance was significantly (P<0.05) influenced by soil disturbance (Figure 7). During autumn, spring and summer, productions were lower for the treatments with higher degrees of disturbance (Table 1). Winter productions were similarly low (P>0.05) – regardless of tillage practice. Shallow or deep soil disturbance resulted in lower autumn productions.

Pure kikuyu and kikuyu over-sown with ryegrass (no-till) had the highest pasture production, while annual pastures (herbicide treated) had the lowest pasture production.

Less disturbance was more favourable to high pasture productivity, compared to shallow or deep tillage.

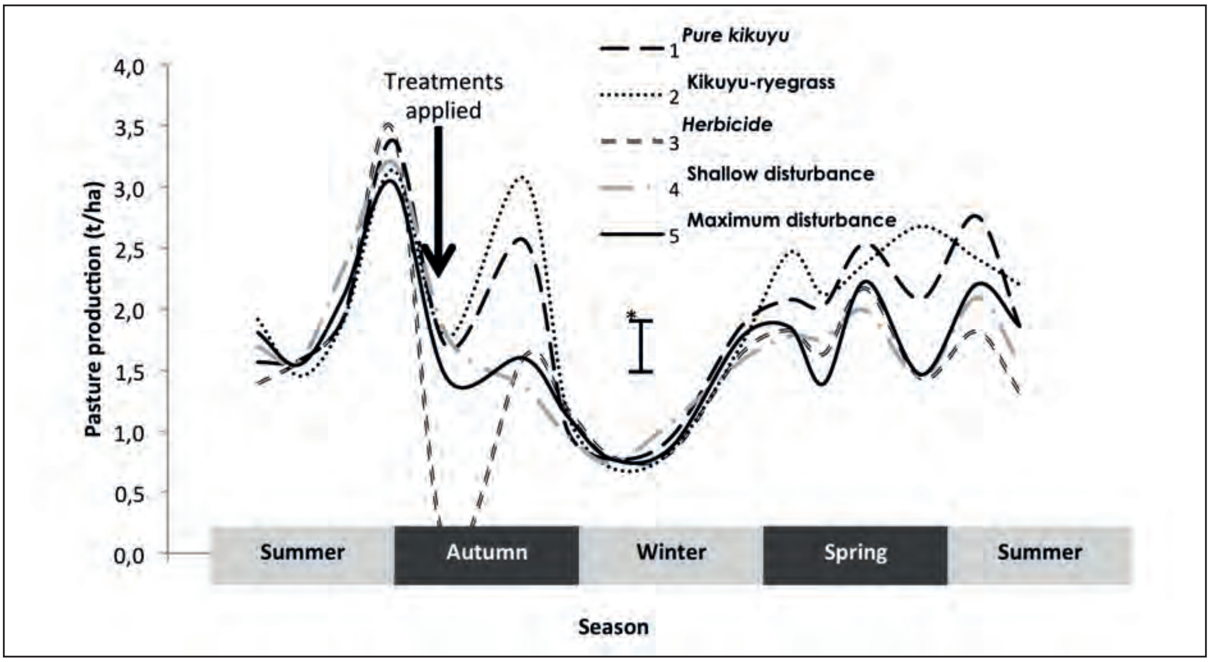


Figure 7: Pasture performance as affected by tillage practice. [*The error bar indicates the approximate least significant difference (P=0.05)].

Table 1: Seasonal and annual pasture productions, as affected by tillage practice.

Treatment	Autumn	Winter	Spring	Summer	Annual
Pure kikuyu	6.0a	1.5a	6.3a	7.5a	**21.3a**
Kikuyu-ryegrass (no-till planter)	5.3a	1.7a	6.0a	7.4a	**20.3a**
Ryegrass only weeds eradicated (Glyphosate)	2.8c	1.6a	5.1b	5.4b	**14.9c**
Shallow disturbance	4.1b	1.8a	5.1b	5.5b	**16.6bc**
Deep disturbance	3.9b	1.8a	5.0b	5.9b	**16.6b**
LSD (0.05)	0.938	0.152	0.837	0.746	**1.687**

Conclusion

When soil compaction, soil organic matter, and pasture performance are considered, the best practices will be pure kikuyu pasture, or kikuyu over-sown with ryegrass. Annual pastures (herbicide treated) had intermediate compaction figures and organic matter contents – but the lowest pasture productions when compared to permanent pastures. Deep or shallow tillage resulted in less stocks of energy for microbial activity and the highest compaction, and root penetration could be impaired.

MESSAGE TO THE FARMER

1. To lessen soil compaction and to sustain the living component in soil (good soil health), the best options to cultivate pastures were:
   1.1 Kikuyu pasture with no disturbance
   1.2 No-till kikuyu based pastures over-sown with ryegrass
2. The most compact and lifeless pastures were those that were often deeply tilled.
3. The best method to maximise pasture quantity and quality was no-till kikuyu-based pastures over-sown with ryegrass.

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2. The importance of soil organic matter for effective nitrogen fixation by white clover

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Introduction

Agricultural practices have undergone a worldwide paradigm shift that entails rectifying damaged or degraded ecosystems, and maintaining soil health in order to sustain food security. One factor that contributed to these altered views on sustainability in agriculture, is the high inorganic N fertiliser price – that puts the profit margins of dairy-farming systems under pressure. Sustainability in agriculture is defined as successful management of natural resources – such as soil and water – in order to satisfy changing human needs, whilst maintaining or enhancing the health of the environment and conserving resources (Bohlool *et al.*, 1992). Current southern Cape dairy-farming systems do not support sustainable production, as the recommended fertilisation rates are very high (Labuschagne, 2009). White clover (*Trifolium repens*) is a promising alternative to keep up the supply of N, as it forms a symbiotic relationship with *Rhizobium* – a bacterium that transforms plant-unavailable atmospheric N into organic nitrogenous compounds, available for plants (Sprent, 1979). This is necessary to decrease N fertiliser inputs which are necessary to sustain soil health.

Soil organic matter (SOM) is the main attribute for maintaining healthy soils (Carter, 2002). By increasing the levels of SOM, this can have a direct effect on the legume plant itself, or indirectly affect the rhizobial populations that infect the roots of the legume. Apart from the afore-mentioned biological effects of SOM, it also has many beneficial effects on soil physical and chemical characteristics.

The importance of SOM and legumes – as part of a farming system that will be beneficial to all units of ecosystems – are stressed in this study. The aim was to assess the effect that soil C had on free-living and symbiotic *Rhizobium* populations, the biological N fixation of these bacteria in companion with *T. repens*, and the efficiency of the symbiotic relationship.

Materials and Methods

The study was carried out on Outeniqua Research Farm near George, South Africa. It consisted of a pot trial, which was conducted under a structure covered with 50% shade net with open sides.

Five soils from an Estcourt soil type – with different levels of soil carbon (C) – were identified on the Outeniqua Research Farm. The soil C contents were: 1.29%, 2.03%, 2.77%, 3.80% and 4.25%.
There were three treatments, replicated nine times, and tested on each of the five soils:

- White clover (cultivar: Haifa), seeds inoculated with *Rhizobium leguminosarum* bv. *Trifolii*;
- White clover (cultivar: Haifa), not inoculated (subject to only free-living rhizobia); and
- Cape weed (*Arctotheca calendula*).

White clover was grown from seed sown directly into the pots (diameter: 160 mm; height 220 mm) – at a density of two plants per pot. Pots were arranged in a randomised block design, and replicates were placed in separate rows. Plants were watered using drip irrigation and the soil-moisture status was determined using tensiometers (Botha, 2002).

Plants were harvested in the twelfth week after planting. Soil was carefully removed from the roots by rinsing them with water (Somasegaran & Hoben, 1985). Thereafter, the nodulation index was calculated

– as described by Prevoust and Antoun (2008) – using a procedure entailing the scoring of nodules according to size, number and colour.

Subsamples of 32 ml were taken from the rhizosphere soil, and then refrigerated during transportation to the microbiological laboratory for analyses.

Plastic pouches (Mega International, St Paul, Minneapolis) were used to determine the most probable number (MPN) of symbiotic *Rhizobium* cells per gram of soil – by using the plant-infection count method of analysis.

Culturable (free living and symbiotic) rhizobia were quantified using the plate-count method, where serial dilutions of the soil were plated out on yeast mannitol agar (YMA).

Cape weed served as the non-fixating reference plant, and was used to quantify biological N fixation with the N difference technique. The symbiotic effectiveness was measured as biomass weight (dry matter). Each plant's roots and shoots were dried at 60˚C for 72 hours, and were weighed and milled as described by Botha (2003).

An analysis of variance was performed using SAS 9.2 (2003–2008) for the continuous variables. Assumptions of normality were tested to determine significant difference between means, and the student t-test was conducted at a 5% significance level. A chi-square analysis was performed for ordinal data (SAS Institute Inc., 2008).

Results and discussion

The plant infection technique highlighted the presence of symbiotic *Rhizobium* – and not free-living *Rhizobium*. The MPN of symbiotic rhizobia, ranged from as little as 7, to over 8900 bacterial cells per gram of soil. It is clear that inoculation had an effect on the MPN values (see Figure 1), even though not statistically different from other treatment means – but this can be ascribed to the variation of results caused by the technique, rather than the treatments themselves. At a particular soil C content of approximately 2.03% to 3.80%, the most symbiotic *Rhizobium* was detected from either inoculated or non-inoculated soils. It is interesting to note that the soils containing the highest soil C content had depressed values of symbiotic *Rhizobium* – contrary to expectation.

Rhizobium was detected in all soils, regardless of level of soil C or treatment with inoculant – which emphasises the robustness and adaptability of the genus in different levels of soil C. *Rhizobium* and soil C play vital roles in the maintenance of soil health, by increasing its capacity to function as a living system and in sustaining pasture productivity. Soil health deals with integrated management practices

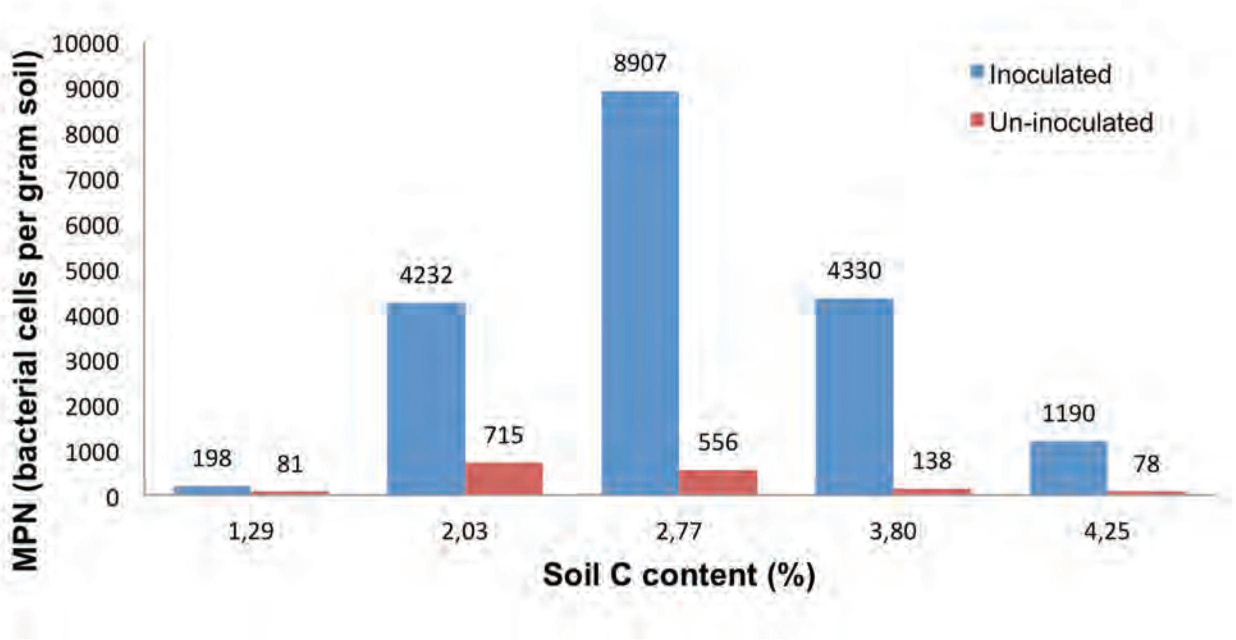


Figure 1: Most-Probable-Number (MPN) values – as affected by soil C content and seed inoculation.

to improve productivity in an economically and environmentally compatible manner (Barabasz *et al.*, 2002). It has been proposed that *Rhizobium* is a viable and accurate indicator of soil-health status (Van Bruggen & Semenov, 2000; Nielsen & Winding, 2002). Microorganisms – especially *Rhizobium* in association with SOM – also contribute to soil's physical factors related to soil resilience (Bot & Benites, 2005; Patra *et al.*, 2005). Thus, the particular soils will likely have a large potential to return to equilibrium after disturbances – being rich in soil C and *Rhizobium*.

The plate-count technique provided data which emphasises that the total culturable (symbiotic and free living) rhizobia were not drastically influenced by the different levels of soil C (see Figure 2). This supports the findings of Brockwell (1963), and Weaver and Frederick (1972).

The data in Figure 2 concur with those obtained for the symbiotic rhizobia in Figure 1. These data, however, differ in that free-living *Rhizobium* is more prevalent in extreme soil C content soils.

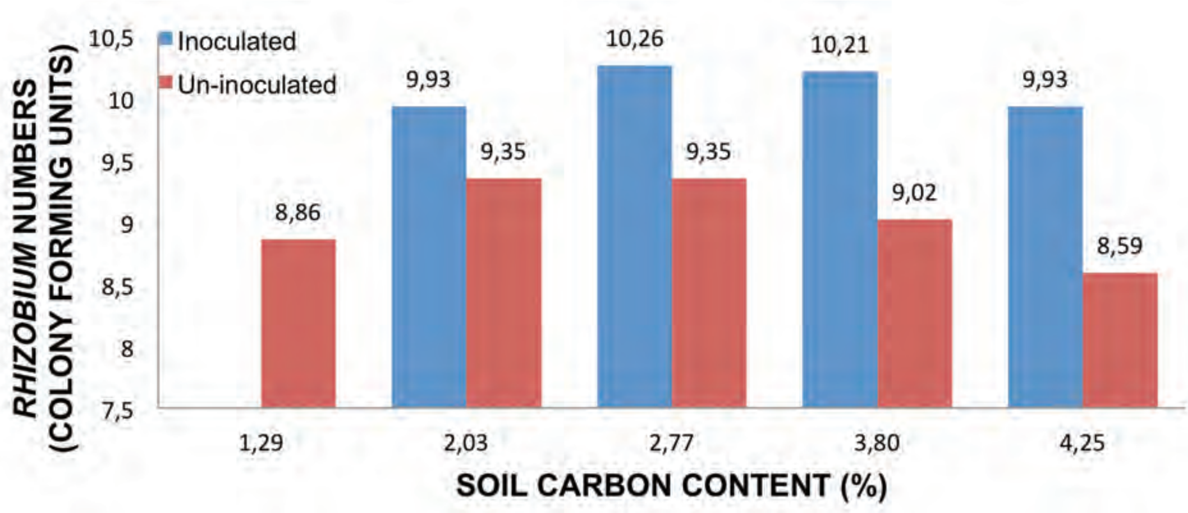


Figure 2: *Rhizobium* colony-forming units, as affected by soil C content and seed inoculation.

A similar soil C content threshold exists between 2.03 and 3.80% C, where free-living and symbiotic *Rhizobium* predominate. It is deducted from the data that free-living rhizobia have a lower potential to infect white clover than the introduced symbiotic rhizobia. White clover is not necessarily host specific to these free-living rhizobia.

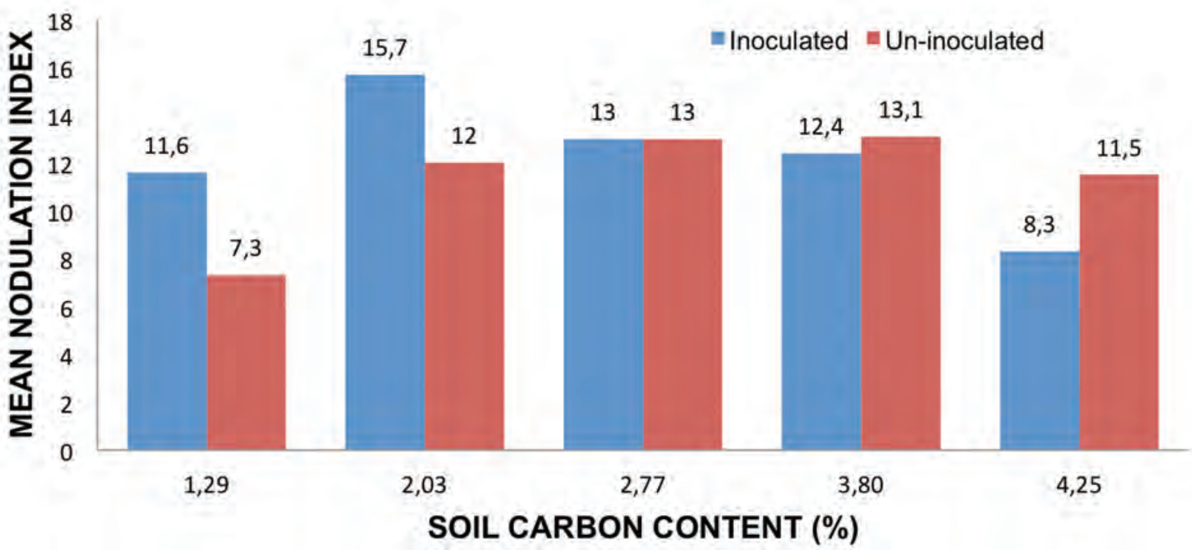


Figure 3: Mean nodulation indices of white clover – as affected by soil C content and seed inoculation.

Figure 3 represents the actual success of nodulation. It illustrates that there was no significant difference in success of nodulation between inoculated versus non-inoculated treatments – irrespective of the different soil C contents.

Lack of legume response to inoculation may be due to limitations in the soil, such as non-vigorous plant growth, high indigenous rhizobial numbers, or highly effective indigenous strains and the availability of mineral N in the soil (Keyser *et al.*, 1992; Turk *et al.*, 1993; Brockwell *et al.*, 1995). The high, free-living *Rhizobium* numbers in the soil was the possible reason for the lack of response to inoculation.

Free-living and symbiotic rhizobia fix N – however, most N is fixed by symbiotic N fixation. N fixation by free-living rhizobia is difficult to quantify, and also expensive. Symbiotic N fixation was quantified, and is shown in Table 1 – where it is clear that soil C content had a significant affect on the amount of atmospheric N_2 fixed (%Ndfa). As soil C content increased, mean %Ndfa decreased proportionally – from 1.793% to 0.680% N.

Even though the plants growing in the low C soil fixed the most atmospheric N, the soil N content was 6.25 g kg^{-1} in comparison to the high C soil which had a N content of 39 g kg^{-1}. Therefore, plants growing in the high C soil caused an increase in soil N of more than six times that of the low C soil (see Table 1). In low N input grass-clover mixed swards, this will be exceptionally important – as the grasses will be able to utilise only this rhizo-deposited N.

Table 1: Mean percentage N derived from the atmosphere (%Ndfa), and final soil N content as affected by soil C content.

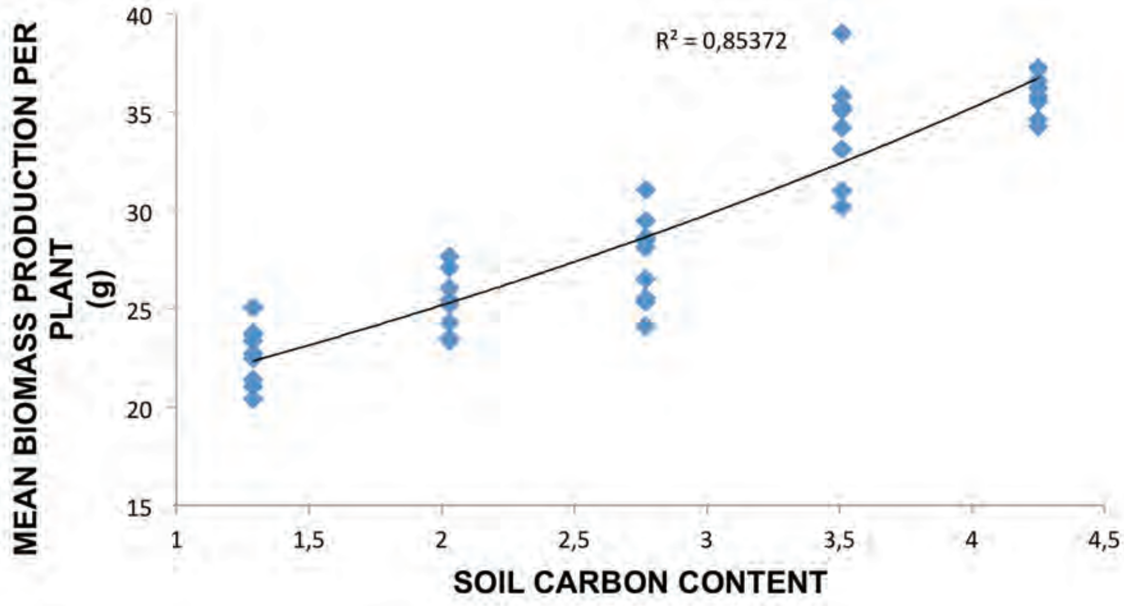
Soil C content (%)	**Mean %Ndfa**	**Final soil N content (g kg^{-1})**
1.29	1.793^{a}	6.25^{a}
2.03	1.335^{b}	12.5^{b}
2.77	0.985^{c}	17.0^{c}
3.51	0.897^{c}	29.4^{d}
4.25	0.680^{d}	39.0^{e}
LSD (0.05)	**0.1762**	**2.060**

LSD = Least Significant Difference (P-value = 0.05)
^{abc}Means with no common superscript differed significantly (P-value < 0.05).

Plant sanctions are the process where plants preferentially supply more photosynthetic resources to bacterial root nodules that are fixing more atmospheric N than other nodules. The aim of this process is to improve nodule efficiency. This also implies that the plants will not divert as much energy to the nodules if soil C is freely available as a source of energy to the microbes – as in soil with the highest C content (4.25%), compared with that of the low C soil (1.29%). The amount of fixed atmospheric N in white clover plants in the high C soils – was substantially lower (Table 1). This will subsequently lead to senescence of many nodules, and soil N content will increase by rhizo-deposition (Keyser *et al.*, 1992, Slattery *et al.*, 2001). The literature suggests that the possible reason for lower soil N content of low C soil, is a result of more plant energy being available for plant growth – rendering biomass production more efficient. Biomass production was the parameter used to measure efficiency of N fixation.

The interaction of soil C and biomass production – where seeds were inoculated – was significantly higher, regardless of treatment with inoculant (Figures 4 & 5).

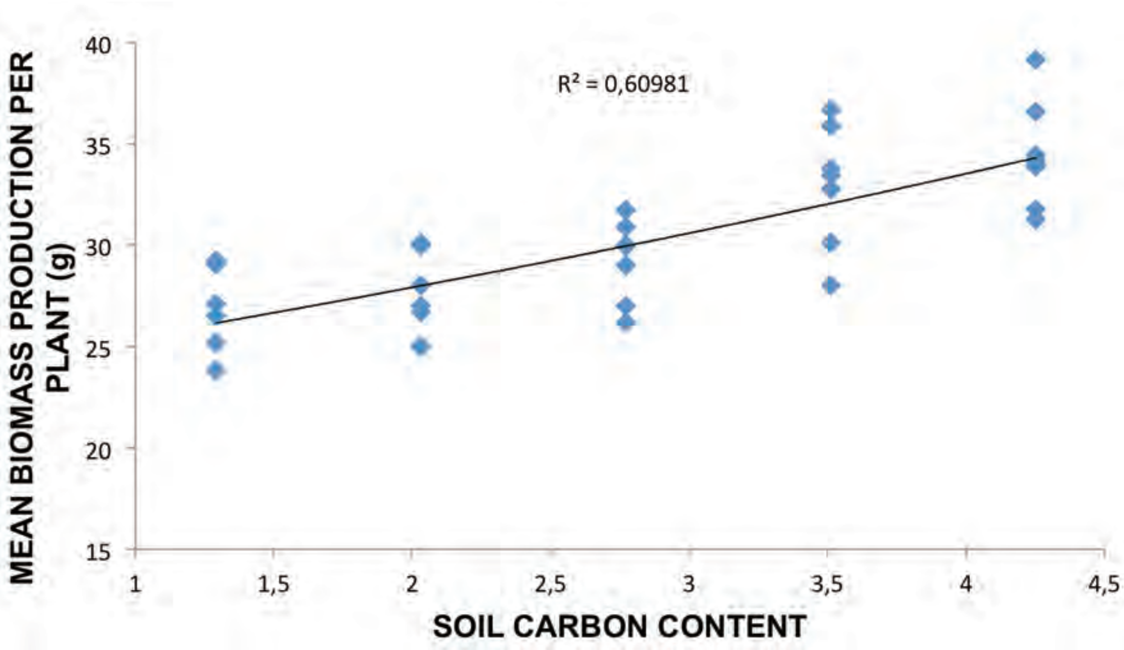
Even though the N fixation of the plants in the low C soil was the highest (see Table 1), the biomass production of the specific plants remained the lowest. The plants in the low C soil were thus greatly dependent on the rhizobia for a source of N by fixation. In exchange, the plants divert much of the photosynthetic energy to the nodules that could otherwise have been used for growth and production. Efficiency of N fixation remained highest in the soil with a C content of 4.25% – regardless of inoculation.



[abcde]Means with no common superscript differed significantly (P-value < 0.05).

Figure 4: Mean biomass production (dry weight), as affected by soil C content where seeds were inoculated with *Rhizobium leguminosarum* bv. *trifolii*.

It is evident from Figures 2 and 4 that the mean biomass production of white clover was much higher in the non-inoculated, low C content soils – compared to the inoculated low C content soils. This illustrates that biomass production of white clover was more dependent on the N provided by free-living rhizobia in low C content soils (Figure 5). The opposite scenario is suggested in Figure 4, where the biomass production of white clover was more dependent on the N provided by the more efficient symbiotic rhizobia introduced by inoculation in the higher C content soils.



[abcde]Means with no common superscript differed significantly (P-value < 0.05).

Figure 5: Mean biomass production (dry weight), as affected by soil C content where seeds were only subject to indigenous, free-living *Rhizobium* bacteria (not inoculated).

Summary

- *Rhizobium* was detected in all soils.
- Most *Rhizobium* was detected in a soil C content between 2.03 and 3.80%.
- *Rhizobium* is beneficial to soil as a living entity, and also is an indicator of a healthy soil.
- Free-living rhizobia were more adapted and prevalent in extremes of soil C content.
- Free-living rhizobia had a lower potential to infect white clover; it remains vital to inoculate.
- The higher the soil C content, the lower the amount of N fixed.
- Soil N content increased with increasing levels of soil C.
- Biomass production was lowest in low C soil.
- Biomass production, in low C soil, was more dependent on N provided by free-living rhizobia.
- Biomass production, in high C soil, was more dependent on N provided by symbiotic rhizobia.

Conclusion

Conditions affecting N fixation must be optimal, so that fixed N can be transported and redistributed throughout the plant. Diverse management strategies to help increase soil C content of pastures containing white clover – are necessary to maximise the efficiency of N fixed, and also rhizo-deposition. The environment in which mixed pastures are grown should also be managed efficiently, so that the grass component can utilise the N fixed by the legume component of these mixed pastures.

Farmers in the southern Cape need to give innovative attention to soil health and resilience – as the current high N input pasture systems are unsustainable. *Rhizobium leguminosarum* bv. *trifolli*, being an indicator of soil health, is a common and beneficial bacteria species in pasture soils in the George area, in South Africa. This species is robust and adaptable under many soil conditions. Introduction of rhizobia by means of inoculation of seed, may therefore be beneficial. This is because indigenous strains might form nodules, but can still be ineffective in supplying the plant with N. Soil organic matter is the most important contributor to soil health, and rhizobia are accepted as important biological indicators of a healthy soil.

Management that will increase soil organic matter is very important, and farmers are urged to adapt management in order to sustain production.

MESSAGE TO THE FARMER

Some features of soils are relatively easy to change or manipulate – such as chemical characteristics. However, most of the physical characteristics of soil, such as soil type, depth, and texture, are difficult or impossible to change. Improving characteristics of soil that can be manipulated, and preserving characteristics that cannot easily be manipulated, need to be an area of focus. Increasing soil organic matter is critical for converting degraded soil into healthy soil, or for enhancing already healthy soils. This study showed that soil organic matter is necessary to maintain life in the soil – bacteria and plants alike directly require it as a nutrient source. In addition, oil organic matter also influences almost all physical, chemical and biological characteristics of soil – which has an indirect effect on plant production. Soil organic matter is even critical for limiting damage from pathogens and pests.

Possible approaches for increasing soil organic matter are:

- Amend the soil with organic matter (compost, manure, mulches, green manure, legumes, crop residues, and other organic materials).
- Use diverse sources of organic matter to supply various nutrient groups.
- Adapt to a no-till system, or at least to minimum tillage.
- Conservative fertilisation practices need to be adopted – maintain the fertility status of the soil (soil pH, macro- and micro-nutrients)
- Include legumes in the planted pasture and rotational systems.
- Grow cover crops or living mulches in applicable systems.
- Adopt rotations that allow for high amounts of residues after harvesting.
- Prevent salinisation of soils.

Unfortunately there is no easy-and-quick way to build soil organic matter. Management has to be adapted and prolonged, and patience and perseverance are required.

Take-home message

Building and maintaining soil organic matter content are the most important management factors for ensuring sustainable pasture production. This is the foundation of profitable pasture production.

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3. The production potential of perennial ryegrass and ryegrass hybrid cultivars over a three year evaluation period

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Introduction

Grass-legume pastures form the backbone of milk and beef production in the southern Cape, South Africa (Botha, 2008). Perennial ryegrass (*Lolium perenne*) is a perennial cool-season pasture crop that produces fodder of a high quality during spring and autumn (Donaldson, 2001). Perennial ryegrass is an important component of grass-legume mixtures, due to the persistence of the perennial grass under optimum management (Botha & Gerber, 2008).

Previous system trials on Outeniqua Research Farm have indicated that pasture and milk production is higher when kikuyu is over-sown with perennial ryegrass rather than annual ryegrass (Van der Colf *et al.*, 2010). It is important to consider the production system when selecting the type of ryegrass – cultivar has a significant effect on the production potential of the pasture. The production system will determine the type of ryegrass used (Ammann *et al.*, 2006); annual and seasonal production of perennial ryegrass pasture will be determined by cultivar (Botha *et al.*, 2008).

Milk and beef producers in the southern Cape region are constantly searching for productive and adapted cultivars to use in their production systems. These cultivars should be able to produce a sufficient amount of dry matter (DM) sustainably. A large number of perennial ryegrass (*Lolium perenne*) and ryegrass hybrids (*L. multiflorum* x *L. perenne; L. multiflorum* x *Festuca* spp.) are available in South Africa. In order to determine the best adapted and highest producing cultivar to use in pasture systems, it is important that these cultivars be evaluated on a regular basis. The aim of this study was to evaluate the production potential and persistence of 18 perennial ryegrass and ryegrass hybrid cultivars over three years.

Materials and Methods

This study was carried out on the Outeniqua Research Farm near George (Altitude 201 m, 33º 58' 38" S, 22º 25' 16" E, rainfall 728 mm year^{-1}) in the Western Cape Province of South Africa and was executed under sprinkler irrigation on a Witfontein soil form. Irrigation scheduling was done according to tensiometer readings, commencing at –25 kPa and terminated at –10 kPa (Botha, 2002). Fertilizer was applied to raise the soil nutrient levels to soil analysis recommendations. Phosphorous (P) and potassium (K) were applied before planting, to raise soil nutrient levels in accordance with the soil analysis report. Nitrogen (N) and K were applied after each cutting at a rate of 50 kg N ha^{-1} and 20 kg K ha^{-1}, respectively.

The trial was planted on 7 June 2010. A kongskilde was used to create a seedbed and to mechanically eradicate weeds. Seed was planted in rows and plots rolled with a land roller. Each treatment, consisting of 18 cultivars (treatments), was replicated three times. The species, cultivar name, ploidy and seeding rate of perennial ryegrass and perennial ryegrass hybrids evaluated during the study, are shown in Table 1. The trial layout is described as a randomised block design, consisting of 54 plots. Plot size was 2,1 m x 6 m (= 12,6 m^2). Plots were sampled on a 28-day cycle. A strip of pasture (1,27 m x 4,8 m = 6,1 m^2) was cut to a height of 50 mm above ground level for pasture sampling. The weight of the cut strip was determined – thereafter approximately 500 g of the sample was placed in a brown paper bag and weighed wet and dry to determine dry matter (DM) content. Samples were dried in an oven at 60ºC for 72 hours to determine dry weight.

An appropriate analysis of variance was performed on growth rate, seasonal DM production and total annual DM production. The assumption of normality of the residuals (Shapiro & Wilk, 1965) was fulfilled. Therefore, the results are statistically sound. A Student least significant difference (LSD) at 5% significance level was done to compare the treatment means (Ott,1998). The STATS module of SAS version 9.2 (SAS Institute Inc., 2008) was used to analyse the data.

Table 1. The species, cultivar, ploidy and seeding rate of perennial ryegrass and ryegrass hybrids evaluated during the study

Species	Cultivar	Ploidy	Seeding rate (kg ha^{-1})
Perennial ryegrass	Alto	Diploid	20
Perennial ryegrass	Bronsyn	Diploid	20
Perennial ryegrass	Commando	Diploid	20
Perennial ryegrass	Nui	Diploid	20
Perennial ryegrass	Indiana	Diploid	20
Perennial ryegrass	Bealy	Tetraploid	25
Perennial ryegrass	Sterling	Tetraploid	25
Perennial ryegrass	Impresarrio	Tetraploid	25
Perennial ryegrass	Cheliac	Tetraploid	25
Perennial ryegrass	Polim	Tetraploid	25
Perennial ryegrass	Fitzroy	Tetraploid	25
Perennial ryegrass	Quartet	Tetraploid	25
Perennial x Italian hybrid ryegrass	Fortimo	Tetraploid	25
Perennial x Italian hybrid ryegrass	Storm	Tetraploid	25
Perennial x Italian hybrid ryegrass	Tirna	Tetraploid	25
Perennial x Italian hybrid ryegrass	Solid	Tetraploid	25
Festulolium	Perseus	Tetraploid	25
Tall Fescue	Kora	Hexaploid	25

Results and discussion

The mean monthly growth rate (kg DM ha^{-1} day^{-1}) of perennial ryegrass, hybrid ryegrass, Festulolium and Fescue cultivars during year 1 to year 3 is shown in Table 2 to Table 4 respectively. The highest growth rate was achieved by different cultivars during different months.

The total seasonal and annual DM production of perennial ryegrass, hybrid ryegrass, and Festulolium and Fescue cultivars during year 1, 2 and 3 is shown in Table 5, Table 6 and Table 7 respectively. Fitzroy was the only cultivar that maintained a DM production, that was the highest (P<0.05,) or similar (P>0.05) to the highest, producing cultivar throughout all seasons during year 1 and year 3. During year 2, Bealy was the only cultivar that had the highest (P<0.05,) or similar (P>0.05) to the highest, seasonal DM production throughout all seasons. The total annual DM production of Fitzroy was similar (P>0.05) to that of Alto, Bronsyn and Bealy, but higher (P<0.05) than the rest during year 1. Bealy had the highest (P<0.05) annual DM production during year 2, with similar (P>0.05) production from Alto, Bronsyn, Indiana, Impresarrio, Polim, Fitzroy, Storm, Tirna and the Fescue cultivar Kora. During year 3, the total annual dry matter production of the Tall Fescue cultivar, Kora, was similar (P>0.05) to that of Bronsyn, Bealy, Sterling, Fitzroy, Solid and Perseus, but higher (P<0.05) than the rest.

The total annual DM production during year 1, 2 and 3, total DM production over the three years, and the reduction in yield (%) from year 1 to 2, year 2 to 3 and year 1 to 3, are shown in Table 8. The perennial ryegrass cultivars Bronsyn, Bealy and Fitzroy had the highest (P<0.05,) or similar (P>0.05) to the highest, annual dry matter production during all three years. Bronsyn, Bealy and Fitzroy were the only cultivars that had a yield above 27 tons for the three years. The Fescue cultivar Kora, was similar (P>0.05) to the lowest yielding cultivar during year 1, but had a similar (P>0.05) yield to the highest yielding cultivar during year

2 and year 3. Aside from Tirna and Kora, all other cultivars showed reduction in yield of above 30% from year 1 to 2, with the highest reduction in yield 47%. The decline in yield over the three year period varied between 33- 58%, with the lowest decline in yield found in the Tall Fescue cultivar, Kora.

Conclusion

1. The perennial ryegrass cultivars Bealy, Bronsyn and Fitzroy, had the highest annual dry matter production over the three years.
2. The Tall Fescue cultivar Kora, had a similar yield to Bealy during year 2 and 3, and showed the lowest decline in yield from year 1 to year 3.
3. The persistence of perennial grasses should be considered along with production potential, when deciding on which cultivar or variety to use.
4. Ploidy had no significant impact on production.

MESSAGE TO THE FARMER

- The production potential of perennial ryegrass declines after the first year of production.
- The selection of a perennial grass for inclusion in a system should be based on seasonal production potential and the persistence of the species/cultivar over years.
- Based on production and persistence over years, Bealy, Bronsyn and Fitzroy maintained higher productivity compared to other cultivars.

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Table 2. Mean monthly growth rate (kg DM ha^{-1}) of perennial ryegrass, hybrid ryegrass, Festulolium and fescue cultivars during year 1.

Species	Cultivar	Ploidy	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
PR[1]	Alto	Dip[5]	14.8^{abcd}	59.6^{bcd}	76.9^{abc}	59.3^{abcd}	49.1^{ab}	17.3^{bc}	4.66^{bcd}	16.7^{bcd}	31.5^{bc}	39.4^{abcd}
PR	Bronsyn	Dip	15.6^{ab}	66.3^{ab}	80.8^{abc}	59.5^{abcd}	45.0^{abc}	12.1^{c}	2.09^{efg}	14.2^{bcd}	53.03^{a}	41.2^{abc}
PR	Commando	Dip	10.8^{gh}	44.2^{cd}	75.1^{abc}	55.7^{abcd}	39.6^{abc}	11.6^{c}	4.34^{cde}	17.0^{bcd}	30.32^{bc}	44.0^{a}
PR	Nui	Dip	16.4^{a}	56.0^{bcd}	67.8^{c}	50.3^{d}	37.9^{bc}	16.7^{bc}	1.59^{g}	0.68^{e}	27.9^{bc}	39.6^{abcd}
PR	Indiana	Dip	14.8^{abcd}	52.5^{bcd}	75.9^{abc}	62.4^{ab}	42.0^{abc}	16.5^{bc}	1.82^{fg}	16.7^{bcd}	31.6^{bc}	37.3^{abcd}
PR	Bealy	Tet[6]	17.0^{a}	59.3^{bcd}	83.5^{ab}	58.1^{abcd}	47.1^{abc}	19.1^{bc}	6.07^{bc}	22.3^{b}	30.2^{bc}	37.9^{abcd}
PR	Sterling	Tet	11.9^{efg}	54.6^{bcd}	69.3^{bc}	58.4^{abcd}	37.4^{bc}	12.3^{c}	1.91^{fg}	19.1^{bc}	43.3^{abc}	37.5^{abcd}
PR	Impresarrio	Tet	14.2^{abcdef}	55.2^{bcd}	80.7^{abc}	59.9^{abc}	34.7^{c}	17.3^{bc}	2.01^{fg}	6.92^{cde}	33.9^{abc}	33.2^{bcde}
PR	Cheliac	Tet	12.1^{defg}	58.5^{bcd}	72.4^{abc}	59.7^{abcd}	52.4^{a}	14.9^{bc}	1.89^{fg}	7.94^{cde}	34.3^{abc}	31.5^{cde}
PR	Polim	Tet	12.4^{cdefg}	55.3^{bcd}	71.2^{abc}	57.3^{abcd}	35.5^{c}	11.9^{c}	2.29^{efg}	4.00^{de}	41.38^{abc}	44.3^{a}
PR	Fitzroy	Tet	15.6^{ab}	81.1^{a}	82.5^{abc}	52.0^{cd}	38.5^{bc}	17.8^{bc}	10.5^{a}	40.1^{a}	40.7^{abc}	39.0^{abcd}
PR	Quartet	Tet	14.5^{abcde}	54.5^{bcd}	74.7^{abc}	53.1^{bcd}	37.1^{bc}	14.0^{bc}	2.43^{defg}	9.49^{bcde}	33.9^{abc}	36.7^{abcd}
Hybrid[2]	Fortimo	Tet	13.2^{bcdefg}	50.4^{bcd}	80.7^{abc}	59.3^{abcd}	37.3^{bc}	17.0^{bc}	1.16^{g}	7.78^{cde}	31.3^{bc}	41.7^{ab}
Hybrid	Storm	Tet	15.2^{abc}	51.1^{bcd}	72.8^{abc}	56.1^{abcd}	39.4^{abc}	14.3^{bc}	1.71^{fg}	5.63^{de}	27.7^{bc}	40.4^{abc}
Hybrid	Tirna	Tet	10.7^{gh}	54.9^{bcd}	67.4^{c}	50.7^{cd}	43.0^{abc}	15.4^{bc}	2.35^{efg}	7.57^{cde}	23.8^{c}	33.4^{bcde}
Hybrid	Solid	Tet	11.4^{fg}	52.3^{bcd}	67.9^{c}	52.2^{cd}	37.8^{bc}	17.5^{bc}	3.95^{cdef}	21.9^{b}	37.3^{abc}	31.8^{cde}
Festulolium[3]	Perseus	Tet	15.1^{abc}	60.3^{bc}	86.1^{a}	63.6^{a}	37.0^{bc}	21.9^{ab}	0.92^{g}	5.04^{de}	28.2^{bc}	30.2^{de}
Fescue[4]	Kora	Hex[7]	8.00^{h}	40.3^{d}	68.2^{bc}	59.2^{abcd}	45.3^{abc}	27.8^{a}	6.79^{b}	19.2^{bc}	47.0^{ab}	25.1^{e}
LSD (0.05)			2.876	19.64	15.44	9.455	13.39	8.320	2.268	13.32	20.532	9.926

LSD (0.05) compares over cultivars within month.
^{abc} Means with no common superscript, differ significantly.
[1] PR: Perennial ryegrass
[2] Hybrid: Perennial x Italian ryegrass hybrid
[3] Festulolium: Meadow fescue x Italian ryegrass hybrid
[4] Tall Fescue
[5] Diploid
[6] Tetraploid
[7] Hexaploid

Table 3. Mean monthly growth rate (kg DM ha^{-1} day^{-1}) of perennial ryegrass, hybrid ryegrass, Festulolium and fescue cultivars during year 2

Species	Cultivar	Ploidy	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
PR[1]	Alto	Dip[5]	30.4^{a}	32.4^{abc}	16.1^{bcdef}	42.1^{abc}	20.3^{de}	33.5^{abcdef}	24.6^{bcd}	7.36^{bc}	13.7^{bcdefg}	14.3^{bcdef}	8.64^{cde}	9.08^{a}
PR	Bronsyn	Dip	28.1^{ab}	32.6^{ab}	18.0^{bcd}	38.4^{bcd}	21.2^{de}	28.4^{cdef}	25.3^{bc}	10.5^{b}	19.1^{abc}	17.6^{abc}	6.97^{de}	8.07^{abcd}
PR	Commando	Dip	26.2^{abc}	23.9^{cde}	11.7^{f}	35.3^{bcd}	24.9^{bcd}	32.4^{bcdef}	21.0^{cd}	7.17^{bc}	15.4^{bcdef}	14.4^{bcdef}	8.44^{cde}	8.39^{abc}
PR	Nui	Dip	29.5^{a}	33.8^{a}	17.8^{bcd}	39.5^{abcd}	17.4^{de}	26.0^{def}	22.6^{bcd}	9.10^{bc}	12.4^{cdefg}	11.5^{cdefg}	6.07^{e}	9.03^{a}
PR	Indiana	Dip	27.9^{ab}	28.5^{abcd}	13.8^{def}	39.9^{abcd}	23.7^{cd}	43.4^{a}	24.5^{bcd}	6.21^{bc}	17.0^{bcde}	19.3^{ab}	8.63^{cde}	8.81^{a}
PR	Bealy	Tet[6]	25.1^{abcd}	26.3^{abcde}	17.7^{bcd}	33.7^{cd}	25.2^{bcd}	42.8^{a}	27.9^{ab}	17.0^{a}	21.4^{ab}	23.9^{a}	14.1^{ab}	10.5^{a}
PR	Sterling	Tet	21.0^{cde}	22.9^{def}	13.8^{def}	31.7^{cd}	20.1^{de}	29.4^{bcdef}	21.0^{cd}	6.78^{bc}	18.8^{abcd}	15.9^{bcde}	5.94^{e}	4.19^{e}
PR	Impresarrio	Tet	27.8^{ab}	30.1^{abcd}	16.6^{bcde}	40.5^{abc}	23.5^{cd}	35.1^{abcde}	22.5^{bcd}	7.20^{bc}	9.84^{efg}	11.9^{cdefg}	9.15^{cde}	8.58^{ab}
PR	Cheliac	Tet	22.8^{bcd}	24.4^{bcde}	15.3^{cdef}	33.0^{cd}	23.7^{cd}	31.2^{bcdef}	22.3^{bcd}	7.63^{bc}	15.2^{bcdefg}	11.3^{cdefg}	7.92^{cde}	3.83^{e}
PR	Polim	Tet	29.8^{a}	22.9^{def}	12.7^{ef}	41.0^{abc}	23.6^{cd}	37.2^{abc}	24.6^{bcd}	7.77^{bc}	14.7^{bcdefg}	20.6^{ab}	12.0^{abc}	8.63^{ab}
PR	Fitzroy	Tet	24.8^{abcd}	28.1^{abcd}	23.6^{a}	49.9^{a}	27.9^{abcd}	25.1^{ef}	22.7^{bcd}	7.97^{bc}	21.4^{ab}	17.2^{bcd}	7.77^{cde}	5.40^{cde}
PR	Quartet	Tet	25.7^{abcd}	28.8^{abcd}	16.8^{bcde}	29.6^{d}	12.6^{e}	24.6^{f}	18.6^{d}	7.27^{bc}	14.4^{bcdefg}	10.9^{defg}	5.57^{e}	5.62^{bcde}
Hybrid[2]	Fortimo	Tet	22.3^{bcd}	24.7^{bcde}	19.1^{bc}	37.5^{bcd}	32.4^{abc}	28.5^{cdef}	20.5^{cd}	4.49^{c}	7.54^{g}	9.17^{fg}	6.62^{de}	5.41^{cde}
Hybrid	Storm	Tet	29.8^{a}	26.8^{abcde}	19.7^{ab}	45.8^{ab}	34.7^{ab}	35.4^{abcd}	25.2^{bc}	5.84^{bc}	8.22^{fg}	9.94^{efg}	8.61^{cde}	8.36^{abc}
Hybrid	Tirna	Tet	25.1^{abcd}	23.4^{def}	17.4^{bcd}	36.7^{bcd}	32.9^{abc}	39.0^{ab}	27.5^{ab}	10.1^{bc}	18.1^{abcd}	15.1^{bcdef}	10.9^{abcd}	8.98^{a}
Hybrid	Solid	Tet	19.7^{de}	18.3^{ef}	16.4^{bcde}	32.2^{cd}	21.2^{de}	28.0^{cdef}	20.4^{cd}	9.00^{bc}	24.8^{a}	19.0^{ab}	9.92^{bcde}	5.30^{cde}
Festulolium[3]	Perseus	Tet	23.3^{bcd}	18.9^{ef}	19.8^{ab}	39.9^{abcd}	32.7^{abc}	26.6^{def}	21.8^{bcd}	9.22^{bc}	11.1^{defg}	7.53^{g}	7.02^{de}	5.00^{de}
Fescue[4]	Kora	Hex[7]	15.6^{e}	15.1^{f}	18.5^{bc}	34.5^{cd}	35.7^{a}	36.0^{abcd}	31.9^{a}	18.0^{a}	21.4^{ab}	23.7^{a}	15.3^{a}	7.37^{abcd}
LSD (0.05)			6.214	8.600	4.360	10.92	10.50	10.01	6.340	6.020	7.746	6.515	4.534	3.118

LSD (0.05) compares over cultivars within month.

[abc] Means with no common superscript, differ significantly.

[1] PR: Perennial ryegrass

[2] Hybrid: Perennial x Italian ryegrass hybrid

[3] Festulolium: Meadow fescue x Italian ryegrass hybrid

[4] Tall Fescue

[5] Diploid

[6] Tetraploid

[7] Hexaploid

Table 4. Mean monthly growth rate (kg DM ha^{-1} day^{-1}) of perennial ryegrass, hybrid ryegrass, Festulolium and fescue cultivars during year 3.

Species	Cultivar	Ploidy	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
PR[1]	Alto	Dip[5]	9.13^{a}	6.93^{abcde}	4.13^{bcde}	26.4^{bc}	17.6^{de}	20.3^{ghi}	22.5^{bcd}	24.0^{ab}	14.3^{bcde}	15.2^{bc}	11.4^{bc}	12.5^{ab}
PR	Bronsyn	Dip	8.70^{ab}	8.23^{ab}	6.23^{ab}	24.6^{bc}	26.5^{bc}	32.3^{abcd}	23.8^{abcd}	24.3^{ab}	21.0^{bcd}	18.1^{bc}	16.4^{abc}	16.5^{a}
PR	Commando	Dip	5.37^{cdefg}	4.07^{efg}	2.10^{e}	23.8^{bc}	23.0^{cde}	17.8^{i}	22.6^{bcd}	24.9^{ab}	11.9^{de}	19.2^{abc}	14.5^{abc}	10.8^{b}
PR	Nui	Dip	7.87^{abcd}	6.43^{abcdef}	3.77^{bcde}	23.0^{bc}	15.9^{e}	18.6^{hi}	20.3^{d}	24.0^{ab}	11.4^{de}	11.0^{cd}	10.6^{c}	11.4^{ab}
PR	Indiana	Dip	3.80^{efg}	4.97^{cdefg}	2.57^{e}	24.1^{bc}	22.8^{cde}	22.3^{fghi}	21.3^{cd}	25.2^{ab}	12.7^{cde}	19.3^{abc}	11.6^{bc}	12.2^{ab}
PR	Bealy	Tet[6]	6.70^{abcde}	9.17^{a}	5.57^{bc}	22.8^{bc}	26.6^{bc}	$25.3^{cdefghi}$	25.5^{abcd}	27.0^{ab}	23.6^{bc}	20.8^{ab}	16.6^{abc}	14.3^{ab}
PR	Sterling	Tet	5.03^{defg}	4.20^{efg}	2.73^{de}	24.8^{bc}	24.9^{bcd}	34.2^{abc}	26.2^{abcd}	23.6^{ab}	19.6^{bcde}	15.4^{bc}	16.7^{abc}	12.4^{ab}
PR	Impresarrio	Tet	5.60^{cdef}	6.53^{abcdef}	3.47^{cde}	24.3^{bc}	24.6^{bcd}	29.0^{bcdefg}	28.9^{abc}	21.8^{ab}	12.0^{de}	12.5^{bcd}	11.1^{bc}	10.9^{b}
PR	Cheliac	Tet	4.57^{efg}	5.17^{cdefg}	4.27^{bcde}	23.9^{bc}	24.7^{bcd}	$27.3^{bcdefgh}$	30.7^{a}	26.3^{ab}	16.0^{bcde}	11.1^{cd}	10.3^{c}	11.6^{ab}
PR	Polim	Tet	5.30^{cdefg}	5.10^{cdefg}	2.53^{e}	24.4^{bc}	20.7^{cde}	22.7^{efghi}	22.2^{cd}	19.5^{b}	19.9^{bcde}	18.9^{bc}	19.4^{a}	13.1^{ab}
PR	Fitzroy	Tet	4.07^{efg}	4.50^{defg}	8.33^{a}	41.9^{a}	32.3^{b}	21.5^{fghi}	25.4^{abcd}	20.7^{b}	21.5^{bcd}	19.0^{bc}	17.6^{abc}	15.3^{ab}
PR	Quartet	Tet	5.97^{bcde}	7.30^{abcd}	2.87^{de}	23.6^{bc}	16.2^{e}	29.6^{abcdef}	19.5^{d}	30.0^{a}	19.8^{bcde}	12.4^{bcd}	14.8^{abc}	13.7^{ab}
Hybrid[2]	Fortimo	Tet	4.77^{efg}	7.90^{abc}	6.37^{ab}	25.8^{bc}	26.4^{bc}	30.6^{abcdef}	26.7^{abcd}	22.7^{ab}	11.6^{de}	5.07^{d}	10.5^{c}	12.9^{ab}
Hybrid	Storm	Tet	8.27^{abc}	6.07^{bcdef}	5.30^{bcd}	29.5^{b}	26.5^{bc}	22.7^{efghi}	26.1^{abcd}	22.7^{ab}	9.50^{e}	9.83^{cd}	11.0^{bc}	13.3^{ab}
Hybrid	Tirna	Tet	6.13^{abcde}	3.83^{fg}	2.93^{de}	27.6^{bc}	24.8^{bcd}	24.6^{defghi}	26.5^{abcd}	24.2^{ab}	16.7^{bcde}	11.1^{cd}	10.8^{c}	11.5^{ab}
Hybrid	Solid	Tet	2.90^{fg}	4.40^{defg}	1.67^{e}	22.3^{c}	24.1^{bcde}	31.5^{abcde}	22.4^{bcd}	27.5^{ab}	25.2^{ab}	21.6^{ab}	18.6^{ab}	12.0^{ab}
Festulolium[3]	Perseus	Tet	5.43^{cdef}	7.37^{abcd}	6.20^{ab}	29.6^{b}	22.8^{cde}	38.0^{a}	30.5^{ab}	28.1^{ab}	12.1^{de}	13.3^{bcd}	10.2^{c}	11.7^{ab}
Fescue[4]	Fesc:Kora	Hex[7]	2.37^{g}	2.47^{g}	2.37^{e}	24.9^{bc}	43.4^{a}	34.6^{ab}	19.9^{d}	25.6^{ab}	35.3^{a}	28.5^{a}	19.8^{a}	14.6^{ab}
LSD (0.05)			3.044	3.020	2.612	7.089	8.296	9.135	8.095	9.263	11.19	9.491	7.728	5.856

LSD (0.05) compares over cultivars within month.

^{abc} Means with no common superscript ,differ significantly.

[1] PR: Perennial ryegrass

[2] Hybrid: Perennial x Italian ryegrass hybrid

[3] Festulolium: Meadow fescue x Italian ryegrass hybrid

[4] Tall Fescue

[5] Diploid

[6] Tetraploid

[7] Hexaploid

Table 5. Total seasonal and annual dry matter production (kg DM ha^{-1}) of perennial ryegrass, hybrid ryegrass, Festulolium and fescue cultivars during year 1

Species	Cultivars	Ploidy	Winter	Spring	Summer	Autumn	Annual
PR[1]	Alto	Dip[5]	1272^{abcd}	6280^{abcd}	2347^{abc}	2468^{bcdef}	12367^{abcd}
PR	Bronsyn	Dip	1340^{ab}	6612^{abc}	1938^{bcde}	3076^{ab}	12966^{ab}
PR	Commando	Dip	930^{gh}	5653^{cde}	1813^{bcde}	2571^{bcd}	10966^{de}
PR	Nui	Dip	1411^{a}	5571^{de}	1887^{bcde}	1937^{def}	10806^{de}
PR	Indiana	Dip	1270^{abcd}	6150^{abcd}	2012^{bcde}	2391^{bcdef}	11823^{bcd}
PR	Bealy	Tet[6]	1459^{a}	6450^{abcd}	2398^{ab}	2538^{bcde}	12844^{abc}
PR	Sterling	Tet	1020^{efg}	5859^{abcde}	1706^{de}	2821^{abc}	11405^{bcde}
PR	Impresario	Tet	1219^{abcdef}	6298^{abcd}	1825^{bcde}	2100^{cdef}	11441^{bcde}
PR	Cheliac	Tet	1038^{defg}	6155^{abcd}	2272^{abcd}	2089^{def}	11514^{bcde}
PR	Polim	Tet	1069^{cdefg}	5902^{abcde}	1642^{e}	2547^{bcde}	11160^{cde}
PR	Fitzroy	Tet	1344^{ab}	6484^{a}	2201^{abcde}	3354^{a}	13742^{a}
PR	Quartet	Tet	1246^{abcde}	5851^{abcde}	1778^{cde}	2268^{cdef}	11142^{cde}
Hybrid[2]	Fortimo	Tet	1131^{bcdefg}	6142^{abcd}	1870^{bcde}	2286^{cdef}	11429^{bcde}
Hybrid	Storm	Tet	1304^{abc}	5790^{bcde}	1840^{bcde}	2087^{def}	11021^{de}
Hybrid	Tirna	Tet	923^{gh}	5012^{e}	2011^{bcde}	1831^{ef}	9777^{e}
Hybrid	Solid	Tet	977^{fg}	5534^{de}	1982^{bcde}	2565^{bcd}	11058^{de}
Festulolium[3]	Perseus	Tet	1296^{abc}	6767^{ab}	2050^{bcde}	1798^{f}	11910^{bcd}
Fescue[4]	Fesc:Kora	Hex[7]	688^{h}	5042^{e}	2705^{a}	2583^{bcd}	11019^{de}
LSD (0.05)			247.2	1016	608.2	728.2	1763

LSD (0.05) compares over cultivars within season.

^{abc} Means with no common superscript, differ significantly.

[1] PR: Perennial ryegrass

[2] Hybrid: Perennial x Italian ryegrass hybrid

[3] Festulolium: Meadow fescue x Italian ryegrass hybrid

[4] Tall Fescue

[5] Diploid

[6] Tetraploid

[7] Hexaploid

Table 6. Total seasonal and annual dry matter production (kg DM ha^{-1}) of perennial ryegrass, hybrid ryegrass, Festulolium and fescue cultivars during year 2

Species	Cultivars	Ploidy	Winter	Spring	Summer	Autumn	Annual
PR[1]	Alto	Dip[5]	2399^{a}	2606^{abcde}	1472^{cde}	924^{cdefg}	7401^{abcde}
PR	Bronsyn	Dip	2393^{ab}	2395^{bcdef}	1825^{bc}	941^{cdef}	7554^{abcde}
PR	Commando	Dip	1880^{def}	2505^{abcde}	1413^{cde}	901^{cdefgh}	6699^{bcdef}
PR	Nui	Dip	2465^{a}	2265^{cdef}	1480^{cde}	781^{defghi}	6992^{bcdef}
PR	Indiana	Dip	2136^{abcde}	2881^{abc}	1503^{cde}	1055^{bcd}	7575^{abcde}
PR	Bealy	Tet[6]	2092^{abcde}	2728^{abcde}	2324^{ab}	1377^{a}	8522^{a}
PR	Sterling	Tet	1751^{efg}	2198^{ef}	1493^{cde}	737^{efghi}	6180^{ef}
PR	Impresarrio	Tet	2258^{abcd}	2685^{abcde}	1297^{cde}	855^{defghi}	7094^{abcdef}
PR	Cheliac	Tet	1893^{def}	2378^{bcdef}	1468^{cde}	644^{fghi}	6383^{cdef}
PR	Polim	Tet	1980^{cdef}	2754^{abcde}	1523^{cde}	1169^{abc}	7426^{abcde}
PR	Fitzroy	Tet	2307^{abc}	2827^{abcde}	1679^{cd}	859^{defghi}	7672^{abcd}
PR	Quartet	Tet	2163^{abcd}	1812^{f}	1326^{cde}	634^{ghi}	5936^{f}
Hybrid[2]	Fortimo	Tet	1995^{bcdef}	2673^{abcde}	1024^{e}	606^{hi}	6299^{def}
Hybrid	Storm	Tet	2307^{abc}	3149^{a}	1246^{de}	778^{defghi}	7481^{abcde}
Hybrid	Tirna	Tet	1988^{cdef}	2929^{ab}	1833^{bc}	999^{bcde}	7749^{abc}
Hybrid	Solid	Tet	1637^{fg}	2207^{def}	1773^{cd}	960^{cde}	6578^{cdef}
Festulolium[3]	Perseus	Tet	1858^{defg}	2704^{abcde}	1426^{cde}	556^{i}	6544^{cdef}
Fescue[4]	Fesc:Kora	Hex[7]	1470^{g}	2864^{abcd}	2491^{a}	1296^{ab}	8123^{ab}
LSD (0.05)			400.04	663.5	543.4	303.5	1447

LSD (0.05) compares over cultivars within season.

abc Means with no common superscript, differ significantly.

[1] PR: Perennial ryegrass

[2] Hybrid: Perennial x Italian ryegrass hybrid

[3] Festulolium: Meadow fescue x Italian ryegrass hybrid

[4] Tall Fescue

[5] Diploid

[6] Tetraploid

[7] Hexaploid

Table 7. Total seasonal and annual dry matter production (kg DM ha^{-1}) of perennial ryegrass, hybrid ryegrass, Festulolium and fescue cultivars during year 3

Species	Cultivars	Ploidy	Winter	Spring	Summer	Autumn	Annual
PR[1]	Alto	Dip[5]	530^{abc}	1902^{ef}	1724^{ab}	1096^{bcde}	5251^{cd}
PR	Bronsyn	Dip	614^{a}	2482^{bcd}	1959^{ab}	1443^{abcd}	6498^{abc}
PR	Commando	Dip	301^{def}	1955d^{ef}	1687^{ab}	1249^{bcde}	5191^{cd}
PR	Nui	Dip	474^{abcd}	1699^{f}	1578^{b}	933^{e}	4683^{d}
PR	Indiana	Dip	302^{def}	2077^{def}	1678^{ab}	1201^{bcde}	5257^{cd}
PR	Bealy	Tet[6]	574^{ab}	2252^{cde}	2159^{ab}	1455^{abc}	6439^{abc}
PR	Sterling	Tet	315^{def}	2478^{bcd}	1968^{ab}	1263^{bcde}	6023^{abcd}
PR	Impresarrio	Tet	414^{bcde}	2299^{cde}	1787^{ab}	974de	5474^{bcd}
PR	Cheliac	Tet	374^{cdef}	2268^{cde}	1776^{ab}	932^{e}	5350^{bcd}
PR	Polim	Tet	341^{cdef}	2018^{def}	1748^{ab}	1458^{abc}	5565^{bcd}
PR	Fitzroy	Tet	456^{abcd}	2894^{ab}	1921^{ab}	1467^{abc}	6738^{ab}
PR	Quartet	Tet	429^{abcde}	2012^{def}	1961^{ab}	1164^{bcde}	5566^{bcd}
Hybrid[2]	Fortimo	Tet	513^{abc}	2470^{bcd}	1734^{ab}	820^{e}	5538^{bcd}
Hybrid	Storm	Tet	517^{abc}	2370^{bcde}	1661^{b}	968de	5516^{bcd}
Hybrid	Tirna	Tet	336^{cdef}	2307^{cde}	1916^{ab}	943^{e}	5501^{bcd}
Hybrid	Solid	Tet	240^{ef}	2312^{cde}	2127^{ab}	1475^{ab}	6152^{abc}
Festulolium[3]	Perseus	Tet	510^{abc}	2635^{abc}	2009^{ab}	989^{cde}	6143^{abc}
Fescue[4]	Fesc:Kora	Hex[7]	192^{f}	3158^{a}	2281^{a}	1762^{a}	7392^{a}
LSD (0.05)			195.3	529.35	607.82	480.06	1459

LSD (0.05) compares over cultivars within season.
^{abc} Means with no common superscript, differ significantly.
[1] PR: Perennial ryegrass
[2] Hybrid: Perennial x Italian ryegrass hybrid
[3] Festulolium: Meadow fescue x Italian ryegrass hybrid
[4] Tall Fescue
[5] Diploid
[6] Tetraploid
[7] Hexaploid

Table 8. The annual dry matter production during year 1 and 2 (kg DM ha^{-1}), total production over two years (kg DM ha^{-1}), reduction in yield from year 1 to 3 (kg DM ha^{-1}) and the percentage reduction from year 1 to 2, year 2 to 3 and year 1 to 3 of perennial ryegrass, hybrid ryegrass, Festulolium and fescue cultivars

Species	Cultivars	Ploidy	Year 1	Year 2	Year 3	Total over three years	Reduction in yield (%)		
							Year 1 to 2	Year 2 to 3	Year 1 to 3
PR[1]	Alto	Dip[5]	12367^{abcd}	7401^{abcde}	5251^{cd}	25019	40	29	58
PR	Bronsyn	Dip	12966^{ab}	7554^{abcde}	6498^{abc}	27018	42	14	50
PR	Commando	Dip	10966de	6699^{bcdef}	5191^{cd}	22856	39	23	53
PR	Nui	Dip	10806de	6992^{bcdef}	4683^{d}	22481	35	33	57
PR	Indiana	Dip	11823^{bcd}	7575^{abcde}	5257^{cd}	24655	36	31	56
PR	Bealy	Tet[6]	12844^{abc}	8522^{a}	6439^{abc}	27805	34	24	50
PR	Sterling	Tet	11405^{bcde}	6180^{ef}	6023^{abcd}	23608	46	3	47
PR	Impresarrio	Tet	11441^{bcde}	7094^{abcdef}	5474^{bcd}	24009	38	23	52
PR	Cheliac	Tet	11514^{bcde}	6383^{cdef}	5350^{bcd}	23247	45	16	54
PR	Polim	Tet	11160^{cde}	7426^{abcde}	5565^{bcd}	24151	33	25	50
PR	Fitzroy	Tet	13742^{a}	7672^{abcd}	6738^{ab}	28152	44	12	51
PR	Quartet	Tet	11142^{cde}	5936^{f}	5566^{bcd}	22644	47	6	50
Hybrid[2]	Fortimo	Tet	11429^{bcde}	6299^{def}	5538^{bcd}	23266	45	12	52
Hybrid	Storm	Tet	11021de	7481^{abcde}	5516^{bcd}	24018	32	26	50
Hybrid	Tirna	Tet	9777^{e}	7749^{abc}	5501^{bcd}	23027	21	29	44
Hybrid	Solid	Tet	11058de	6578^{cdef}	6152^{abc}	23788	41	6	44
Festulolium[3]	Perseus	Tet	11910^{bcd}	6544^{cdef}	6143^{abc}	24597	45	6	48
Fescue[4]	Fesc:Kora	Hex[7]	11019de	8123^{ab}	7392^{a}	26534	26	9	33
LSD (0.05)			1763	1447	1459				

[1] PR: Perennial ryegrass
[2] Hybrid: Perennial x Italian ryegrass hybrid
[3] Festulolium: Meadow fescue x Italian ryegrass hybrid
[4] Tall Fescue
[5] Diploid
[6] Tetraploid
[7] Hexaploid

4. The production potential of fescue, cocksfoot, perennial ryegrass and *Bromus* spp. over two years

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Introduction

Pastures in the main milk-producing regions of the southern Cape, South Africa, are primarily based on kikuyu, over-sown with annual or perennial ryegrass. Although these pastures can maintain production rates of between 15 and 18 t DM ha^{-1} annum^{-1} (Van der Colf, 2010), both annual and perennial ryegrass display poor persistence and must be re-established by over-sowing ryegrass annually during autumn (Botha *et al.*, 2003; Botha *et al.*, 2008). Tall fescue (*Festuca arundinacea*), cocksfoot (*Dactylis glomerata*) and *Bromus* spp. are alternative temperate perennial grasses that could improve the persistence and stress tolerance (Reed, 1996; Callow *et al.*, 2003; Nie *et al.*, 2008) of the temperate grass component within kikuyu systems. There is, however, limited data available on the production potential and forage quality of the most recent cultivars of these species under irrigation in the southern Cape. The aim of this study was to evaluate the production potential of various cultivars of temperate perennial grasses. The study will be carried out over a period of three years, but only the first two years of data will be presented here.

Materials and Methods

The study was carried out on the Outeniqua Research Farm near George (Altitude 201 m, 33° 58' 38" S, 22° 25' 16" E, rainfall 728 mm year^{-1}) in the Western Cape Province of South Africa on a Witfontein soil form (Soil Classification Workgroup, 1991). The study area is under permanent overhead sprinkler irrigation, with irrigation scheduling undertaken by means of a tensiometer. Irrigation commences at a tensiometer reading of -25 kPa and terminates at a reading of -10 kPa (Botha, 2002).

Prior to establishment, soil samples were taken to a depth of 150 mm and analysed for Ca, Mg, Na, K, P, Cu, Zn, Mn, B, S, and C levels. Fertiliser was applied according to the soil analysis to raise the P level of the soil to 35 mg kg^{-1}, K level to 80 mg kg^{-1} and pH (KCl) to 5.5 (Beyers, 1973).

Species under evaluation include Tall Fescue (*Festuca arundinacea*), Meadow Fescue (*Festuca pratensis*), chewings fescue (*Festuca rubra* subsp. *commutata*), red fescue (*Festuca rubra*), cocksfoot (*Dactylis glomerata*), Perennial ryegrass (*Lolium perenne*) and two Bromus species (*Bromus catharticus* and *B. parodii*). A total of 38 cultivars are being evaluated in the form of a randomised plot design, with three replicates per cultivar. The scientific name, common name, cultivar name and seeding rate of the species under evaluation are given in Table 1.

Table 1. The scientific name, common name, cultivar name and seeding rate (kg ha^{-1}) of species evaluated during the study.

	Scientific name	Common name	Cultivar name	Seeding rate
1	*Festuca arundinacea*	Tall fescue	Kora	20
2	*Festuca arundinacea*	Tall fescue	Tuscany	20
3	*Festuca arundinacea*	Tall fescue	Barlite	20
4	*Festuca arundinacea*	Tall fescue	Verdant	20
5	*Festuca arundinacea*	Tall fescue	Jenna	20

	Scientific name	Common name	Cultivar name	Seeding rate
6	*Festuca arundinacea*	Tall fescue	KR5605	20
7	*Festuca arundinacea*	Tall fescue	GFM24	20
8	*Festuca arundinacea*	Tall fescue	GFM29	20
9	*Festuca arundinacea*	Tall fescue	Bronson forage	20
10	*Festuca arundinacea*	Tall fescue	Baroptima	20
11	*Festuca arundinacea*	Tall fescue	Bariane	20
12	*Festuca arundinacea*	Tall fescue	Barverde	20
13	*Festuca arundinacea*	Tall fescue	Boschoek	20
14	*Festuca arundinacea*	Tall fescue	Advance	20
15	*Festuca pratensis*	Meadow fescue	Laura	20
16	*Festuca pratensis*	Meadow fescue	Jamaica	20
17	*Festuca arundinacea*	Tall fescue (Turf)	Cochise	20
18	*Festuca arundinacea*	Tall fescue (Turf)	Sidewinder	20
19	*Festuca rubra* sub. *commuta*	Chewings fescue	Rushmore	20
20	*Festuca rubra*	Red fescue	Gibralter	20
21	*Dactylis glomerata*	Cocksfoot	Athos	15
22	*Dactylis glomerata*	Cocksfoot	Sparta	15
23	*Dactylis glomerata*	Cocksfoot	Niva	15
24	*Dactylis glomerata*	Cocksfoot	Cristobal	15
25	*Dactylis glomerata*	Cocksfoot	Adremo	15
26	*Dactylis glomerata*	Cocksfoot	Barvillo	15
27	*Dactylis glomerata*	Cocksfoot	Barexcel	15
28	*Dactylis glomerata*	Cocksfoot	Oxen	15
29	*Dactylis glomerata*	Cocksfoot	Hera	15
30	*Dactylis glomerata*	Cocksfoot	Wana	15
31	*Dactylis glomerata*	Cocksfoot	Pizza	15
32	*Lolium perenne*	Perennial ryegrass	Bealy	20
33	*Lolium perenne*	Perennial ryegrass	Trojan	20
34	*Lolium perenne*	Perennial ryegrass	Arrow	20
35	*Lolium perenne*	Perennial ryegrass	Bronsyn	20
36	*Lolium perenne*	Perennial ryegrass	Remington	20
37	*Bromus catharticus*		Ceres Atom	20
38	*Bromus parodii*		GBP02	20

The trial was established on 5 May 2011 on a paddock previously planted to perennial ryegrass-clover pastures. The paddock was sprayed with herbicide during January and tilled during February to remove existing sward. Three subsequent herbicide applications (up to establishment) were aimed at eradication of emerging weeds. Prior to establishment, the trial area was tilled with a disk harrow and kongskilde and rolled with a light land roller to create a firm seedbed and eradicate any remaining weeds. The various cultivars/species were planted according to commercially recommended seeding rates, adapted for germination percentages. Plots were 2,1 m x 6 m per treatment (12,6 m^2), with 14 rows, at 15 cm intervals. After establishment plots were raked lightly to cover seeds.

Plots were harvested every 28 days – quadrats were used to determine growth rate (kg DM ha^{-1} day-1) and total dry matter production (kg DM ha^{-1}). Three quadrats of 0,25 m^2 were randomly placed per plot and cut to a height of 50 mm above ground level. The samples were pooled and weighed.

A grab sample of approximately 500 g green material was taken from the pooled sample, weighed wet and dry to determine DM content. Samples were dried at 60°C for 72 hours to determine dry weight. Afterwards sampling plots were cut to a uniform height of 50 mm using a Honda Lawnmower. All plots received a top-dressing of 50 kg N ha^{-1} and 20 kg K ha^{-1} after each harvest (ARC, 2005).

A Student least significant difference (LSD) at 5% significance level was performed to compare the treatment means (Ott, 1998). The STATS module of SAS version 9.2 (2008) was used to analyse the data. Data was also combined within species to compare the production potential of the various species and analysed within species to compare the production potential of different cultivars within the species Cocksfoot and Fescue.

Results and discussion

Species compared

The mean monthly growth rate of perennial ryegrass, fescue, cocksfoot and *Bromus* during year 1 and year 2 is given in Table 2 and Table 3. *Bromus catharticus* had the highest (P<0.05), or similar (P>0.05) to the highest, growth rate during all months except April and May during year 1. From June to February in year 2, *Bromus catharticus* had the highest (P<0.05), or similar (P>0.05) to the highest, growth rate during all months, except November.

Since perennial ryegrass is the most widely-used temperate perennial grass species in the southern Cape, it was used as a reference species. *Bromus catharticus* had a similar (P>0.05), or higher (P<0.05), growth rate than perennial ryegrass during all months, in both year 1 and year 2. From September onwards during year 1, tall fescue, meadow fescue, cocksfoot and *Bromus parodii* had a growth rate that was similar (P>0.05) to, or higher (P<0.05) than that of perennial ryegrass. Tall fescue had a higher (P<0.05), or similar (P>0.05), growth rate to perennial ryegrass during all months in year 2, except July, when it was lower. Meadow fescue, red fescue, cocksfoot and both *Bromus* spp. had a similar (P>0.05), or higher (P<0.05) growth rate than perennial ryegrass during all months in year 2.

The total seasonal and annual dry matter (DM) production of perennial ryegrass, fescue, cocksfoot and *Bromus* during year 1 and year 2 are given in Table 4 and Table 5. *Bromus catharticus* had the highest (P<0.05), or similar (P>0.05) to the highest, seasonal DM production during all seasons in year 1, and from winter to summer in year 2. *Bromus catharticus* and *Bromus parodii* were the only species that had the highest (P<0.05), or similar (P>0.05) to the highest, total annual DM production during both years.

From spring to autumn during year 1, the seasonal DM production of the *Bromus* spp., Tall fescue and cocksfoot was similar (P>0.05) to, or higher (P<0.05) than that of perennial ryegrass. Perennial ryegrass had a similar (P>0.05) total annual DM production to Tall Fescue and Cocksfoot, but lower than both *Bromus* species during year 1. During year 2, the seasonal dry matter production of Meadow Fescue, Red Fescue and Cocksfoot, was similar (P>0.05) to perennial ryegrass during all seasons. Tall Fescue had a higher (P<0.05) seasonal production than perennial ryegrass during summer and autumn, but similar (P>0.05) during winter and spring. *Bromus parodii* had a similar (P>0.05) seasonal DM production to perennial ryegrass during all seasons, except summer, when it was higher (P<0.05) for *Bromus*. From winter to summer, the seasonal DM production of *Bromus catharticus* was higher (P<0.05) than that of perennial ryegrass. The total annual dry matter production of perennial ryegrass was similar (P>0.05) to that of Meadow Fescue, Red Fescue and Turf Tall Fescue, but lower (P<0.05) than for Tall Fescue, Cocksfoot and both *Bromus* species.

Bromus catharticus was the only species that could maintain a high production throughout all seasons and that had a higher (P<0.05) annual DM production than perennial ryegrass during both years. Cocksfoot and Tall Fescue had the potential to have a similar (P>0.05) total annual yield to perennial ryegrass during year 1, and a higher (P<0.05) yield during year 2. The seasonal distribution of dry matter production of the species should be noted. *Bromus catharticus* was the only species that had a high dry matter production during winter in both years. From spring to autumn various species had the potential to out-yield perennial ryegrass.

Fescue cultivars compared

The mean monthly growth rate of fescue cultivars during year 1 is shown in Table 6. The highest growth rate was obtained by different cultivars during different months. Verdant was the only cultivar that had the highest (P<0.05), or similar (P>0.05) to the highest, growth rate during all months from July to November. However, during December, February, April and May, the growth rate of Verdant was lower (P<0.05) than the highest growth rate. The cultivars Tuscany and Bariane, maintained the highest (P<0.05,) or similar (P>0.05) to the highest, growth rate from October to May.

The mean monthly growth rate of fescue cultivars during year 2 is shown in Table 7. The highest growth rate was obtained by different cultivars during different months. The cultivars KR6505, GFM24 and Barverde, were the only cultivars that maintained the highest (P<0.05), or similar (P>0.05) to the highest, growth rate during the winter months June to August. From November (late spring) to May (autumn), the cultivars Tuscany, Verdant, Jenna, Baroptima and Boschoek had the highest (P<0.05), or similar (P>0.05) to the highest, growth rate throughout the period.

The total seasonal and annual DM production of Fescue cultivars during year 1 is given in Table 8. Verdant had the highest (P<0.05) seasonal production in winter. The cultivars Tuscany, Barlite, Jenna, KR6506, Bronson Forage, Baropitima and Bariane had the highest (P<0.05), or similar (P>0.05) to the highest, seasonal DM production during all seasons from spring to autumn. Bariane had the highest (P<0.05) annual DM production, with similar (P>0.05) productions from Kora, Tuscany, Barlite, Verdant, Jenna, KR6506, Bronson Forage, Baroptima, Boschoek and Advance.

The total seasonal and annual DM production of Fescue cultivars during year 2 is given in Table 9. The winter production of KR6505, GFM24 and Barverde was higher (P<0.05) than all other Fescue cultivars. Tuscany, Verdant, Jenna and Boschoek had the highest (P<0.05), or similar (P>0.05) to the highest, seasonal DM production throughout all seasons from spring to autumn. The total annual DM production of Jenna was similar (P>0.05) to that of Tuscany, Barlite, Verdant, Barverde and Boschoek, but higher (P<0.05) than the rest.

The Tall Fescue cultivars Tuscany Barlite, Verdant, Jenna, Baroptima and Boschoek were the only cultivars that had the highest or similar (P>0.05) dry matter production during both years. All these cultivars had two or more seasons in which seasonal DM production was the highest (P<0.05), or similar (P>0.05) to the highest, specifically between spring and autumn. A limited number of cultivars maintained a high production during the winter/early spring period from June to September.

Cocksfoot cultivars compared

The mean monthly growth rate of cocksfoot cultivars during year 1 and year 2 is shown in Table 10 and Table 11 respectively. The highest (P<0.05) growth rate was obtained by different cultivars during different months.

The total seasonal and annual DM production of cocksfoot cultivars during year 1 and year 2 is given in Table 12 and 13 respectively. Athos, Cristobal and Oxen had the highest (P<0.05), or similar (P>0.05) to the highest, seasonal DM production during all seasons of year 1. During year 2 Athos was the only cultivar that had the highest (P<0.05), or similar (P>0.05) to the highest, seasonal DM production during all seasons. The cultivars Cristobal and Adremo had the highest (P<0.05) total annual DM production during year 1, with similar (P>0.05) production achieved by Athos, Barvillo and Oxen. During year 2, the total annual DM production of Athos, Adremo and Barvillo was higher (P<0.05) than for Barexcel, but similar (P>0.05) to all other cultivars.

The cultivars Athos, Cristobal, Adremo, Barvillo and Oxen had the highest (P<0.05,) or similar (P>0.05) to the highest, total annual DM production during both years.

All cultivars compared

The monthly growth rate of temperate perennial grasses during year 1 is shown in Table 14. The perennial ryegrass cultivars Trojan, Arrow and Bronsyn, as well as the *Bromus* cultivar Ceres Atom, were the only cultivars that maintained the highest (P<0.05), or similar (P>0.05) to the highest, growth rate throughout the months from July to October. From October to March, however, the monthly growth rate of all these perennial ryegrass cultivars was lower (P<0.05) than the highest growth rate. The Tall Fescue cultivar Bariane was the only cultivar that maintained the highest (P<0.05), or similar (P>0.05) to the highest, growth rate from January to May.

The monthly growth rate of temperate perennial grasses during year 2 is shown in Table 15. The Tall Fescue cultivars KR6505 and GFM24 and *Bromus* cultivar Ceres Atom were the only cultivars that had the highest (P<0.05), or similar (P>0.05) to the highest, growth rate from June to September (winter/early spring). From November to May (late spring/autumn,) the Tall Fescue cultivars Tuscany, Verdant, Jenna, Baroptima and Boschoek had the highest, or similar (P>0.05) to the highest (P<0.05), growth rate throughout all months.

The total seasonal and annual DM production of temperate perennial grass cultivars during year 1 is shown in Table 16. There was no single cultivar that achieved the highest (P<0.05) seasonal DM during all seasons. The perennial ryegrass cultivars Trojan, Arrow and Bronsyn, and Fescue cultivar Verdant, had the highest (P<0.05), or similar (P>0.05) to the highest, DM production during winter and spring, but their DM production was lower (P<0.05) than the highest producing cultivar during summer and autumn. The *Bromus* cultivar Ceres Atom had the highest (P<0.05), or similar (P>0.05) to the highest, seasonal DM production during all seasons from winter to summer. The highest (P<0.05) annual DM production was from the *Bromus* cultivar Ceres Atom, with similar (P>0.05) production achieved by the *Bromus* cultivar GBP02 and the Cocksfoot cultivar Cristobal. Various Fescue and Cocksfoot cultivars had a total annual DM production (P>0.05) similar to the highest yielding perennial ryegrass cultivar.

The total seasonal and annual DM production of temperate perennial grass cultivars during year 2 is shown in Table 17. During year 2, the Tall Fescue cultivars KR6505, GFM24 and Braverde and the *Bromus* cultivar Ceres Atom had the highest (P<0.05), or similar (P>0.05) to the highest, seasonal DM production from winter to spring. The Tall Fescue cultivars Tuscany, Verdant, Jenna and Boschoek had the highest (P<0.05), or similar (P>0.05) to the highest, seasonal DM production from spring to autumn. The Fescue cultivar Jenna had a similar (P>0.05) total annual DM production to the Fescue cultivars Tuscany, Barlite, Verdant, Barverde and Boschoek, and the Cocksfoot cultivars Athos, Adremo and Barvillo, but higher (P<0.05) than the rest.

The total annual dry matter production during year 1 and year 2, total yield over two years and % reduction in yield from year 1 to year 2 of perennial grass cultivars, are shown in Table 18. No cultivar achieved the highest total annual dry matter production during both years. All cultivars showed a decline in production from year 1 to year 2, with the exception of the Turf Tall Fescue Sidewinder. The *Bromus* and four of the five perennial ryegrass cultivars showed a decline in annual production higher than 35%. The Tall Fescue cultivar Jenna and *Bromus* cultivar Ceres Atom had a DM yield of more than 30 t ha-1 over the two years, while Jenna showed a decline of only 8% from year 1 to year 2.

Conclusions

1. *Bromus* as a species, and the two *Bromus* cultivars, Ceres Atom and GBP02, were highly productive during year 1. However, during year 2, the total annual DM production of the two *Bromus* cultivars was lower than the highest producing cultivars.
2. Aside from the Fescue cultivar Verdant, all Cocksfoot and Fescue cultivars were slow to establish and had lower productions than highest producing perennial ryegrass cultivars during the winter of year 1.
3. From spring in year 1 onwards, various Cocksfoot and Fescue cultivars had similar or higher production than the highest producing perennial ryegrass cultivars.
4. The seasonal spread in production varied for different cultivars, with some having higher winter/spring production and others higher spring to autumn production.
5. Various Tall Fescue and Cocksfoot cultivars have the potential of a similar yield to perennial ryegrass during year 1 and out-yield it during year 2.

MESSAGE TO THE FARMER

- Temperate perennial grasses are available for use in pastures, as an alternative to perennial ryegrass.
- Although some species, such as Cocksfoot and Tall Fescue, are slower to establish than perennial ryegrass, they can be as productive as ryegrass from spring in the first year onwards.
- *Bromus catharticus* cv. Ceres Atom, has a high yield in year 1, but not year 2, compared to other temperate perennial grass cultivars.
- The recommended Fescue cultivars, based on production over two years, are Tuscany, Barlite, Verdant, Jenna, Baroptima and Boschoek.
- The recommended Cocksfoot cultivars, based on production over two years, are Athos, Cristobal, Adremo, Barvillo and Oxen.
- The decision on which cultivar/species to include in a fodder-flow programme, should be based on the seasonal dry matter production and persistence of the species, and the role it can play in the fodder-flow programme.

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Table 2. Mean monthly growth rate (kg DM ha^{-1} day^{-1}) of perennial ryegrass, Fescue, Cocksfoot and *Bromus* during year 1.

Species	July*	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Perennial ryegrass	4.62^{a}	24.9^{a}	62.8^{ab}	113^{ab}	80.3^{abc}	56.3^{c}	48.4^{cde}	34.9^{bc}	38.1^{bc}	49.3^{ab}	27.9^{b}
Tall Fescue	1.71^{b}	12.1^{b}	47.0^{b}	106^{ab}	72.5^{bc}	57.0^{c}	63.1^{abc}	39.0^{abc}	50.1^{a}	51.6^{a}	29.6^{b}
Meadow fescue	1.29^{b}	10.8^{bc}	46.1^{b}	95.0^{b}	68.8^{cd}	55.7^{c}	55.0^{bcd}	35.1^{bc}	35.5^{c}	49.9^{a}	25.7^{b}
Tall Fescue turf	0.39^{b}	1.73^{d}	16.6^{c}	58.0^{c}	37.6^{e}	29.5^{d}	32.0^{f}	30.7^{c}	31.7^{cd}	36.9^{cd}	24.4^{b}
Chewings Fescue	-	3.64^{bcd}	7.22^{c}	50.6^{c}	54.7^{d}	52.7^{c}	37.8^{ef}	33.4^{bc}	23.0^{d}	34.0^{d}	28.7^{b}
Red Fescue	-	2.19^{cd}	8.18^{c}	51.9^{c}	73.1^{bc}	55.5^{c}	43.2^{def}	47.3^{a}	37.3^{bc}	46.5^{abc}	38.8^{a}
Cocksfoot	0.86^{b}	9.68^{bcd}	46.7^{b}	107^{ab}	81.7^{abc}	78.0^{b}	53.3^{bcde}	34.3^{bc}	46.6^{ab}	44.5^{abc}	23.3^{b}
Bromus parodii	1.80^{b}	12.2^{b}	68.0^{a}	116^{ab}	90.6^{a}	96.5^{a}	72.6^{a}	41.9^{ab}	50.1^{a}	42.1^{abcd}	24.2^{b}
Bromus catharticus	5.17^{a}	32.0^{a}	77.2^{a}	121^{a}	87.8^{ab}	110^{a}	65.3^{ab}	40.0^{ab}	53.1^{a}	39.1^{bcd}	29.2^{b}
	1.953	9.006	18.308	23.122	16.424	15.324	15.891	9.0274	10.083	10.261	8.2469

LSD (0.05) compares over species within months.
abc Means with no common superscript, differ significantly.
*Growth rate from establishment to first harvest

Table 3. Mean monthly growth rate (kg DM ha^{-1} day^{-1}) of perennial ryegrass, Fescue, Cocksfoot and *Bromus* during year 2.

Species	Jun	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Perennial ryegrass	15.4^{a}	19.2^{bc}	14.2^{bc}	26.8^{ab}	44.7^{bc}	47.9^{abc}	36.3^{abc}	30.3^{cd}	25.6^{c}	24.5^{cd}	25.5^{cd}	20.8^{ab}
Tall Fescue	14.4^{ab}	8.22^{d}	13.9^{bc}	30.0^{ab}	52.4^{b}	55.0^{ab}	46.9^{a}	45.9^{a}	40.4^{ab}	47.1^{a}	40.5^{a}	26.8^{a}
Meadow fescue	13.8^{ab}	18.4^{c}	7.21^{cd}	20.2^{b}	39.9^{bc}	43.1^{c}	33.2^{bc}	31.6^{bcd}	33.2^{abc}	33.5^{bc}	26.1^{bcd}	19.1^{b}
Tall Fescue turf	7.61^{b}	17.2^{c}	5.74^{d}	19.3^{b}	35.6^{bc}	49.9^{ab}	30.6^{c}	33.8^{abcd}	28.9^{bc}	34.4^{abc}	32.01^{abc}	18.4^{b}
Chewings Fescue	16.8^{a}	15.2^{cd}	7.37^{cd}	21.8^{b}	44.2^{bc}	31.3^{c}	39.5^{ab}	24.8^{d}	24.2^{c}	11.6^{d}	20.3^{d}	9.85^{c}
Red Fescue	18.6^{a}	22.2^{ab}	11.9^{cd}	21.2^{b}	30.8^{c}	55.3^{ab}	42.8^{abc}	37.9^{abc}	38.4^{abc}	27.6^{c}	34.4^{ab}	18.2^{b}
Cocksfoot	13.4^{ab}	17.4^{c}	10.7^{cd}	23.7^{b}	54.9^{b}	62.8^{a}	44.6^{ab}	39.8^{abc}	44.4^{a}	37.6^{abc}	31.4^{bc}	18.6^{b}
Bromus parodii	17.5^{a}	27.8^{ab}	21.3^{ab}	28.3^{ab}	38.7^{bc}	38.2^{bc}	47.4^{a}	44.2^{ab}	43.0^{ab}	46.6^{ab}	21.2^{d}	16.6^{b}
Bromus catharticus	19.9^{a}	29.8^{a}	24.6^{a}	36.3^{a}	91.3^{a}	41.0^{bc}	38.9^{abc}	41.1^{abc}	32.8^{abc}	26.4^{c}	22.6^{d}	16.6^{b}
	7.0198	8.9479	8.1063	11.892	21.242	18.406	12.668	12.664	14.767	13.135	8.6749	6.7352

LSD (0.05) compares over species within months.
abc Means with no common superscript, differ significantly.

Table 4. Total seasonal and annual dry matter production (kg DM ha^{-1}) of perennial ryegrass, fescue, cocksfoot and *Bromus* during year 1.

	Winter	Spring	Summer	Autumn	Annual
Perennial ryegrass	1193^{a}	7498^{ab}	4030^{bc}	3195^{ab}	15916^{b}
Tall Fescue	522^{bc}	6616^{bc}	4565^{b}	3651^{a}	15354^{bc}
Meadow fescue	440^{bcd}	6176^{c}	4196^{bc}	3072^{bc}	13883^{c}
Tall Fescue turf	62.3^{d}	3313^{d}	2640^{d}	2585^{cd}	8600^{e}
Chewings Fescue	102^{cd}	3353^{d}	3588^{c}	2383^{d}	9426^{e}
Red Fescue	61.5^{d}	4086^{d}	4211^{bc}	3415^{ab}	11774^{d}
Cocksfoot	363^{bcd}	6949^{bc}	4817^{b}	3184^{ab}	15313^{bc}
Bromus parodii	534^{b}	8083^{a}	6126^{a}	3247^{ab}	18000^{a}
Bromus catharticus	1449^{a}	8356^{a}	6289^{a}	3404^{ab}	19497^{a}
LSD (0.05)	423.34	1118	802	524.7	1944

LSD (0.05) compares within season and over species.
^{abc} Means with no common superscript, differ significantly.

Table 5. Total seasonal and annual dry matter production (kg DM ha^{-1}) of perennial ryegrass, fescue, cocksfoot and *Bromus* during year 2.

	Winter	Spring	Summer	Autumn	Annual
Perennial ryegrass	1463^{bc}	3578^{bcd}	2642^{c}	2005^{b}	9688^{c}
Tall Fescue	1372^{c}	4121^{abc}	3820^{a}	3247^{a}	12561^{a}
Meadow fescue	1148^{cd}	3103^{cd}	2807^{bc}	2238^{b}	9296^{cd}
Tall Fescue turf	642^{d}	3168^{bcd}	2681^{c}	2412^{b}	8903^{cd}
Chewings Fescue	1144^{cd}	2893^{d}	2529^{c}	1179^{c}	7745^{d}
Red Fescue	1552^{bc}	3255^{bcd}	3410^{abc}	2272^{b}	10489^{bc}
Cocksfoot	1236^{cd}	4267^{ab}	3686^{ab}	2491^{b}	11678^{ab}
Bromus parodii	2020^{ab}	3137^{cd}	3859^{a}	2412^{b}	11428^{ab}
Bromus catharticus	2257^{a}	4978^{a}	3244^{abc}	1864^{b}	12342^{a}
LSD (0.05)	595	1121	960	667	1706

LSD (0.05) compares within season and over species.
^{abc} Means with no common superscript, differ significantly.

Table 6. Mean monthly growth rate (kg DM ha^{-1} day^{-1}) of Fescue cultivars during year 1.

Species	Cultivar	July*	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
TF	Kora	1.75^{bc}	10.9^{bcde}	48.8^{bcd}	99.6^{ab}	79.8^{abc}	57.9^{abc}	64.9^{ab}	35.6^{cde}	45.1^{bcde}	48.0^{b}	26.0^{b}
TF	Tuscany	0.74^{bc}	6.44^{def}	40.2^{bcd}	111^{ab}	75.8^{abcd}	60.4^{abc}	70.7^{a}	49.8^{ab}	51.8^{ab}	52.3^{ab}	30.3^{ab}
TF	Barlite	0.80^{bc}	6.98^{def}	28.9^{de}	115^{ab}	73.9^{abcdef}	60.4^{abc}	74.3^{a}	43.0^{abcd}	49.5^{abc}	53.9^{ab}	27.3^{b}
TF	Verdant	5.27^{a}	25.5^{a}	71.1^{a}	102^{ab}	76.1^{abcd}	46.6^{bcde}	66.7^{a}	30.1^{e}	53.6^{ab}	46.2^{bcd}	26.0^{b}
TF	Jenna	2.02^{bc}	19.0^{ab}	57.5^{ab}	116^{ab}	81.1^{ab}	44.5^{cde}	74.8^{a}	34.2^{de}	52.8^{ab}	51.9^{ab}	30.9^{ab}
TF	KR6505	2.09^{bc}	18.0^{abc}	52.7^{abc}	107^{ab}	58.8^{defg}	72.6^{a}	62.4^{abc}	37.8^{bcde}	57.2^{ab}	60.0^{a}	31.0^{ab}
TF	GFM24	2.34^{b}	10.4^{bcdef}	43.4^{bcd}	102^{ab}	61.3^{cdef}	60.8^{abc}	40.9^{cdef}	30.3^{e}	35.8^{def}	48.0^{b}	32.6^{ab}
TF	GFM29	0.97^{bc}	9.87^{bcdef}	41.7^{bcd}	102^{ab}	62.3^{bcdef}	58.4^{abc}	58.3^{abcd}	38.9^{bcde}	46.0^{abcd}	47.9^{a}	25.9^{b}
TF	Bronson forage	1.21^{bc}	8.39^{def}	45.4^{bcd}	95.6^{ab}	76.5^{abcd}	58.3^{abc}	70.4^{a}	41.2^{bcde}	49.5^{abc}	50.4^{ab}	30.9^{ab}
TF	Baroptima	1.35^{bc}	11.5^{bcde}	44.7^{bcd}	122^{a}	74.6^{abcde}	65.9^{ab}	60.4^{abc}	41.0^{bcde}	56.7^{ab}	54.8^{ab}	33.2^{ab}
TF	Bariane	1.26^{bc}	10.1^{bcdef}	46.7^{bcd}	116^{ab}	83.9^{a}	62.5^{abc}	66.3^{a}	53.4^{a}	58.6^{a}	55.9^{ab}	34.9^{ab}
TF	Barverde	1.41^{bc}	8.95^{cdef}	34.9^{cde}	90.0^{bc}	56.1^{efg}	45.9^{bcde}	55.8^{abcd}	32.5^{de}	44.6^{bcde}	54.3^{ab}	28.5^{ab}
TF	Boschoek	1.28^{bc}	9.67^{cdef}	45.1^{bcd}	105^{ab}	82.4^{a}	47.9^{bcd}	57.6^{abcd}	37.1^{cde}	51.1^{ab}	51.5^{ab}	28.1^{b}
TF	Advance	1.53^{bc}	13.4^{bcd}	56.7^{ab}	95.9^{ab}	72.0^{abcdef}	56.6^{abc}	60.3^{abc}	41.5^{abcde}	48.7^{abc}	47.2^{bc}	28.5^{ab}
MF	Laura	1.11^{bc}	8.53^{def}	43.2^{bcd}	91.1^{bc}	62.3^{cdef}	51.3^{bcd}	55.9^{abcd}	36.0^{cde}	32.9^{efg}	46.2^{bcd}	26.1^{b}
MF	Jamaica	1.47^{bc}	13.0^{bcd}	48.9^{bc}	98.9^{ab}	75.4^{abcde}	60.2^{abc}	54.1^{abcde}	34.2^{de}	38.1^{cdef}	53.7^{ab}	25.3^{bc}
TFT	Cochise	0.28^{c}	2.17^{ef}	16.2^{ef}	67.3^{cd}	39.7^{gh}	32.7^{de}	30.3^{f}	31.8^{de}	37.8^{cdef}	37.2^{cde}	33.7^{ab}
TFT	Sidewinder	-	1.28^{f}	17.1^{ef}	48.7^{d}	35.6^{h}	26.3^{e}	33.8^{ef}	29.6^{e}	25.6^{fg}	36.6^{de}	15.2^{c}
CF	Rushmore	-	3.64^{ef}	8.18^{f}	50.6^{d}	54.7^{fgh}	52.7^{abcd}	37.8^{def}	33.4^{de}	23.0^{g}	34.0^{e}	28.7^{ab}
RF	Gibraltar	-	2.19^{ef}	7.22^{f}	51.9^{d}	73.1^{abcdef}	55.5^{abc}	43.2^{bcdef}	47.3^{abc}	37.3^{cdef}	46.5^{bcd}	38.8^{a}
LSD (0.05)		1.878	9.350	19.85	28.27	19.59	20.36	21.80	12.02	12.69	10.3	10.66

LSD (0.05) compares within month and over cultivars.
^{abc} Means with no common superscript, differ significantly.
*Growth rate from establishment to first harvest

Table 7. Mean monthly growth rate (kg DM ha^{-1} day^{-1}) of Fescue cultivars during year 2.

Species	Cultivar	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
TF	Kora	9.64^{efgh}	12.8^{ghij}	9.84^{cde}	21.5^{defg}	46.1^{bcd}	59.1^{abc}	49.0^{abcd}	51.2^{abc}	39.5^{abcdef}	49.3^{cd}	34.4^{defgh}	20.3^{def}
TF	Tuscany	9.39^{fgh}	11.6^{ghij}	6.77^{de}	30.2^{abcdef}	61.2^{abc}	68.0^{a}	61.7^{a}	59.3^{a}	51.3^{ab}	54.2^{abc}	42.3^{abcde}	26.0^{abcd}
TF	Barlite	15.6^{abcdefg}	16.6^{cdefg}	8.05^{de}	18.4^{efg}	59.0^{abc}	64.8^{a}	48.3^{abcde}	45.9^{abcd}	49.5^{ab}	49.9^{bcd}	42.9^{abcde}	25.7^{abcde}
TF	Verdant	13.2^{bcdefgh}	15.6^{cdefgh}	7.66^{de}	34.3^{abcd}	57.6^{abc}	60.3^{abc}	52.0^{abcd}	51.7^{abc}	45.1^{abcd}	56.1^{abc}	43.7^{abcd}	28.3^{abc}
TF	Jenna	11.1^{defgh}	13.9^{efghi}	14.9^{bcd}	34.6^{abcd}	70.6^{a}	59.4^{abc}	59.3^{a}	58.8^{a}	52.5^{a}	62.7^{a}	45.7^{abc}	32.3^{a}
TF	KR6505	20.4^{ab}	29.8^{a}	25.9^{a}	43.0^{a}	43.0^{bcd}	46.7^{abcde}	33.4^{ef}	31.1^{de}	34.0^{bcdefg}	47.0^{cde}	38.9^{bcdef}	30.5^{ab}
TF	GFM24	21.7^{a}	29.7^{a}	30.5^{a}	41.7^{ab}	56.4^{abc}	40.1^{bcde}	37.0^{def}	24.8^{e}	16.7^{gh}	23.8^{h}	26.2^{hij}	24.0^{bcde}
TF	GFM29	14.9^{abcdefg}	19.7^{cdef}	17.1^{bc}	32.9^{abcde}	56.6^{abc}	47.5^{abcde}	33.3^{ef}	31.5^{de}	11.5^{h}	27.5^{gh}	27.5^{ghij}	18.3^{ef}
TF	Bronson forage	9.12^{gh}	9.22^{hij}	10.9^{cde}	27.2^{bcdefg}	60.3^{abc}	54.9^{abcd}	39.7^{cdef}	44.5^{abcd}	47.0^{abc}	48.3^{cde}	40.6^{abcdef}	29.3^{abc}
TF	Baroptima	13.0^{bcdefgh}	8.24^{ij}	8.49^{cde}	16.5^{fg}	42.6^{bcd}	55.3^{abcd}	52.7^{abc}	50.4^{abc}	47.7^{abc}	54.6^{abc}	49.8^{a}	29.0^{abc}
TF	Bariane	17.5^{abcde}	10.5^{ghij}	5.02^{e}	14.3^{g}	31.4^{d}	40.0^{bcde}	43.7^{bcdef}	55.0^{ab}	51.5^{ab}	50.0^{bcd}	44.9^{abcd}	24.0^{bcde}
TF	Barverde	19.7^{abc}	28.4^{ab}	22.0^{ab}	41.13^{ab}	63.1^{ab}	62.4^{ab}	40.4^{cdef}	40.3^{bcd}	25.7^{efgh}	25.7^{h}	37.6^{cdefg}	29.0^{abc}
TF	Boschoek	11.9^{cdefgh}	12.9^{fghij}	14.6^{bcd}	39.2^{abc}	41.0^{bcd}	60.8^{abc}	56.9^{ab}	54.3^{ab}	50.8^{ab}	60.4^{ab}	49.4^{ab}	31.0^{ab}
TF	Advance	14.5^{abcdefg}	22.0^{bcd}	13.0^{cde}	25.2^{cdefg}	44.0^{bcd}	52.0^{abcde}	48.7^{abcde}	43.1^{bcd}	43.4^{abcde}	49.7^{bcd}	42.6^{abcde}	27.3^{abcd}
MF	Laura	10.5^{efgh}	16.9^{cdefg}	9.06^{cde}	25.7^{cdefg}	48.3^{abcd}	47.4^{abcde}	37.1^{def}	32.4^{de}	39.8^{abcdef}	41.4^{def}	30.7^{fghij}	22.3^{cdef}
MF	Jamaica	17.1^{abcdef}	20.0^{cde}	5.35^{e}	14.6^{g}	31.6^{d}	38.9^{cde}	29.3^{f}	30.7^{de}	26.5^{efgh}	25.6^{h}	21.4^{ij}	15.7^{fg}
TFT	Cochise	9.73^{efgh}	6.74^{j}	6.36^{de}	21.4^{defg}	32.8^{d}	35.2^{de}	28.3^{f}	34.4^{de}	30.2^{cdefg}	31.1^{fgh}	32.7^{efgh}	16.3^{fg}
TFT	Sidewinder	5.49^{h}	9.7^{hij}	5.11^{e}	17.3^{fg}	38.3^{cd}	64.6^{a}	32.8^{f}	33.3^{de}	27.6^{defgh}	37.7^{efg}	31.4^{fghi}	20.7^{def}
CF	Rushmore	16.8^{abcdefg}	15.2^{defgh}	7.37^{de}	21.8^{defg}	44.2^{bcd}	31.3^{e}	39.5^{cdef}	24.8^{e}	24.2^{fgh}	11.6^{i}	20.3^{j}	9.85^{g}
RF	Gibraltar	18.6^{abcd}	22.2^{bc}	11.9^{cde}	21.2^{defg}	30.8^{d}	55.3^{abcd}	42.8^{bcdef}	37.9^{cde}	38.4^{abcdef}	27.6^{gh}	34.4^{defgh}	18.3^{ef}
LSD (0.05)		7.969	6.884	8.698	15.30	23.47	23.26	15.43	15.19	17.87	10.83	10.59	7.437

LSD (0.05) compares within month and over cultivars

^{abc} Means with no common superscript, differ significantly.

TF: Tall Fescue; MF: Meadow Fescue; TFT: Tall Fescue Turf; CF: Chewings Fescue; RF: Red Fescue

Table 8. Total seasonal and annual dry matter (kg DM ha^{-1}) production of Fescue cultivars during year 1.

Species	Cultivar	Winter	Spring	Summer	Autumn	Annual
TF	Kora	490^{bcde}	6738^{abc}	4546^{abcd}	3309^{cde}	15082^{abcd}
TF	Tuscany	260^{def}	6697^{abc}	5175^{a}	3742^{abc}	15874^{abc}
TF	Barlite	281^{def}	6432^{abcd}	5080^{ab}	3627^{abc}	15419^{abc}
TF	Verdant	1277^{a}	7280^{ab}	4087^{bcd}	3507^{bcd}	16150^{ab}
TF	Jenna	749^{b}	7465^{a}	4356^{abcd}	3775^{abc}	16345^{ab}
TF	KR6505	727^{bc}	6353^{abcd}	4993^{ab}	4118^{a}	16190^{ab}
TF	GFM24	543^{bcd}	6063^{bcd}	3837^{cd}	3231^{cde}	13674^{cde}
TF	GFM29	380^{bcdef}	6032^{bcd}	4475^{abcd}	3330^{cde}	14217^{bcd}
TF	Bronson forage	364^{bcdef}	6429^{abcd}	4863^{abc}	3642^{abc}	15297^{abcd}
TF	Baroptima	467^{bcde}	7083^{abc}	4821^{abc}	4030^{ab}	16401^{ab}
TF	Bariane	417^{bcdef}	7270^{ab}	5223^{a}	4163^{a}	17073^{a}
TF	Barverde	402^{bcdef}	5315^{de}	3838^{cd}	3531^{bcd}	13086^{de}
TF	Boschoek	407^{bcdef}	6880^{abc}	4081^{bcd}	3643^{abc}	15003^{abcd}
TF	Advance	539^{bcd}	6590^{abcd}	4543^{abcd}	3467^{cde}	15138^{abcd}
MF	Laura	357^{cdef}	5773^{cd}	4108^{bcd}	2909^{ef}	13148^{de}
MF	Jamaica	522^{bcd}	6579^{abcd}	4284^{abcd}	3233^{cde}	14619^{bcd}
TFT	Cochise	70.9^{f}	3629^{f}	2723^{e}	3039^{de}	9461^{f}
TFT	Sidewinder	35.9^{f}	2998^{f}	2557^{e}	2123^{g}	7723^{f}
CF	Rushmore	102^{ef}	3353^{f}	3588^{de}	2383^{fg}	9462^{f}
RF	Gibraltar	61.5f	4086^{ef}	4211^{abcd}	3415^{cde}	11774^{e}
		389.1	1367	1046	562.2	2254

LSD (0.05) compares within season and over cultivars.
^{abc} Means with no common superscript, differ significantly.
TF: Tall Fescue; MF: Meadow Fescue; TFT: Tall Fescue Turf; CF: Chewings Fescue; RF: Red Fescue

Table 9. Total seasonal and annual dry matter (kg DM ha^{-1}) production of Fescue cultivars during year 2.

Species	Cultivar	Winter	Spring	Summer	Autumn	Annual
TF	Kora	974^{def}	$3831^{abcdefgh}$	4013^{abcdef}	2957^{cd}	11775^{bcdef}
TF	Tuscany	821^{def}	4795^{abc}	4945^{a}	3479^{abc}	14040^{ab}
TF	Barlite	1175^{bcd}	4302^{abcde}	4118^{abcde}	3366^{bc}	12961^{abcd}
TF	Verdant	1071^{cdef}	4561^{abcd}	4270^{abcd}	3635^{ab}	13537^{abc}
TF	Jenna	1226^{bcd}	4916^{ab}	4894^{ab}	3998^{a}	15035^{a}
TF	KR6505	2320^{a}	$3945^{abcdefg}$	2819^{ghi}	3307^{bc}	12390^{bcde}
TF	GFM24	2514^{a}	4087^{abcdef}	2249^{i}	2091^{fg}	10940^{cdef}
TF	Cochise	681^{ef}	2676^{gh}	2672^{hi}	2268^{efg}	8297^{gh}
TF	Sidewinder	604^{f}	$3659^{bcdefgh}$	2691^{hi}	2555^{def}	9509^{fgh}
TF	GFM29	1572^{b}	4083^{abcdef}	2202^{i}	2083^{fg}	9941^{efgh}
TF	Bronson forage	896^{def}	4265^{abcde}	3764^{cdefg}	3363^{bc}	12288^{bcde}
TF	Baroptima	888^{def}	3469^{defgh}	4322^{abcd}	3789^{ab}	12468^{abcde}
TF	Bariane	949^{def}	2589^{h}	4317^{abcd}	3386^{bc}	11241^{cdef}
TF	Barverde	2117^{a}	4979^{a}	3059^{fghi}	2616^{def}	12772^{abcd}
TF	Boschoek	1208^{bcd}	4229^{abcde}	4644^{abc}	3995^{a}	14075^{ab}
TF	Advance	1475^{bc}	$3648^{bcdefgh}$	3870^{bcdef}	3401^{bc}	12394^{bcde}
MF	Laura	1081^{cdef}	3635^{cdefgh}	3128^{efghi}	2689^{de}	10533^{defg}
MF	Jamaica	1215^{bcd}	2571^{h}	2487^{hi}	1787^{g}	8059^{gh}
TFT	Cochise	681^{ef}	2676^{gh}	2672^{hi}	2268^{efg}	8297^{gh}
TFT	Sidewinder	604^{f}	$3659^{bcdefgh}$	2691^{hi}	2555^{def}	9509^{fgh}
CF	Rushmore	1144^{bcde}	2893^{fgh}	2529^{hi}	1179^{h}	7745^{h}
RF	Gibraltar	1552^{bc}	3255^{efgh}	3410^{defgh}	2272^{efg}	10489^{defg}
		487	1279	1025	580	2630

LSD (0.05) compares within season and over cultivars.
^{abc} Means with no common superscript, differ significantly.
TF: Tall Fescue; MF: Meadow Fescue; TFT: Tall Fescue Turf; CF: Chewings Fescue; RF: Red Fescue

Table 10. Mean monthly growth rate (kg DM ha^{-1} day^{-1}) of Cocksfoot cultivars during year 1.

Cultivar	July*	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Athos	0.93^{ab}	11.6^{abc}	36.8^{c}	134^{a}	81.4^{b}	79.6^{ab}	58.4^{ab}	33.6^{abc}	47.2^{b}	54.0^{ab}	23.7^{ab}
Sparta	0.38^{b}	7.77^{bc}	36.5^{c}	93.3^{bc}	67.5^{b}	87.2^{a}	51.0^{ab}	33.1^{abc}	45.2^{b}	37.7^{cd}	17.4^{bc}
Niva	0.55^{b}	4.94^{c}	29.7^{c}	106^{abc}	77.4^{b}	83.1^{ab}	46.4^{b}	37.3^{abc}	40.4^{b}	37.3^{cd}	12.4^{c}
Cristobal	2.17^{a}	15.0^{ab}	66.6^{ab}	122^{ab}	84.9^{b}	90.1^{a}	55.6^{ab}	35.3^{abc}	44.4^{b}	47.6^{abc}	27.8^{ab}
Adremo	0.50^{b}	10.1^{abc}	47.2^{bc}	118^{ab}	110^{a}	77.5^{ab}	54.1^{ab}	34.4^{abc}	50.4^{ab}	46.8^{bcd}	30.9^{a}
Barvillo	0.56^{b}	9.61^{bc}	45.8^{c}	103^{abc}	81.6^{b}	84.3^{ab}	61.7^{a}	39.1^{ab}	45.1^{b}	47.0^{abc}	26.9^{ab}
Barexcel	0.48^{b}	8.61^{bc}	46.4^{bc}	104^{abc}	85.6^{b}	69.4^{b}	47.8^{ab}	30.9^{bc}	42.7^{b}	44.6^{bcd}	23.2^{ab}
Oxen	2.10^{a}	19.6^{a}	74.5^{a}	118^{ab}	72.8^{b}	68.0^{b}	58.8^{ab}	33.3^{abc}	45.9^{b}	42.0^{cd}	28.5^{a}
Hera	0.69^{b}	7.80^{bc}	47.1^{bc}	107^{abc}	81.3^{b}	69.9^{b}	44.8^{b}	28.9^{c}	47.4^{b}	39.0^{cd}	22.7^{abc}
Wana	0.49^{b}	6.49^{bc}	41.0^{c}	80.7^{c}	74.7^{b}	75.5^{ab}	54.6^{ab}	41.0^{a}	44.6^{b}	57.8^{a}	22.1^{abc}
Pizza	0.63^{b}	5.0^{c}	42.4^{c}	89.5^{bc}	83.5^{b}	72.9^{ab}	53.8^{ab}	30.3^{c}	59.1^{a}	35.9^{d}	20.8^{abc}
LSD (0.05)	1.251	9.520	20.44	37.03	20.23	17.24	14.67	8.675	11.47	10.92	10.49

LSD (0.05) compares within month and over cultivars.
^{abc} Means with no common superscript, differ significantly.
*Growth rate from establishment to first harvest

Table 11. Mean monthly growth rate (kg DM ha^{-1} day^{-1}) of Cocksfoot cultivars during year 2.

Cultivar	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Athos	14.9^{bc}	21.6^{abc}	12.9^{abc}	25.3^{abc}	55.4^{ab}	73.4^{a}	51.8^{ab}	37.6^{abc}	47.3^{a}	47.0^{a}	38.4^{a}	23.0^{a}
Sparta	9.80^{cd}	12.3^{ef}	10.8^{abcd}	22.5^{bc}	55.2^{ab}	63.4^{a}	38.1^{cd}	43.7^{ab}	42.2^{a}	38.9^{a}	32.3^{abc}	14.0^{bc}
Niva	11.4^{cd}	13.6^{cde}	10.8^{abcd}	24.8^{abc}	69.4^{a}	58.0^{a}	46.2^{abcd}	32.2^{c}	47.0^{a}	34.9^{a}	29.5^{bc}	19.0^{abc}
Cristobal	20.0^{ab}	29.8^{a}	10.1^{bcd}	19.6^{bc}	43.8^{ab}	59.5^{a}	44.7^{abcd}	39.6^{abc}	43.6^{a}	35.0^{a}	33.5^{abc}	18.8^{abc}
Adremo	11.5^{cd}	19.4^{bcde}	12.8^{abc}	27.1^{ab}	56.9^{ab}	78.0^{a}	46.5^{abc}	43.6^{ab}	45.6^{a}	40.9^{a}	34.6^{ab}	21.0^{ab}
Barvillo	11.9^{c}	16.5^{bcde}	15.8^{a}	31.7^{a}	65.9^{a}	54.8^{a}	56.2^{a}	45.0^{a}	43.2^{a}	38.5^{a}	30.3^{bc}	24.3^{a}
Barexcel	15.7^{abc}	13.2^{de}	5.93^{de}	17.9^{c}	37.4^{b}	62.3^{a}	40.9^{bcd}	42.4^{abc}	41.2^{a}	33.3^{a}	29.2^{bc}	17.7^{abc}
Oxen	22.0^{a}	24.2^{ab}	11.6^{abc}	23.8^{abc}	46.7^{ab}	55.9^{a}	34.0^{d}	43.8^{ab}	44.5^{a}	37.4^{a}	30.7^{bc}	18.0^{abc}
Hera	13.3^{bc}	15.3^{cde}	8.68^{cde}	24.0^{abc}	54.8^{ab}	65.3^{a}	43.7^{bcd}	43.8^{ab}	46.8^{a}	39.4^{a}	28.0^{bc}	13.7^{c}
Wana	12.7^{c}	21.2^{bcd}	14.9^{ab}	24.3^{abc}	66.3^{a}	59.1^{a}	41.7^{bcd}	37.9^{abc}	44.5^{a}	34.5^{a}	32.2^{abc}	19.5^{abc}
Pizza	4.64^{d}	4.11^{f}	3.57^{e}	19.5^{bc}	52.2^{ab}	62.5^{a}	46.7^{abc}	34.3^{bc}	42.3^{a}	33.8^{a}	27.0^{c}	15.3^{bc}
LSD (0.05)	6.950	8.280	5.134	8.650	26.07	24.69	12.20	10.32	10.63	13.88	7.052	7.017

LSD (0.05) compares within month and over cultivars.
^{abc} Means with no common superscript, differ significantly.

Table 12. Total seasonal and annual dry matter (kg DM ha^{-1}) production of Cocksfoot cultivars during year 1.

Cultivar	Winter	Spring	Summer	Autumn	Annual
Athos	423^{abc}	7439^{abc}	4987^{ab}	3460^{a}	16309^{ab}
Sparta	259^{c}	5824^{d}	5005^{ab}	2796^{bc}	13884^{c}
Niva	197^{c}	6317^{cd}	4873^{ab}	2500^{c}	13888^{c}
Cristobal	651^{ab}	8015^{a}	5282^{a}	3332^{ab}	17280^{a}
Adremo	337^{bc}	8196^{a}	4825^{ab}	3572^{a}	16930^{a}
Barvillo	329^{bc}	6814^{abcd}	5374^{a}	3311^{ab}	15828^{abc}
Barexcel	285^{bc}	6937^{abcd}	4306^{b}	3071^{abc}	14599^{bc}
Oxen	773^{a}	7727^{ab}	4627^{ab}	3249^{ab}	16376^{ab}
Hera	293^{bc}	6937^{abcd}	4185^{b}	3048^{abc}	14463^{bc}
Wana	234^{c}	5833^{d}	4961^{ab}	3433^{a}	14462^{bc}
Pizza	207^{c}	6405^{bcd}	4560^{ab}	3250^{ab}	14422^{bc}
LSD (0.05)	386.0	1396	861.8	605.1	2312

LSD (0.05) compares within season and over cultivars.
^{abc} Means with no common superscript, differ significantly.

Table 13. Total seasonal and annual dry matter (kg DM ha^{-1}) production of Cocksfoot cultivars during year 2.

Cultivar	Winter	Spring	Summer	Autumn	Annual
Athos	1471^{ab}	4663^{a}	3900^{ab}	3087^{a}	13121^{a}
Sparta	998^{d}	4258^{a}	3560^{ab}	2423^{b}	11238^{ab}
Niva	1079^{cd}	4561^{a}	3575^{ab}	2367^{b}	11581^{ab}
Cristobal	1738^{a}	3721^{a}	3660^{ab}	2480^{b}	11599^{ab}
Adremo	1317^{bcd}	4908^{a}	3884^{ab}	2743^{ab}	12851^{a}
Barvillo	1351^{bc}	4553^{a}	4131^{a}	2648^{ab}	12684^{a}
Barexcel	1008^{d}	3547^{a}	3570^{ab}	2275^{b}	10399^{b}
Oxen	1689^{a}	3810^{a}	3343^{b}	2449^{b}	11290^{ab}
Hera	1100^{cd}	4354^{a}	3847^{ab}	2308^{b}	11609^{ab}
Wana	1473^{ab}	4496^{a}	3550^{ab}	2448^{b}	11968^{ab}
Pizza	369^{e}	4061^{a}	3521^{ab}	2167^{b}	10118^{ab}
LSD (0.05)	335	1442	702	599	2164

LSD (0.05) compares within season and over cultivars.
^{abc} Means with no common superscript, differ significantly.

Table 14. Mean monthly growth rate (kg DM ha^{-1} day^{-1}) of temperate perennial grass cultivars during year 1.

Species	Cultivar	July*	August	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May
TF	Kora	1.75^{b}	10.9^{efghij}	48.8^{defghijk}	99.6^{bcde}	80.0^{bcde}	57.9^{hijkl}	64.9^{abcde}	35.6^{defghij}	45.1^{cdefghijk}	48.0^{cdefgh}	26.0^{bcdefgh}
TF	Tuscany	0.74^{b}	6.4^{ghij}	40.2^{hijk}	111^{abcd}	75.8^{bcdef}	60.4^{ghijkl}	70.7^{abc}	49.8^{ab}	51.8^{abcdef}	52.3^{bcdef}	30.3^{abcdefg}
TF	Barlite	0.80^{b}	7.0^{ghij}	28.9^{klm}	115^{abcd}	73.9^{cdefgh}	60.4^{ghijkl}	74.3^{ab}	43.0^{bcd}	49.5^{abcdefgh}	53.9^{bcde}	27.3^{bcdefgh}
TF	Verdant	5.26^{a}	25.5^{abc}	71.1^{abc}	102^{bcde}	76.1^{bcdef}	46.6^{lm}	66.7^{abcd}	30.1^{ghij}	53.6^{abcd}	46.2^{defghij}	26.0^{bcdefgh}
TF	Jenna	2.02^{b}	19.0^{bcde}	57.5^{abcdefgh}	116^{abcd}	81.1^{bcd}	44.5^{lmn}	74.8^{a}	34.2^{defghij}	52.8^{abcde}	51.9^{bcdef}	30.9^{abcdef}
TF	KR6505	2.09^{b}	18.0^{cdef}	52.7^{cdefghi}	107^{abcde}	58.8^{fghi}	72.6^{cdefghi}	62.4^{abcdef}	37.8^{cdefghij}	57.2^{ab}	60.0^{ab}	31.0^{abcdef}
TF	GFM24	2.34^{b}	10.4^{defghij}	43.4^{hijk}	102^{bcde}	61.3^{efgh}	60.8^{fghijkl}	40.9^{ghijk}	30.3^{ghij}	35.8^{jklmn}	48.0^{cdefgh}	32.6^{abcde}
TF	GFM29	0.97^{b}	9.9^{defghij}	41.7^{hijk}	102^{bcde}	62.3^{defgh}	58.4^{hijkl}	58.3^{abcdefgh}	38.9^{cdefghi}	46.1^{bcdefghijk}	47.9^{cdefgh}	25.9^{bcdefgh}
TF	Bronson forage	1.21^{b}	8.4^{fghij}	45.4^{ghijk}	95.6^{bcdef}	76.5^{bcdef}	58.3^{hijkl}	70.4^{abc}	41.2^{bcdef}	49.5^{abcdefgh}	50.4^{bcdefg}	30.9^{abcdef}
TF	Baroptima	1.35^{b}	11.5^{efghij}	44.7^{hijk}	122^{ab}	74.6^{bcdefg}	65.9^{efghijk}	60.4^{abcdefg}	41.0^{bcdef}	56.7^{abc}	54.8^{bcde}	33.2^{abcd}
TF	Bariane	1.26^{b}	10.1^{defghij}	46.1^{fghijk}	116^{abcd}	83.9^{bc}	62.5^{fghijkl}	66.3^{abcd}	53.4^{a}	58.6^{a}	55.8^{abcd}	34.9^{ab}
TF	Barverde	1.41^{b}	9.0^{efghij}	34.8^{ijklm}	90.0^{def}	56.1^{ghi}	45.9^{lm}	55.8^{abcdefgh}	32.5^{efghij}	44.6^{efghijkl}	54.3^{bcde}	28.5^{bcdefg}
TF	Boschoek	1.28^{b}	9.7^{defghij}	45.1^{ghijk}	105^{bcde}	82.4^{bc}	47.9^{klm}	57.6^{abcdefgh}	37.1^{defghij}	51.1^{abcdef}	51.5^{bcdefg}	28.1^{bcdefg}
TF	Advance	1.53^{b}	13.4^{defgh}	56.7^{bcdefgh}	95.9^{bcdef}	72.0^{bcdefgh}	56.6^{hijkl}	60.3^{abcdefg}	41.5^{bcdef}	48.7^{abcdefghi}	47.2^{cdefghi}	28.5^{bcdefg}
MF	Laura	1.11^{b}	8.5^{fghij}	43.2^{hijk}	91.1^{cdef}	62.3^{defgh}	51.2^{jklm}	55.9^{abcdefgh}	36.0^{defghij}	32.9^{lmno}	46.2^{defghij}	26.1^{bcdefgh}
MF	Jamaica	1.47^{b}	13.0^{defgh}	48.9^{defghij}	98.9^{bcde}	75.4^{bcdefg}	60.2^{ghijkl}	54.1^{bcdefghij}	34.2^{defghij}	38.1^{ghijklm}	53.7^{bcde}	25.3^{bcdefgh}
TFT	Cochise	0.28^{b}	2.2^{ij}	16.2^{mn}	67.3^{fgh}	39.7^{ij}	32.7^{mn}	30.3^{k}	31.8^{fghij}	37.8^{hijklm}	37.2^{hijk}	33.7^{abc}
TFT	Sidewinder	0.50^{b}	1.3^{j}	17.1^{lmn}	48.7^{h}	35.6^{j}	26.3^{n}	33.8^{jk}	29.6^{hij}	25.6^{no}	36.6^{ijk}	15.1^{ij}
CF	Rushmore	-	3.6^{hij}	7.2^{n}	50.6^{h}	54.7^{hij}	52.7^{jkl}	37.8^{hijk}	29.5^{hij}	23.0^{o}	34.0^{k}	28.7^{bcdefg}
RF	Gibraltar	-	2.2^{ij}	8.2^{n}	51.9^{gh}	73.1^{bcdefgh}	55.5^{ijkl}	43.2^{fghijk}	47.3^{abc}	37.3^{ijklmn}	46.5^{defghij}	38.8^{a}
CoF	Athos	0.93^{b}	11.6^{efghij}	36.8^{ijkl}	134^{a}	81.4^{bcd}	79.6^{bcdef}	58.4^{abcdefg}	33.6^{defghij}	45.7^{bcdefghijk}	54.0^{bcde}	23.7^{defghi}
CoF	Sparta	0.38^{b}	7.0^{fghij}	36.5^{ijkl}	93.3^{bcdef}	64.5^{cdefgh}	87.2^{bcd}	51.0^{cdefghij}	33.1^{defghij}	45.2^{bcdefghijk}	37.7^{hijk}	12.4^{j}
CoF	Niva	0.68^{b}	4.9^{ghij}	29.7^{jklm}	106^{abcde}	77.4^{bcdef}	83.1^{bcde}	46.4^{defghijk}	37.3^{cdefghij}	40.4^{fghijklm}	37.3^{hijk}	17.4^{hij}
CoF	Cristobal	2.17^{b}	15.0^{defg}	66.6^{abcde}	122^{ab}	84.9^{bc}	90.1^{bc}	55.6^{abcdefgh}	35.3^{defghij}	44.4^{defghijklm}	47.6^{cdefgh}	27.8^{bcdefg}
CoF	Adremo	0.50^{b}	10.1^{defghij}	47.2^{efghijk}	118^{abcd}	110^{a}	77.5^{cdefg}	54.1^{bcdefghij}	34.4^{defghij}	50.4^{abcdef}	46.8^{defghij}	30.9^{abcdef}
CoF	Barvillo	0.56^{b}	9.6^{defghij}	45.8^{fghijk}	103^{bcde}	81.6^{bcd}	84.3^{bcde}	61.7^{abcdef}	39.1^{cdefgh}	45.1^{cdefghijk}	47.0^{cdefghi}	26.9^{bcdefgh}
CoF	Barexcel	0.48^{b}	8.6^{fghij}	46.4^{fghijk}	104^{bcde}	83.6^{bc}	69.4^{defghij}	47.8^{defghijk}	30.9^{ghij}	42.7^{defghijklm}	44.6^{efghijk}	23.2^{efghi}
CoF	Oxen	2.10^{b}	19.6^{bcd}	74.5^{ab}	118^{abcd}	72.8^{bcdefgh}	68.0^{efghij}	58.9^{abcdefg}	33.3^{defghij}	45.9^{bcdefghijk}	42.0^{fghijk}	28.5^{bcdefg}
CoF	Hera	0.69^{b}	7.8^{fghij}	47.1^{efghijk}	107^{abcde}	81.3^{bcd}	68.9^{defghij}	44.8^{efghijk}	28.9^{j}	47.4^{abcdefghij}	39.0^{hijk}	22.7^{efghi}
CoF	Wana	0.49^{b}	6.5^{ghij}	41.0^{hijk}	80.7^{efg}	74.7^{bcdefg}	75.5^{cdefgh}	54.6^{abcdefghi}	41.0^{bcdef}	44.6^{defghijkl}	57.8^{abc}	22.1^{fghij}
CoF	Pizza	0.63^{b}	5.0^{ghij}	42.4^{hijk}	89.5^{def}	83.5^{bc}	72.9^{cdefghi}	53.8^{bcdefghij}	30.3^{ghij}	59.1^{a}	35.9^{jk}	20.8^{ghij}
PR	Remington	1.81^{b}	15.1^{cdefg}	52.6^{cdefghi}	106^{abcde}	74.1^{bcdefg}	45.6^{lm}	34.4^{ijk}	33.8^{defghij}	32.4^{mno}	40.8^{ghijk}	29.1^{abcdefg}
PR	Bealy	4.97^{a}	19.3^{bcde}	65.6^{abcdef}	120^{abc}	78.0^{bcdef}	62.3^{fghijkl}	57.6^{abcdefgh}	41.9^{bcde}	44.7^{cdefghijkl}	53.9^{bcde}	28.7^{bcdefg}
PR	Trojan	5.48^{a}	31.2^{a}	74.0^{ab}	121^{ab}	79.7^{bcde}	56.9^{hijkl}	49.7^{defghijk}	29.0^{ij}	37.8^{hijklm}	40.8^{ghijk}	30.0^{abcdefg}
PR	Arrow	5.42^{a}	30.5^{a}	68.5^{abcd}	110^{abcd}	88.5^{b}	67.9^{efghij}	51.0^{cdefghij}	33.2^{defghij}	34.1^{klmno}	66.3^{a}	26.3^{bcdefgh}
PR	Bronsyn	5.44^{a}	28.6^{ab}	64.9^{abcdefg}	106^{abcde}	81.1^{bcd}	48.8^{klm}	49.3^{defghijk}	36.9^{defghij}	41.5^{efghijklm}	44.7^{efghijk}	25.4^{bcdefgh}
BC	Ceres Atom	5.17^{a}	32.0^{a}	77.2^{a}	121^{ab}	87.8^{b}	110^{a}	65.3^{abcde}	40.0^{bcdefg}	53.1^{abcde}	39.1^{hijk}	29.2^{abcdefg}
BP	GBP02	1.80^{b}	12.2^{defghi}	68.0^{abcd}	116^{abcd}	90.6^{ab}	96.5^{ab}	72.6^{ab}	41.9^{bcde}	50.1^{abcdefg}	42.1^{fghijk}	24.2^{cdefghi}
LSD (0.05)		2.34	10.36	19.83	28.96	19.35	18.88	20.58	9.98	12.05	10.91	9.940

LSD (0.05) compares within month and over cultivars ^{abc} Means with no common superscript, differ significantly.
TF: Tall Fescue; MF: Meadow Fescue; TFT: Tall Fescue Turf; CF: Chewings Fescue; RF: Red Fescue; CoF: Cocksfoot; PR: Perennial ryegrass; BC: *Bromus catharticus*; BP: *Bromus parodii*. *Growth rate from establishment to first harvest

Table 15. Mean monthly growth rate (kg DM ha^{-1} day^{-1}) of temperate perennial grass cultivars during year 2.

Species	Cultivar	June	July	August	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May
TF	Kora	9.64^{ghij}	12.8^{ijklmno}	9.84^{fghijklm}	21.5^{fghijkl}	46.1^{bcdefghi}	59.1^{abcde}	49.0^{abcdefg}	51.2^{abcdef}	39.5^{abcdefg}	49.3^{bcde}	34.4^{defghi}	20.3^{efghijklmn}
TF	Tuscany	9.39^{ghij}	11.6^{jklmno}	6.77^{klm}	30.2^{abcdefghij}	61.2^{bcdefg}	68.0^{abc}	61.7^{a}	59.3^{a}	51.3^{a}	54.2^{abc}	42.3^{abcde}	26.0^{abcdef}
TF	Barlite	15.6^{abcdefgh}	16.6^{efghijkl}	8.05^{hijklm}	18.4^{ijkl}	59.0^{bcdefgh}	64.8^{abc}	48.3^{abcdefghi}	45.9^{bcdefgh}	49.5^{a}	49.9^{bcde}	42.9^{abcd}	25.7^{abcdefg}
TF	Verdant	13.2^{bcdefghi}	15.6^{fghijklm}	7.66^{ijklm}	34.3^{abcdefg}	57.6^{bcdefghi}	60.3^{abcde}	52.0^{abcdef}	51.7^{abcde}	45.1^{abc}	56.1^{abc}	43.7^{abc}	28.3^{abcd}
TF	Jenna	11.1^{defghij}	13.9^{ghijklmn}	14.9^{cdfgh}	34.6^{abcdef}	70.6^{ab}	59.4^{abcde}	59.3^{ab}	58.8^{ab}	52.5^{a}	62.7^{a}	45.7^{ab}	32.3^{a}
TF	KR6505	20.4^{ab}	29.8^{a}	25.9^{ab}	43.0^{a}	43.0^{cdefghi}	46.7^{cdefg}	33.4^{jklm}	31.1^{klmnopq}	34.0^{bcdefghi}	47.0^{cdef}	38.9^{bcdefg}	30.5^{ab}
TF	GFM24	21.7^{a}	29.7^{a}	30.5^{a}	41.7^{ab}	56.4^{bcdefghi}	40.1^{defg}	37.0^{ghijklm}	24.8^{pq}	16.7^{jk}	23.8^{klm}	26.2^{ijklmno}	24.0^{bcdefghij}
TF	GFM29	14.9^{abcdefgh}	19.7^{defghi}	17.1^{cde}	32.9^{abcdefg}	56.6^{bcdefghi}	47.5^{cdefg}	33.3^{jklm}	31.5^{jklmnopq}	11.5^{k}	27.5^{ijkl}	27.5^{ijklmno}	18.3^{fghijklmn}
TF	Bronson forage	9.12^{hij}	9.22^{mnop}	10.9^{efghijkl}	27.2^{defghijkl}	60.3^{bcdefg}	54.9^{abcdef}	39.7^{efghijklm}	44.5^{cdefghi}	47.0^{ab}	48.3^{cdef}	40.6^{abcdef}	29.3^{abc}
TF	Baroptima	13.0^{bcdefghi}	8.24^{nop}	8.49^{hijklm}	16.5^{kl}	42.6^{cdefghi}	55.3^{abcdef}	52.7^{abcde}	50.4^{abcdefg}	47.7^{ab}	54.6^{abc}	49.8^{a}	29.0^{abc}
TF	Bariane	17.5^{abcdef}	10.5^{klmnop}	5.02^{lm}	14.3^{l}	31.4^{i}	40.0^{defg}	43.7^{cdefefghijkl}	55.0^{abc}	51.5^{a}	50.0^{bcd}	44.9^{ab}	24.0^{bcdefghi}
TF	Barverde	19.7^{abc}	28.4^{ab}	22.0^{bc}	41.13^{abc}	63.1^{bcdef}	62.4^{abcd}	40.4^{efghijklm}	40.3^{efghijklmno}	25.7^{ghijk}	25.7^{kl}	37.6^{bcdefgh}	29.0^{abc}
TF	Boschoek	11.9^{cdefghij}	12.9^{hijklmno}	14.6^{defghi}	39.2^{abcd}	41.0^{defghi}	60.8^{abcde}	56.9^{abc}	54.3^{abcd}	50.8^{a}	60.4^{ab}	49.4^{a}	31.0^{ab}
TF	Advance	14.5^{abcdefgh}	22.0^{bcdef}	13.0^{efghijk}	25.2^{ghijkl}	44.0^{bcdefghi}	52.0^{bcdefg}	48.7^{abcdefgh}	43.1^{cdefghijklmn}	43.4^{abcd}	49.7^{bcde}	42.6^{abcde}	27.3^{abcde}
TFT	Cochise	9.73^{fghij}	6.74^{op}	6.36^{klm}	21.4^{ghijkl}	32.8^{hi}	35.2^{fg}	28.3^{m}	34.4^{hijklmnopq}	30.2^{cdefghij}	31.1^{ghijk}	32.7^{fghijk}	16.3^{jklmno}
TFT	Sidewinder	5.49^{ij}	9.70^{lmnop}	5.11^{lm}	17.3^{jkl}	38.3^{fghi}	64.6^{abc}	32.8^{klm}	33.3^{hijklmnopq}	27.6^{efghij}	37.7^{fghij}	31.4^{fghijkl}	20.7^{defghijklmn}
MF	Laura	10.5^{efghij}	16.9^{efghijk}	9.06^{ghijklm}	25.7^{efghijkl}	48.3^{bcdefghi}	47.4^{cdefg}	37.1^{ghijklm}	32.4^{ijklmnopq}	39.8^{abcdefg}	41.4^{defg}	30.7^{ghijklm}	22.3^{cdefghijkl}
MF	Jamaica	17.1^{abcdefg}	20.0^{defgh}	5.35^{lm}	14.6^{l}	31.6^{i}	38.9^{efg}	29.3^{lm}	30.7^{lpq}	26.5^{fghijk}	25.6^{kl}	21.4^{mno}	15.7^{klmno}
CF	Rushmore	16.8^{abcdefgh}	15.2^{fghijklmn}	7.37^{jklm}	21.8^{fghijkl}	44.2^{bcdefghi}	31.3^{g}	39.5^{efghijklm}	24.8^{lmnopq}	24.2^{hijk}	11.6^{n}	20.3^{o}	9.58^{o}
RF	Gibraltar	18.6^{abcd}	22.2^{bcdef}	11.9^{efghijkl}	21.2^{ghijkl}	30.8^{i}	55.3^{abcdef}	42.8^{cdefghijklm}	37.9^{ghijklmnop}	38.4^{abcdefgh}	27.6^{ijkl}	34.4^{defghi}	18.3^{fghijklmn}
CoF	Athos	14.9^{abcdefgh}	21.6^{bcdef}	12.9^{efghijk}	25.3^{efghijkl}	55.4^{bcdefghi}	73.4^{ab}	51.8^{abcdef}	37.6^{ghijklmnop}	47.3^{ab}	47.0^{cdef}	38.4^{bcdefg}	23.2^{bcdefghijk}
CoF	Sparta	9.80^{fghij}	12.3^{jklmno}	10.8^{efghijkl}	22.5^{fghijkl}	55.2^{bcdefghi}	63.4^{abcd}	38.1^{fghijklm}	43.7^{cdefghijklm}	42.2^{abcde}	38.9^{defghi}	32.3^{fghijk}	14.0^{mno}
CoF	Niva	11.4^{defghij}	13.6^{ghijklmno}	10.8^{efghijkl}	24.8^{efghijkl}	69.4^{abc}	58.0^{abcdef}	46.2^{bcdefghijk}	32.2^{ijklmnopq}	47.0^{ab}	34.9^{ghijk}	29.5^{hijklmno}	19.0^{fghijklmn}
CoF	Cristobal	20.0^{ab}	29.8^{a}	10.1^{efghijklm}	19.6^{hijkl}	43.8^{bcdefghi}	59.5^{abcde}	44.7^{cdefghijk}	39.6^{efghijklmno}	43.6^{abcd}	35.0^{ghijk}	33.5^{efghij}	18.8^{fghijklmn}
CoF	Adremo	11.5^{defghij}	19.4^{defghi}	12.8^{efghijk}	27.1^{defghijkl}	56.9^{bcdefghi}	78.0^{a}	46.5^{bcdefghijk}	43.6^{cdefghijklm}	45.6^{ab}	40.9^{defg}	34.6^{cdefghi}	21.0^{defghijklm}
CoF	Barvillo	11.9^{cdefghij}	16.5^{efghijkl}	15.8^{cdefg}	31.7^{abcdefgh}	65.9^{abcde}	54.8^{abcdef}	56.2^{abcd}	45.0^{cdefghi}	43.2^{abcd}	38.5^{efghi}	30.3^{ghijklmn}	24.3^{bcdefgh}
CoF	Barexcel	15.7^{abcdefgh}	13.2^{ghijklmno}	5.93^{klm}	17.9^{ijkl}	37.4^{fghi}	62.3^{abcde}	40.9^{efghijklm}	42.4^{cdefghijklmn}	41.2^{abcdef}	33.3^{ghijk}	29.2^{hijklmno}	17.7^{hijklmno}
CoF	Oxen	22.0^{a}	24.2^{abcd}	11.6^{efghijkl}	23.8^{efghijkl}	46.7^{bcdefghi}	55.9^{abcdef}	34.0^{ijklm}	43.8^{fghijklmno}	44.5^{abc}	37.4^{fghij}	30.7^{ghijklm}	18.0^{ghijklmn}
CoF	Hera	13.3^{bcdefghi}	15.3^{fghijklmn}	8.68^{ghijklm}	24.0^{efghijkl}	54.8^{bcdefghi}	65.3^{abc}	43.7^{cdefghijkl}	43.8^{cdefghijkl}	46.8^{ab}	39.4^{defgh}	28.0^{ijklmno}	13.7^{mno}
CoF	Wana	12.7^{bcdefghi}	21.2^{cdef}	14.9^{cdefgh}	24.3^{efghijkl}	66.3^{abcd}	59.1^{abcde}	41.7^{defghijklm}	37.9^{ghijklmnop}	44.5^{abc}	34.5^{ghijk}	32.2^{fghijk}	19.5^{fghijklmn}
CoF	Pizza	4.64^{j}	4.11^{p}	3.57^{m}	19.5^{hijkl}	52.2^{bcdefghi}	62.5^{abcd}	46.7^{bcdefghijk}	34.3^{hijklmnopq}	42.3^{abcde}	33.8^{ghijk}	27.0^{ijklmno}	15.3^{klmno}
PR	Remington	10.9^{defghij}	13.1^{hijklmno}	7.27^{jklmn}	23.5^{efghijkl}	34.8^{ghi}	38.7^{efg}	32.3^{klm}	21.8^{q}	17.0^{jk}	18.7^{lmn}	21.6^{mno}	13.3^{no}
PR	Bealy	16.2^{abcdefgh}	21.8^{bcdef}	17.2^{cde}	30.7^{abcdefghi}	52.1^{bcdefghi}	58.5^{abcdef}	38.4^{efghijklm}	41.9^{cdefghijklmn}	34.1^{bcdefghi}	31.8^{ghijk}	30.0^{ghijklmn}	22.1^{cdefghijkl}
PR	Trojan	14.7^{abcdefgh}	18.0^{defghij}	15.8^{cdefg}	26.4^{fghijkl}	40.0^{defghi}	54.0^{bcdefg}	34.2^{hijklm}	27.3^{opq}	23.1^{ijk}	13.7^{mn}	24.1^{klmno}	20.2^{efghijklmn}
PR	Arrow	18.0^{abcde}	22.9^{abcde}	16.5^{cdef}	29.8^{bcdefghij}	56.0^{bcdefghi}	49.9^{bcdefg}	40.1^{efghijklm}	30.0^{nopq}	25.3^{ghijk}	28.7^{hijkl}	27.6^{ijklmno}	25.7^{abcdefg}
PR	Bronsyn	17.2^{abcdefg}	20.3^{defg}	14.1^{efghij}	23.6^{efghijkl}	40.7^{defghi}	38.3^{efg}	36.5^{ghijklm}	30.5^{mnopq}	28.5^{defghij}	29.4^{hijkl}	24.4^{jklmno}	22.5^{cdefghijkl}
BC	Ceres Atom	19.9^{ab}	29.8^{a}	24.6^{ab}	36.3^{abcde}	91.3^{a}	41.0^{defg}	38.9^{efghijklm}	41.2^{defghijklmn}	32.8^{bcdefghi}	26.4^{jkl}	22.6^{lmno}	16.6^{jklmno}
BP	GBP02	17.5^{abcdef}	27.8^{abc}	21.3^{bcd}	28.3^{cdefghijk}	38.7^{efghi}	38.2^{efg}	47.4^{abcdefghij}	44.2^{cdefghijk}	43.0^{abcd}	46.6^{cdef}	21.2^{no}	16.6^{ijklmno}
LSD (0.05)		7.836	7.126	7.209	13.17	27.25	23.47	14.51	13.25	15.13	11.44	9.295	7.686

LSD (0.05) compares within month and over cultivars. ^{abc} Means with no common superscript, differ significantly.
TF: Tall Fescue; MF: Meadow Fescue; TFT: Tall Fescue Turf; CF: Chewings Fescue; RF: Red Fescue; CoF: Cocksfoot; PR: Perennial ryegrass;
BC: *Bromus catharticus*; BP: *Bromus parodii*

Table 16. Total seasonal and annual dry matter production (kg DM ha^{-1}) of temperate perennial grass cultivars during year 1.

Species	Cultivar	Winter	Spring	Summer	Autumn	Annual
TF	Kora	490^{cdefgh}	$6738^{defghij}$	$4546^{cdefghijk}$	$3309^{defghij}$	15082^{cdefgh}
TF	Tuscany	260^{efgh}	6697^{efghij}	5175^{bcde}	3742^{abcd}	15874^{bcdef}
TF	Barlite	281^{defgh}	6432	5080^{cdef}	3627^{abcdef}	15419^{cdefg}
TF	Verdant	1277^{a}	$7280^{abcdefghi}$	4087^{ghijkl}	3507^{cdefg}	16150^{bcde}
TF	Jenna	749^{bcd}	$7464^{abcdefgh}$	$4356^{defghijk}$	3775^{abcd}	16345^{bcde}
TF	KR6505	727^{bcde}	6353^{hijk}	4993^{cdefg}	4118^{ab}	16190^{bcde}
TF	GFM24	543^{bcdefg}	6063^{ijk}	3837^{jkl}	$3231^{defghiij}$	13674^{fghi}
TF	GFM29	380^{cdefgh}	6032^{ijk}	$4475^{cdefghijk}$	$3330^{defghij}$	14217^{efgh}
TF	Bronson forage	364^{cdefgh}	6429^{fghijk}	4863^{cdefgh}	3642^{abcde}	15297^{cdefgh}
TF	Baroptima	467^{cdefgh}	$7083^{abcdefghij}$	$4821^{cdefghi}$	4030^{abc}	16401^{bcde}
TF	Bariane	417^{cdefgh}	$7270^{abcdefghi}$	5223^{bcde}	4164^{a}	17073^{bcd}
TF	Barverde	402^{cdefgh}	5315^{kl}	3838^{jkl}	3531^{cdefg}	13086^{hi}
TF	Boschoek	407^{cdefgh}	$6880^{cdefghij}$	4081^{ghijkl}	3634^{abcde}	15003^{defgh}
TF	Advance	539^{cdefg}	$6590^{efghijk}$	$4543^{cdefghijk}$	3467^{cdefgh}	15138^{cdefgh}
MF	Laura	357^{cdefgh}	5773^{jk}	4108^{ghijkl}	2910^{hijkl}	13148^{hi}
MF	Jamaica	522^{cdefg}	$6579^{efghijk}$	$4284^{efghijk}$	$3234^{defghij}$	14619^{efgh}
TFT	Cochise	70.9^{gh}	3629^{m}	2723^{mn}	3039^{ghijk}	9461^{j}
TFT	Sidewinder	35.9^{h}	2998^{m}	2557^{n}	2132^{m}	7723^{j}
CF	Rushmore	102^{gh}	3353^{m}	3588^{klm}	2383^{lm}	9426^{j}
RF	Gibraltar	61.5^{gh}	4086^{lm}	4211^{ghijkl}	3415^{defghi}	11774^{i}
CoF	Athos	423^{cdefgh}	$7439^{abcdefgh}$	4987^{cdefg}	3460^{cdefgh}	16309^{bcde}
CoF	Sparta	259^{efgh}	5824^{jk}	5005^{cdefg}	2796^{jkl}	13884^{fghi}
CoF	Niva	197^{fgh}	6317^{hijk}	4873^{cdefgh}	2500^{klm}	13888^{fghi}
CoF	Cristobal	651^{bcdef}	8015^{abcd}	5282^{bcd}	$3332^{defghij}$	17280^{abc}
CoF	Adremo	337^{cdefgh}	8196^{ab}	$4825^{cdefghi}$	3572^{bcdefg}	16930^{bcd}
CoF	Barvillo	329^{cdefgh}	$6814^{cdefghij}$	5374^{abc}	$3311^{defghij}$	15828^{bcdef}
CoF	Barexcel	285^{defgh}	$6937^{bcdefghij}$	$4306^{efghijk}$	$3071^{efghijk}$	14599^{efgh}
CoF	Oxen	773^{bc}	7727^{abcdef}	$4627^{cdefghi}$	$3249^{defghij}$	16376^{bcde}
CoF	Hera	293^{cdefgh}	$6937^{bcdefghij}$	$4185^{fghijkl}$	3048^{fghijk}	14463^{efgh}
CoF	Wana	234^{fgh}	5833^{jk}	4961^{cdefg}	3434^{defgh}	14462^{efgh}
CoF	Pizza	207^{fgh}	6405^{ghijk}	$4560^{cdefghij}$	$3250^{defghij}$	14422^{efgh}
PR	Remington	617^{bcdef}	$6833^{cdefghij}$	3288^{lmn}	2845^{ijkl}	13583^{ghi}
PR	Bealy	1071^{ab}	$6581^{efghijk}$	$4659^{cdefghij}$	3529^{cdefg}	15839^{bcdef}
PR	Trojan	1459^{a}	7885^{abcde}	3916^{hijkl}	3025^{ghijk}	16284^{bcde}
PR	Arrow	1435^{a}	$7711^{abcdefg}$	$4412^{defghijk}$	3476^{cdefgh}	17034^{bcd}
PR	Bronsyn	1382^{a}	$7407^{abcdefgh}$	3877_{ijkl}	3100^{efghij}	15766^{bcdefg}
BP	Ceres Atom	1449^{a}	8356^{a}	6289^{a}	3404^{defghi}	19497^{a}
BC	GBP02	534^{cdefg}	8083^{abc}	6126^{ab}	$3247^{defghij}$	17990^{ab}
LSD (0.05)		483.9	1310	962.1	580.0	2241

LSD (0.05) compares within season and over cultivars. ^{abc} Means with no common superscript, differ significantly.
TF: Tall Fescue; MF: Meadow Fescue; TFT: Tall Fescue Turf; CF: Chewings Fescue; RF: Red Fescue; CoF: Cocksfoot; PR: Perennial ryegrass;
BC: *Bromus catharticus*; BP: *Bromus parodii*

Table 17. Total seasonal and annual dry matter production (kg DM ha^{-1}) of temperate perennial grass cultivars during year 2.

Species	Cultivar	Winter	Spring	Summer	Autumn	Annual
TF	Kora	974^{hijkl}	$3831^{abcdefghi}$	4013^{bcdefg}	2957^{defg}	$11775^{bcdefghij}$
TF	Tuscany	821^{jkl}	4795^{abc}	4945^{a}	3479^{abcd}	14040^{abc}
TF	Barlite	1175^{fghij}	4302^{abcdef}	4118^{abcdef}	3366^{bcd}	12961^{abcdef}
TF	Verdant	1071^{ghijk}	4561^{abcd}	4270^{abcde}	3635^{abc}	13537^{abcd}
TF	Jenna	1226^{fghij}	4916^{ab}	4894^{ab}	3998^{a}	15035^{a}
TF	KR6505	2320^{ab}	$3945^{abcdefghi}$	2819^{ijklmn}	3307^{bcde}	$12390^{bcdefghi}$
TF	GFM24	2514^{a}	$4087^{abcdefg}$	2249^{mn}	2091^{ijklm}	$10940^{efghijk}$
TF	GFM29	1572^{ef}	$4083^{abcdefg}$	2202^{mn}	2083^{ijklm}	9941^{ijklmn}
TF	Bronson forage	896^{ijkl}	$4265^{abcdefg}$	3764^{cdefgh}	3363^{bcd}	$12288^{bcdefghi}$
TF	Baroptima	888^{ijkl}	$3469^{cdefghi}$	4322^{abcd}	3789^{ab}	$12468^{bcdefgh}$
TF	Bariane	949^{hijkl}	2589^{i}	4317^{abcd}	3386^{bcd}	$11241^{defghijk}$
TF	Barverde	2117^{abc}	4979^{a}	3059^{hijklm}	2616^{fghi}	$12772^{abcdefg}$
TF	Boschoek	1208^{fghij}	$4229^{abcdefg}$	4644^{abc}	3995^{a}	14075^{ab}
TF	Advance	1475^{efg}	$3648^{abcdefghi}$	3870^{cdefgh}	3401^{bcd}	$12394^{bcdefghi}$
TFT	Cochise	681^{klm}	2676^{hi}	2672^{jklmn}	2268^{hijk}	8297^{lmno}
TFT	Sidewinder	604^{lm}	$3659^{abcdefghi}$	2691^{jklmn}	2555^{fghi}	9509^{klmno}
MF	Laura	1081^{ghijk}	$3635^{abcdefghi}$	$3128^{ghijklm}$	2689^{fgh}	$10533^{fghijkl}$
MF	Jamaica	1215^{fghij}	2571^{i}	2487^{klmn}	1787^{klm}	8059^{mno}
CF	Rushmore	1144^{fghij}	2893^{ghi}	2529^{klmn}	1179^{n}	7745^{no}
RF	Gibraltar	1552^{ef}	3255^{defghi}	$3410^{defghijk}$	2272^{hijk}	$10489^{ghijklm}$
CoF	Athos	1471^{efg}	4663^{abc}	3900^{cdefgh}	3087^{cdef}	13121^{abcde}
CoF	Sparta	998^{hijkl}	$4258^{abcdefg}$	$3560^{defghij}$	2423^{ghij}	$11238^{defghijk}$
CoF	Niva	1079^{ghijk}	4561^{abcd}	$3575^{defghij}$	2367^{hijk}	$11581^{cdefghijk}$
CoF	Cristobal	1738^{cde}	$3721^{abcdefghi}$	3660^{defghi}	2480^{ghi}	$11599^{cdefghijk}$
CoF	Adremo	1317^{efghi}	4908^{ab}	3884^{cdefgh}	2743^{efgh}	$12851^{abcdefg}$
CoF	Barvillo	1351^{efgh}	4553^{abcd}	4131^{abcdef}	2648^{fghi}	$12684^{abcdefg}$
CoF	Barexcel	1008^{hijkl}	$3547^{bcdefghi}$	$3570^{defghij}$	2275^{hijk}	$10399^{ghijklm}$
CoF	Oxen	1689^{cde}	$3810^{abcdefghi}$	$3343^{efghijkl}$	2449^{ghi}	$11290^{defghijk}$
CoF	Hera	1100^{ghijk}	4354^{abcdef}	3847^{cdefgh}	2308^{hijk}	$11609^{bcdefghijk}$
CoF	Wana	1473^{efg}	4496^{abcde}	$3550^{defghij}$	2448^{ghi}	$11968^{bcdefghij}$
CoF	Pizza	369^{m}	$4061^{abcdefgh}$	$3521^{defghij}$	2167^{hijkl}	$10118^{hijklmn}$
PR	Remington	922^{hijkl}	2903^{ghi}	2033^{n}	1520^{mn}	7378^{o}
PR	Bealy	1663^{de}	$4240^{abcdefg}$	$3286^{fghijkl}$	2381^{ghij}	$11570^{cdefghijk}$
PR	Trojan	1467^{efg}	$3630^{abcdefghi}$	2424^{lmn}	1638^{lmn}	9159^{klmno}
PR	Arrow	1722^{cde}	$4054^{abcdefgh}$	2730^{ijklmn}	2324^{hijk}	$10830^{efghijk}$
PR	Bronsyn	1539^{ef}	3063^{fghi}	2736^{ijklmn}	2165^{hijkl}	9504^{klmno}
BP	Ceres Atom	2257^{ab}	4978^{a}	3244^{ijklmn}	1864^{jklm}	$12342^{bcdefghi}$
BC	GBP02	2020^{bcd}	3137^{efghi}	3859^{cdefgh}	2412^{ghij}	$11428^{defghijk}$
LSD (0.05)		483.9	436	1394	930	2471

LSD (0.05) compares within season and over cultivars. ^{abc} Means with no common superscript, differ significantly.
TF: Tall Fescue; MF: Meadow Fescue; TFT: Tall Fescue Turf; CF: Chewings Fescue; RF: Red Fescue; CoF: Cocksfoot; PR: Perennial ryegrass;
BC: *Bromus catharticus*; BP: *Bromus parodii*

Table 18. Total annual dry matter production (kg DM ha^{-1}) during year 1 and 2, total DM production over two years and reduction in yield (%) from year 1 to year 2 of temperate perennial grass cultivars.

Species	Cultivar	Year 1	Year 2	Total over years	% Reduction
TF	Kora	15082^{cdefgh}	$11775^{bcdefghij}$	26857	22
TF	Tuscany	15874^{bcdef}	14040^{abc}	29914	12
TF	Barlite	15419^{cdefg}	12961^{abcdef}	28380	16
TF	Verdant	16150^{bcde}	13537^{abcd}	29687	16
TF	Jenna	16345^{bcde}	15035^{a}	31380	8
TF	KR6505	16190^{bcde}	$12390^{bcdefghi}$	28580	23
TF	GFM24	13674^{fghi}	$10940^{efghijk}$	24614	20
TF	GFM29	14217^{efgh}	9941^{ijklmn}	24158	30
TF	Bronson forage	15297^{cdefgh}	$12288^{bcdefghi}$	27585	20
TF	Baroptima	16401^{bcde}	$12468^{bcdefgh}$	28869	24
TF	Bariane	17073^{bcd}	$11241^{defghijk}$	28314	34
TF	Barverde	13086^{hi}	$12772^{abcdefg}$	25858	2
TF	Boschoek	15003^{defgh}	14075^{ab}	29078	6
TF	Advance	15138^{cdefgh}	$12394^{bcdefghi}$	27532	18
MF	Laura	13148^{hi}	$10533^{fghijkl}$	23681	20
MF	Jamaica	14619^{efgh}	8059^{mno}	22678	45
TFT	Cochise	9461^{j}	8297^{lmno}	17758	12
TFT	Sidewinder	7723^{j}	9509^{klmno}	17232	-23
CF	Rushmore	9426^{j}	7745^{no}	17171	18
RF	Gibraltar	11774^{i}	$10489^{ghijklm}$	22263	11
CoF	Athos	16309^{bcde}	13121^{abcde}	29430	20
CoF	Sparta	13884^{fghi}	$11238^{defghijk}$	25122	19
CoF	Niva	13888^{fghi}	$11581^{cdefghijk}$	25469	17
CoF	Cristobal	17280^{abc}	$11599^{cdefghijk}$	28879	33
CoF	Adremo	16930^{bcd}	$12851^{abcdefg}$	29781	24
CoF	Barvillo	15828^{bcdef}	$12684^{abcdefg}$	28512	20
CoF	Barexcel	14599^{efgh}	$10399^{ghijklm}$	24998	29
CoF	Oxen	16376^{bcde}	$11290^{defghijk}$	27666	31
CoF	Hera	14463^{efgh}	$11609^{bcdefghijk}$	26072	20
CoF	Wana	14462^{efgh}	$11968^{bcdefghij}$	26430	17
CoF	Pizza	14422^{efgh}	$10118^{hijklmn}$	24540	30
PR	Remington	13583^{ghi}	7378^{o}	20961	46
PR	Bealy	15839^{bcdef}	$11570^{cdefghijk}$	27409	27
PR	Trojan	16284^{bcde}	9159^{klmno}	25443	44
PR	Arrow	17034^{bcd}	$10830^{efghijk}$	27864	36
PR	Bronsyn	15766^{bcdefg}	9504^{klmno}	25270	40
BP	Ceres Atom	19497^{a}	$12342^{bcdefghi}$	31839	37
BC	GBP02	17990^{ab}	$11428^{defghijk}$	29418	36
LSD (0.05)		2241	2471		

LSD (0.05) compares within season and over cultivars. ^{abc} Means with no common superscript, differ significantly.
TF: Tall Fescue; MF: Meadow Fescue; TFT: Tall Fescue Turf; CF: Chewings Fescue; RF: Red Fescue; CoF: Cocksfoot; PR: Perennial ryegrass; BC: *Bromus catharticus*; BP: *Bromus parodii*

5. The production potential of red clover, white clover, strawberry clover and trefoil cultivars

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Introduction

Grain and forage legumes occupy 12–15% of the Earth's arable land (Graham & Vance, 2003). Mixed pastures containing legumes, have the advantage over grass pastures – they are often of high quality and add N to the cropping system (Brock & Hay, 2001; Graham & Vance, 2003; Dahlin & Stenberg, 2010). Biologically-fixed nitrogen is derived from solar energy, whereas N fertilizer requires significant amounts of fossil fuels and other commercial energy sources to produce – perennial legumes are the most economical way of decreasing the reliance on these expensive sources of inorganic nitrogen (Neal *et al.*, 2009). The inclusion of perennial legumes and grasses is thus the most likely base for improving the sustainability and long-term survival of pasture systems (Cransberg & McFarlane, 1994). Clovers and trefoil are some of the most important forage legumes worldwide (Graham & Vance, 2003).

The variation in the spread of seasonal production between different cultivars and species, accompanied by the broad range of genetic resources available, necessitates the evaluation of different cultivars of perennial clovers and trefoil under the local climatic and environmental conditions of the Western Cape Province in South Africa. The aim of this study was to evaluate and compare the production potential of different perennial legumes such as white clover, red clover, strawberry clover and birdsfoot trefoil.

Materials and Methods

The study was carried out on the Outeniqua Research farm near George (Altitude 201 m, 33° 58' 38" S, 22° 25' 16" E, rainfall 728 mm year^{-1}) in the Western Cape Province of South Africa on a Witfontein soil form (Soil Classification Workgroup, 1991). The study area was under permanent overhead sprinkler irrigation, with irrigation scheduling undertaken by means of a tensiometer. Irrigation commenced at a tensiometer reading of -25 kPa and was terminated at a reading of -10 kPa (Botha 2002).

Soil samples were taken, prior to establishment, to a depth of 150mm and analysed for Ca, Mg, Na, K, P, Cu, Zn, Mn, B, S, and C levels. Fertiliser was applied according to the soil analysis to raise the P level of the soil to 35 mg kg^{-1}, K level to 80 mg kg^{-1} and pH (KCl) to 5,5 (Beyers 1973).

Species that were evaluated included white clover (*Trifolium repens*), red clover (*Trifolium pratense*), strawberry clover (*Trifolium fragiferum*) and birdsfoot trefoil (*Lotus corniculatis*). A total of 18 cultivars were evaluated in the form of a randomized block design, with three replicates per cultivar (total of 54 plots). The scientific name, common name, cultivar name and seeding rate of the legumes evaluated are given in Table 1.

The trial was established on 5 May 2011, on a paddock previously planted to perennial ryegrass-clover pastures. The paddock was sprayed with herbicide during January and tilled during February to remove existing sward. Three subsequent herbicide applications (up to establishment) were aimed at eradication of emerging weeds. Prior to establishment, the trial area was tilled with a disk harrow and kongskilde and rolled with a light land roller, to create a firm seedbed and eradicate any remaining weeds.

Table 1. The scientific name, common name, cultivar name and seeding rate of perennial legumes that were evaluated.

	Scientific name	Common name	Cultivar name	Seeding rate (kg ha^{-1})
1	*Trifolium repens*	White clover	Haifa	6
2	*Trifolium repens*	White clover	Huia	6
3	*Trifolium repens*	White clover	Agrimatt	6
4	*Trifolium repens*	White clover	Agridan	6
5	*Trifolium repens*	White clover	Riesling	6
6	*Trifolium repens*	White clover	Dusi	6
7	*Trifolium repens*	White clover	Klondike	6
8	*Trifolium repens*	White clover	Alice	6
9	*Trifolium pratense*	Red clover	Quinequeli	8
10	*Trifolium pratense*	Red clover	Tropero	8
11	*Trifolium pratense*	Red clover	Amos	8
12	*Trifolium pratense*	Red clover	Red gold	8
13	*Trifolium pratense*	Red clover	Kenland	8
14	*Trifolium pratense*	Red clover	Suez	8
15	*Trifolium pratense*	Red clover	Rajah	8
16	*Trifolium pratense*	Red clover	Lemmon	8
17	*Lotus corniculatis*	Trefoil	Sao Gabriel	5
18	*Trifolium fragiferum*	Strawberry clover	Palestine	6

The various cultivars/species were planted according to commercially recommended seeding rates, but adapted for germination percentages. Plots were 2,1 m x 6 m per treatment (12,6 m^2), with 14 rows at 15 cm intervals. All seed was inoculated with species-specific *Rhizobium*, a maximum of 2 hours before planting, and kept in a cool place until it could be planted. Seed was also treated with pesticide and fungicide prior to establishment. Immediately after establishment, each plot was raked lightly to cover seeds and maintain inoculant activity.

Plots were harvested using quadrats every 28 days, to determine growth rate (kg DM ha^{-1} day^{-1}) and dry matter (DM) production (kg DM ha^{-1}). Three quadrats of 0,25 m^2 were randomly placed per plot and cut to a height of 50 mm. The samples were pooled and weighed. A grab sample of approximately 500 g green material was taken from the pooled sample, weighed wet and dry to determine DM content. Samples were dried at 60°C for 72 hours to determine the dry weight. Afterwards, sampling plots were cut to a uniform height of 50 mm above ground level, using a Honda Lawnmower. Plots were only fertilised when deficiency symptoms became apparent or if deficiencies were identified in the soil analysis. Weed control was exercised mainly by mechanical means.

A Student LSD (least significant difference) at 5% significance level was performed to compare the treatment means (Ott, 1998). The STATS module of SAS version 9.2 (2008) was used to analyse the data. Data from various cultivars were also combined according to species, to determine the mean production of the different species.

Results and discussion

The mean monthly growth rate of perennial legume cultivars during year 1 and year 2 is shown in Table 2 and Table 3 respectively. During year 1, the white clover cultivar Dusi and red clover cultivars Tropero and Suez had the highest ($P<0.05$), or similar ($P>0.05$) to the highest, growth rate from August to December. From March to May during year 1, all the red clover cultivars had the lowest ($P<0.05$), or similar ($P>0.05$) to the lowest, growth rate. Red clover and trefoil cultivars were terminated after year 1 due to low production. During year 2 the strawberry clover cultivar Palestine had the highest ($P<0.05$,) or similar ($P>0.05$) to the highest, growth rate from July to January. The trial was terminated during January of year 2 due to declining production and weed infestation of the remaining cultivars.

The total seasonal and annual DM production of perennial legume cultivars during year 1 and year 2 is shown in Table 4 and Table 5 respectively. During year 1, the white clover cultivar Dusi and red clover cultivars Kenland, Suez and Rajah had the highest ($P<0.05$), or similar ($P>0.05$) to the highest, seasonal DM production, from winter to summer. During autumn of year 1, all the red clover cultivars and the trefoil cultivar Soa Gabriel had the lowest (P<0.05) DM production. The white clover cultivar Dusi had a similar (P>0.05) annual DM to other white clover cultivars Huia, Agrimatt, Agridan, Riesling and Alice, but higher (P<0.05) than the rest during year 1. During year 2, the strawberry clover cultivar Palestine had the highest (P<0.05) or similar (P>0.05) to the highest seasonal DM production from winter to summer, and the highest (P<0.05) total annual DM production.

Conclusions

1. The red clover cultivars Tropero, Suez and Rajah had high growth rates from August to December, but showed a marked decline in growth from January to May during year 1.
2. The white clover cultivars Dusi had the highest annual dry matter production during year 1, and also maintained a high growth rate from August to December. During year 2, the growth rate of white clover cultivars was lower than strawberry clover during all months except June, August and January.
3. White and red clover had the same production from winter to early summer, but red clover production declined from late summer during year 1 to very low rates during autumn.
4. Due to the ability of white clover to remain productive during autumn, it achieved a higher total annual dry matter production than red clover during year 1.
5. The majority of white clover cultivars showed a higher persistence than red clover. If planted in mixtures, the early growth of red clover and persistence of white clover could complement each other in the fodder-flow programme.
6. Strawberry clover was more productive than white clover in year 2.
7. Perennial legumes show poor persistence in this region.

MESSAGE TO THE FARMER

- The white clover cultivar Dusi, had a similar total annual dry matter production to that of Huia, Agrimatt, Agridan, Riesling and Alice during year 1, but higher than the rest.
- The poor persistence of red clover indicates that its growth pattern represents that of an annual in this region.
- Strawberry clover has the potential to out-yield white clover during the second year of production.
- The selection of complementary species and cultivars can improve fodder flow.

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Table 2. The mean monthly growth rate (kg DM ha^{-1} day^{-1}) of perennial legume cultivars during year 1.

Species	Cultivar	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
WC	Haifa	6.83^{a}	37.1^{fgh}	55.9^{defg}	44.4^{bc}	75.7^{abcd}	6.29^{b}	3.31^{abc}	21.6^{b}	20.9^{d}	18.2^{bc}
WC	Huia	3.89^{abcde}	49.8^{bcde}	56.6^{defg}	52.1^{abc}	59.3^{cd}	14.5^{b}	7.70^{a}	33.9^{a}	22.8^{cd}	26.6^{ab}
WC	Agrimatt	5.95^{abcd}	42.2^{efg}	57.2^{defg}	50.8^{abc}	61.9^{bcd}	12.7^{b}	3.74^{abc}	24.7^{b}	34.0^{a}	24.9^{ab}
WC	Agridan	6.51^{ab}	45.9^{def}	64.0^{bcde}	46.0^{bc}	78.1^{abcd}	13.9^{b}	7.92^{a}	27.6^{ab}	25.0^{cd}	25.5^{ab}
WC	Riesling	5.18^{abcd}	49.1^{bcdef}	60.3^{cdef}	54.0^{ab}	62.4^{bcd}	11.7^{b}	1.54^{bc}	22.0^{b}	27.5^{bc}	25.7^{ab}
WC	Dusi	6.77^{a}	60.7^{abc}	77.6^{a}	62.1^{a}	74.7^{abcd}	14.9^{b}	4.20^{abc}	26.0^{b}	23.1^{cd}	19.6^{abc}
WC	Kolndike	5.04^{abcd}	56.0^{abcd}	52.8^{efg}	43.3^{bc}	57.5^{d}	1.71^{b}	2.00^{bc}	27.4^{ab}	26.4^{bcd}	28.1^{a}
WC	Alice	6.32^{abc}	59.7^{abc}	61.6^{bcdef}	55.6^{ab}	66.4^{bcd}	11.0^{b}	6.61^{ab}	28.2^{ab}	31.2^{ab}	27.9^{a}
RC	Quineiqueli	2.97^{cde}	61.3^{ab}	65.0^{bcd}	37.7^{c}	82.1^{abcd}	8.60^{b}	3.07^{abc}	2.53^{d}	2.74^{f}	3.95^{d}
RC	Tropero	5.40^{abcd}	59.1^{abc}	71.1^{abc}	51.9^{abc}	73.1^{abcd}	6.65^{b}	3.30^{abc}	2.35^{d}	2.70^{f}	6.06^{d}
RC	Amos	2.72^{de}	29.7^{gh}	58.9^{def}	38.0^{c}	62.3^{bcd}	3.89^{b}	0.74^{c}	0^{d}	0^{f}	0.25^{d}
RC	Red gold	5.82^{abcd}	63.2^{a}	58.0^{def}	47.8^{abc}	76.0^{abcd}	7.68^{b}	4.89^{abc}	2.78^{d}	2.61^{f}	2.85^{d}
RC	Kenland	5.05^{abcd}	58.9^{abc}	65.1^{bcd}	51.2^{abc}	87.9^{ab}	12.6^{b}	5.22^{abc}	4.69^{cd}	3.11^{f}	4.23^{d}
RC	Suez	3.58^{abcde}	53.5^{abcde}	71.3^{abc}	53.6^{ab}	99.0^{a}	9.67^{b}	1.30^{bc}	0.54^{d}	0.49^{f}	0.51^{d}
RC	Rajah	3.71^{abcde}	48.9^{bcdef}	72.5^{ab}	53.1^{ab}	80.2^{abcd}	14.1^{b}	1.90^{bc}	4.59^{cd}	2.72^{f}	2.47^{d}
RC	Lemmon	5.21^{abcd}	48.6^{cdef}	64.9^{bcd}	48.5^{abc}	77.8^{abcd}	15.4^{b}	6.02^{abc}	5.06^{cd}	3.95^{f}	4.44^{d}
Trefoil	Soa Gabriel	0.85^{e}	28.3^{h}	51.3^{fg}	46.7^{bc}	79.0^{abcd}	40.3^{a}	2.09^{bc}	6.26^{cd}	0.57^{f}	0^{d}
SC	Palestine	3.25^{bcde}	45.4^{def}	46.1^{g}	16.6^{d}	84.2^{abc}	10.0^{b}	1.69^{bc}	11.4^{c}	14.9^{e}	15.7^{c}
		3.357	12.69	11.89	15.04	26.41	13.71	5.423	7.429	5.899	9.181

WC: white clover
RC: Red clover
SC: Strawberry clover
LSD (0.05) compares over cultivars within months
^{abc} Means with no common superscript, differ significantly

Table 3. The mean monthly growth rate (kg DM ha^{-1} day^{-1}) of perennial legume cultivars during year 2.

Species	Cultivar	June	July	Aug	Sept	Oct	Nov	Dec	Jan
WC	Haifa	8.00^{cd}	11.1^{cd}	14.3^{bc}	23.7^{bc}	24.3^{c}	29.0^{bc}	18.5^{c}	5.27^{bc}
WC	Huia	10.4^{b}	6.88^{de}	7.46^{d}	24.1^{bc}	29.1^{bc}	28.7^{bc}	30.7^{b}	7.21^{abc}
WC	Agrimatt	18.2^{a}	15.5^{bc}	18.4^{ab}	20.6^{bc}	28.6^{bc}	34.1^{b}	16.3^{c}	8.82^{ab}
WC	Agridan	18.0^{a}	16.9^{b}	17.8^{ab}	22.9^{bc}	24.1^{c}	28.2^{bc}	15.7^{c}	6.29^{abc}
WC	Riesling	8.72^{bc}	6.34^{e}	8.01^{d}	14.8^{d}	28.2^{bc}	26.5^{c}	31.0^{b}	13.4^{a}
WC	Dusi	6.88^{cd}	8.74^{de}	14.0^{bc}	17.9^{cd}	27.7^{bc}	31.9^{bc}	35.1^{ab}	11.7^{ab}
WC	Kolndike	8.85^{bc}	6.84^{de}	2.97^{de}	19.5^{bcd}	27.3^{bc}	25.9^{c}	17.1^{c}	7.00^{abc}
WC	Alice	10.8^{b}	10.6^{de}	8.36^{cd}	26.7^{b}	32.1^{b}	28.4^{bc}	33.6^{ab}	12.3^{ab}
RC	Quineiqueli	0^{e}	0^{f}	0^{e}	0^{e}	0^{d}	0^{d}	0^{d}	0^{c}
RC	Tropero	0^{e}	0^{f}	0^{e}	0^{e}	0^{d}	0^{d}	0^{d}	0^{c}
RC	Amos	0^{e}	0^{f}	0^{e}	0^{e}	0^{d}	0^{d}	0^{d}	0^{c}
RC	Red gold	0^{e}	0^{f}	0^{e}	0^{e}	0^{d}	0^{d}	0^{d}	0^{c}
RC	Kenland	0^{e}	0^{f}	0^{e}	0^{e}	0^{d}	0^{d}	0^{d}	0^{c}
RC	Suez	0^{e}	0^{f}	0^{e}	0^{e}	0^{d}	0^{d}	0^{d}	0^{c}
RC	Rajah	0^{e}	0^{f}	0^{e}	0^{e}	0^{d}	0^{d}	0^{d}	0^{c}
RC	Lemmon	0^{e}	0^{f}	0^{e}	0^{e}	0^{d}	0^{d}	0^{d}	0^{c}
Trefoil	Soa Gabriel	0^{e}	0^{f}	0^{e}	0^{e}	0^{d}	0^{d}	0^{d}	0^{c}
SC	Palestine	5.87^{d}	22.7^{a}	22.8^{a}	36.7^{a}	40.1^{a}	48.3^{a}	41.1^{a}	11.1^{ab}
		2.387	4.503	5.950	7.388	6.247	7.485	9.127	7.385

WC: white clover
RC: Red clover
SC: Strawberry clover
LSD (0.05) compares over cultivars within season
^{abc} Means with no common superscript, differ significantly

Table 4. Total seasonal and annual dry matter production (kg DM ha^{-1}) of perennial legume cultivars during year 1.

Species	Cultivar	Winter	Spring	Summer	Autumn	Annual
WC	Haifa	758^{a}	3879^{ef}	2502^{bcd}	1874^{c}	9014^{bcde}
WC	Huia	432^{abcde}	4495^{bcde}	2432^{bcd}	2332^{ab}	9690^{abcd}
WC	Agrimatt	660^{abcd}	4263^{def}	2319^{bcd}	2341^{ab}	9583^{abcd}
WC	Agridan	722^{ab}	4427^{bcde}	2965^{abc}	2187^{abc}	10302^{abc}
WC	Riesling	575^{abcd}	4636^{bcd}	2233^{bcd}	2107^{abc}	9550^{abcd}
WC	Dusi	752^{a}	5689^{a}	2778^{abcd}	1926^{bc}	11145^{a}
WC	Kolndike	560^{abcd}	4313^{cdef}	1785^{d}	2294^{abc}	8952^{bcde}
WC	Alice	702^{abc}	5016^{abc}	2488^{bcd}	2444^{a}	10649^{ab}
RC	Quineiqueli	329^{cde}	4657^{bcd}	2754^{abcde}	258^{e}	7999^{de}
RC	Tropero	599^{abcd}	5168^{ab}	2437^{bcd}	311^{e}	8515^{cde}
RC	Amos	302^{de}	3605^{fg}	1955^{cd}	6.90^{e}	5868^{f}
RC	Red gold	646^{abcd}	4791^{bcd}	2605^{abcd}	231^{e}	8273^{de}
RC	Kenland	560^{abcd}	4971^{abcd}	3119^{ab}	337^{e}	8986^{bcde}
RC	Suez	398^{abcde}	5068^{abc}	3222^{ab}	43.0^{e}	8730^{bcde}
RC	Rajah	412^{abcde}	4961^{abcd}	2839^{abc}	274^{e}	8486^{cde}
RC	Lemmon	579^{abcd}	4601^{bcde}	2939^{abc}	376^{e}	8495^{cde}
Trefoil	Soa Gabriel	94^{e}	3589^{fg}	3648^{a}	191^{e}	7522^{ef}
SC	Palestine	361^{bcde}	3071^{g}	2815^{abcd}	1175^{d}	7422^{ef}
LSD (0.05)		372.6	740.7	1053	452.4	1939

WC: white clover
RC: Red clover
SC: Strawberry clover
LSD (0.05) compares over cultivars within season
^{abc} Means with no common superscript, differ significantly

Table 5. Total seasonal and annual dry matter production (kg DM ha^{-1}) of perennial legume cultivars during year 2.

Species	Cultivar	Winter	Spring	Summer	Annual
WC	Haifa	865^{b}	2443^{bc}	679^{bc}	3987^{bc}
WC	Huia	694^{bc}	2579^{bc}	1085^{ab}	4358^{bc}
WC	Agrimatt	1464^{a}	2625^{bc}	712^{bc}	4801^{b}
WC	Agridan	1477^{a}	2383^{bc}	625^{c}	4484^{b}
WC	Riesling	649^{bc}	2166^{c}	1261^{a}	4077^{bc}
WC	Dusi	840^{b}	2438^{bc}	1335^{a}	4612^{b}
WC	Kolndike	515^{c}	2279^{bc}	679^{bc}	3473^{c}
WC	Alice	829^{b}	2742^{b}	1306^{a}	4877^{b}
RC	Quineiqueli	0^{d}	0^{d}	0^{d}	0^{d}
RC	Tropero	0^{d}	0^{d}	0^{d}	0^{d}
RC	Amos	0^{d}	0^{d}	0^{d}	0^{d}
RC	Red gold	0^{d}	0^{d}	0^{d}	0^{d}
RC	Kenland	0^{d}	0^{d}	0^{d}	0^{d}
RC	Suez	0^{d}	0^{d}	0^{d}	0^{d}
RC	Rajah	0^{d}	0^{d}	0^{d}	0^{d}
RC	Lemmon	0^{d}	0^{d}	0^{d}	0^{d}
Trefoil	Soa Gabriel	0^{d}	0^{d}	0^{d}	0^{d}
SC	Palestine	1439^{a}	3963^{a}	1492^{a}	6895^{a}
LSD (0.05)		257.8	509.8	420.3	975.8

WC: white clover
RC: Red clover
SC: Strawberry clover
LSD (0.05) compares over cultivars within season
^{abc} Means with no common superscript, differ significantly

6.

Production of sub-tropical grass species planted at two planting dates under rain-fed conditions in the southern Cape of South Africa

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Introduction

Milk and beef producers in the southern Cape, South Africa, are constantly searching for adapted cultivars to use in their production systems. These cultivars should be able to produce a sufficient amount of dry matter (DM) sustainably. The cool-season producer, ryegrass (*Lolium* spp.), warm-season producer, kikuyu (*Pennisetum clandestinum*), and a selection of legumes, form the pasture base in the southern Cape.

Traditionally, alternative warm-season grasses are not cultivated in the southern Cape, due to a lack of information about the production potential of these grasses in the area. These sub-tropical grasses include: bottle-brush grass (*Antephora pubescens*), common signal grass (*Brachiaria brizantha*), blue buffalo grass (*Cenchrus cilliaris*), rhodes grass (*Chloris gayana*), bermuda grass (*Cynodon dactylon*), smuts finger grass (*Digitaria eriantha*), weeping lovegrass (*Eragrostis curvula*), buffalo grass (*Panicum maximum*) and common ehrharta (*Ehrharta calycina*).

Warm-season grasses are adapted to warm, humid areas, receiving rain predominately in the summer months (Donaldson, 2001). The southern Cape, with its year round rainfall, is not known for its grass planes (Chippendall & Meredith, 1955). Due to a change in climatic conditions, it is possible that some of these grass species are adapted to produce quality fodder under rain-fed conditions in the southern Cape.

A short summary, focusing on a description of the considered species, requirements and uses thereof can be found in Table 1.

The aim of this study was to evaluate the production potential of 16 perennial sub-tropical grass cultivars planted at two planting dates in the southern Cape.

Materials and Methods

This study was carried out on the Outeniqua Research Farm near George (Altitude 201m, 33º 58' 38" S, 22º 25' 16" E, rainfall 728 mm year^{-1}) in the Western Cape Province of South Africa, and was executed under rain-fed conditions on a Witfontein soil form. Fertiliser was applied to raise the soil nutrient levels according to soil analysis recommendations.

Two trials were planted at different planting dates – 17 March 2010 and 24 November 2010. The trial area was sprayed with glyphosate three weeks before planting. Nitrogen (N) and phosphate (P) was applied at 60 kg ha^{-1} and 20 kg ha^{-1} respectively, before cultivation. The soil was scarified and tilled with a harrow disk and konskilde to create a seedbed, mix the fertiliser with the soil and remove dead plant litter. Seed was planted in 30 cm rows, after which the plots were rolled with a land roller.

Grasses were given sufficient time to establish. Sampling only commenced if 90% of the treatments had emerged and established. For the March trial, the grass was cut down during October 2010 as part of weed control – the first harvest took place three months later, during January 2011 (summer harvest). The November trial was also cut down three months prior to the first harvest in October 2011 (spring harvest).

The trial was managed as foggage and sampled on an approximately 90-day cycle, or when 60% of the trial reached the stage where it was suitable as foggage. A strip of pasture (1,23 m x 4,8 m) was cut with a cutter bar mower to a height of 100 mm and used for pasture yield determination and pasture sampling. A sample of approximately 500 g was placed in a brown paper bag and weighed wet and dry to determine DM content. Samples were dried in an oven at 60ºC for 72 hours to determine dry weight. Plots received post-harvest N and potassium (K) fertiliser at 60 kg N ha^{-1} and 20 kg K ha^{-1} per 1 ton DM produced ha^{-1}.

The experimental design was a randomised block design, with 16 treatments randomly allocated in 3 blocks. An appropriate analysis of variance was performed – the assumption of normality of the residuals was tested to ensure valid and reliable results (Shapiro & Wilk, 1965). A Student LSD (least significant difference) at 5% significance level was done to compare the treatment means (Ott, 1998). The STATS module of SAS version 9.2 was used to analyse the data (SAS Institute, Inc., 2008).

Results and discussion

March trial

Gayanda, the Blue Buffalo grass cultivar, failed to establish in the March trial.

Table 3 indicates the seasonal DM content (%) of perennial sub-tropical grass cultivars evaluated for the period summer 2010 to spring 2011. The cultivar Ermelo (pelleted) had a similar summer ($P>0.05$) DM content to Ermelo, but higher ($P<0.05$) than all the other cultivars. The cultivars Ermelo and Ermelo (pelleted) had a similar ($P>0.05$) autumn DM content to Agpal, PUK E436 and Wollie, but higher ($P<0.05$) than the other cultivars. The cultivars Agpal, Ermelo (pelleted) and Ermelo had the highest ($P<0.05$) winter DM content. The cultivars Ermelo (pelleted) and Ermelo had the highest ($P<0.05$) spring DM content. The cultivars Ermelo and Ermelo (pelleted) were the only cultivars that had the highest ($P<0.05$), and similar ($P>0.05$) to the highest, DM content during all seasons.

Table 4 indicates the seasonal DM production rate (kg DM ha^{-1} day^{-1}) of perennial sub-tropical grass cultivars evaluated for the period summer 2010 to spring 2011. The cultivars Katambora and Katambora (pelleted) had a similar summer ($P>0.05$) DM production rate to PUK E436 and Ermelo (pelleted), but higher ($P<0.05$) than the other cultivars. Katambora and Katambora (pelleted) had a similar autumn ($P>0.05$) DM production rate to Brachiaria, but higher ($P<0.05$) than the other cultivars. The cultivar Mission had the highest winter ($P<0.05$) DM production rate. The cultivars Irene (pelleted), Irene and Ermelo (pelleted) had a similar ($P>0.05$) spring DM production rate to Ermelo, Katambora (pelleted) and PUK E436, but higher ($P<0.05$) than the other cultivars. Katambora (pelleted) had the highest ($P<0.05$), or similar ($P>0.05$) to the highest, DM production rate during all seasons, except winter.

Table 5 indicates the total seasonal and annual dry matter production (kg DM ha^{-1}) of perennial sub-tropical grass cultivars evaluated for the period summer 2010 to spring 2011. The cultivars Katambora and Katambora (pelleted) had a ($P>0.05$) similar summer DM production to PUK E436 and Ermelo (pelleted), but higher ($P<0.05$) than the other cultivars. Katambora and Katambora (pelleted) had a similar autumn ($P>0.05$) DM production to Brachiaria, but higher ($P<0.05$) than all the other cultivars. The cultivar Mission had the highest winter ($P<0.05$) DM production. The cultivars Irene (pelleted), Irene and Ermelo (pelleted) had a similar spring ($P>0.05$) DM production to Ermelo, Katambora (pelleted) and PUK E436, but higher ($P<0.05$) than the other cultivars.

Katambora (pelleted) maintained the highest ($P<0.05$) seasonal DM production during all seasons except winter, when its production was lower ($P<0.05$) than that of the highest producing cultivar, Mission. The cultivar Katambora (pelleted) had a similar total annual ($P>0.05$) DM production to PUK E436 and Katambora, but higher ($P<0.05$) than the other cultivars.

November trial

Table 6 indicates the seasonal DM content of perennial sub-tropical grass cultivars evaluated for the period spring 2011 to winter 2012. The cultivars Wollie, Gayanda and Vaquero failed to produce dry matter during spring. The cultivars Ermelo, Ermelo (pelleted) and Agpal had the highest (P<0.05), or similar (P>0.05) to the highest, DM content during all seasons. Wollie and Mission had the lowest (P<0.05), or similar (P>0.05) to the lowest, DM content throughout all seasons.

Table 7 indicates the seasonal DM production rate (kg DM ha^{-1} day^{-1}) of perennial sub-tropical grass cultivars evaluated for the period spring 2011 to winter 2012. PUK E436 had a similar (P>0.05) spring dry matter production rate to Katambora (pelleted), Gatton and PUK 8, but higher (P<0.05) than all the other cultivars. Katambora and Katambora (pelleted) had a similar (P>0.05) summer dry matter production rate to Ermelo, but higher (P<0.05) than all the other cultivars. The cultivar Brachiaria had a similar (P>0.05) autumn dry matter production rate to Katambora, PUK E436, Ermelo and Gatton, but higher (P<0.05) than all the other cultivars. PUK E436 had the highest (P<0.05) winter dry matter production rate.

Katambora and Ermelo had the highest (P<0.05), or similar (P>0.05) to the highest, dry matter production rate during both summer and autumn. From spring to summer Katambora (pelleted) was the only cultivar that had the highest (P<0.05), or similar (P>0.05) to the highest, growth rate during both seasons. PUK E436 had the highest (P<0.05), or similar to the highest, production rate during all seasons, except autumn. Wollie had the lowest (P<0.05), or similar (P>0.05) to the lowest, production rate during all seasons.

Table 8 indicates the total seasonal and annual dry matter production (kg DM ha^{-1}) of perennial sub-tropical grass cultivars evaluated for the period spring 2011 to winter 2012. PUK E436 had a similar spring (P>0.05) dry matter production to Katambora (pelleted), Gatton and PUK 8, but higher (P<0.05) than all the other cultivars. Katambora and Katambora (pelleted) had a similar summer (P>0.05) dry matter production to Ermelo, but higher (P<0.05) than all the other cultivars. The cultivar Brachiaria had a similar (P>0.05) autumn dry matter production to Katambora, PUK E436, Ermelo and Gatton, but higher (P<0.05) than all the other cultivars. PUK E436 had the highest (P<0.05) winter dry matter production. The cultivars Katambora, Katambora (pelleted) and PUK E436 had a similar total (P>0.05) dry matter production to Ermelo, but higher (P<0.05) than all the other cultivars.

Wollie had the lowest (P<0.05), or similar (P>0.05) to the lowest, seasonal dry matter production throughout all seasons – it also had the lowest (P<0.05) total DM production at 170 kg DM ha^{-1}. Katambora, Katambora (pelleted) and PUK E436 had a similar (P>0.05) total annual DM production to Ermelo, but higher (P>0.05) than the rest. These cultivars achieved high seasonal production for at least two consecutive seasons:

- Katambora: Summer/Autumn
- Katambora (pelleted): Spring/Summer
- PUK E436: Autumn/Winter
- Ermelo: Summer/Autumn

Conclusion

In the March trial, the Rhodes grass cultivars Katambora and Katambora (pelleted) and the weeping lovegrass cultivar PUK E436 were the most productive cultivars. The weeping lovegrass cultivars Ermelo and Ermelo (pelleted) had the highest or similar to the highest, DM content over all four seasons.

Katambora, Katambora (pelleted), PUK E436 and Ermelo were the most productive cultivars in the November trial. Ermelo, Ermelo (pelleted) and the weeping lovegrass cultivar Agpal had the highest or similar to the highest, DM content over all four seasons.

MESSAGE TO THE FARMER

In both the March and November trials, Katambora, Katambora (pelleted), PUK E436 and Ermelo (for the November planting date only) produced the highest total amount of dry matter. This ranged between 16,4 to 17,9 tons per hectare for the March planting date and 11,9 to 12,9 tons per hectare for the November planting date.

The cultivars with the highest dry matter content were not necessarily the cultivars with the highest dry matter production. This was only true for the November planting date where Ermelo had the highest dry matter content over all four seasons (ranging from 39,6 to 50,3 %), as well as being one of the highest dry matter producers.

Katambora had the highest dry matter production during summer and autumn for both planting dates. All cultivars showed a decrease in dry matter production during winter for both planting dates, except Mission.

As foggage, the rhodes grass and weeping lovegrass cultivars may prove to be valuable, especially during summer and autumn. Mission was the only cultivar that had a high winter dry matter production during both years.

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Table 1. Description, soil and climate requirements, as well as application of the different summer grass species.

Species	Description	Soil and climate	Uses
Antephorapubescens	Perennial[1,2,3] Tufted[1,2,3] Creeping rhizomes[1,3] Height: 30-1000 mm[1] Palatable[2]	Soil: Widely adapted but prefers sandy soil[2] Area: Dry, warm[2] Rainfall: >350 mm[2]	Foggage[2]
Brachiaria brizantha	Perennial[1] Robust[1] Height: max 2000 mm[1]	Soil: Adapted to most soil types[4]	Fodder[1] Grazing[4]
Cenchrus ciliaris	Perennial[1,2] Tufted[1,2] Stoloniferous[1] Height: 90-1200 mm[1]	Soil: Widely adapted but not on light sandy soils[2] Area: Dry, warm[2]	Pasture[1] Hay[1,2]
Chloris gayana	Perennial[1,3] Tufted with stolons[1,2,3]	Soil: Adapted to most soil types[2] Area: Sub-tropical to temperate; low rainfall[2]	Pasture[1,2] Hay[1]
Cynodon dactylon	Perennial[1,3] Creeping rhizomes and stolons[1,3]	Soil: High fertility[2] Area: Warm[2] Rainfall: >500 mm[2]	Pasture[2] Hay[2] Pioneer – erosion control[1]
Digitaria eriantha	Perennial[1,2,3] Tufted[1,2,3] Creeping rhizomes[1] Height: 300-900 mm[1]	Soil: Adapted to most soil types[2,3] Rainfall: >500 mm[2]	Foggage[2] Fodder[1] Hay[2]
Eragrostis curvula	Perennial[1,2,3] Tufted[1,2,3] Height: 300-1200 mm[1]	Soil: Widely adapted put prefers acidic sandy soil[2, 3] Rainfall: >650 mm[2]	Fodder[1] Pasture[2] Hay[2] Ley[1]
Panicum maximum	Perennial[1,3] Tufted[1,3] Creeping rhizomes[1,3] Height: 600-2000 mm[1]	Soil: Adapted to most soil types[3] Area: Tropical and sub-tropical[3] Rainfall: >625 mm[3]	Foggage[3] Pasture[1,3] Hay[1,3] Silage[3]
Ehrharta calycina	Perennial[1] Creeping rhizomes[1] Height: 300-700 mm[1]		Pasture[1]

[1] Chippendall & Meredith, 1955; [2] Kynoch Pasture Handbook, 2004;
[3] Donaldson, 2001; [4] Tropical Forages, no date.

Table 2. Different perennial summer grasses and cultivars, with prescribed seeding rates, used in the trials.

Species	Common name	Cultivar	Seeding rate (kg ha⁻¹)*
Antephorapubescens	Bottle Brush Grass / Wool Grass	Wollie	5
Brachiariabrizantha	Common Signal Grass	Brachiaria	4
Cenchruscilliaris	Blue Buffalo Grass	Gayanda	3
Chlorisgayana	Rhodes Grass	Katambora	5
Chlorisgayana	Rhodes Grass	Katambora#	27.5
Cynodondactylon	Bermuda Grass / Couch Grass	Bermuda	6
Cynodondactylon	Bermuda Grass / Couch Grass	Vaquero	6
Digitariaeriantha	Smuts Finger Grass	Irene	3
Digitariaeriantha	Smuts Finger Grass	Irene#	7
Eragrostis curvula	Weeping Lovegrass	PUK E436	2
Eragrostis curvula	Weeping Lovegrass	Ermelo#	3
Eragrostis curvula	Weeping Lovegrass	Agpal	2
Eragrostis curvula	Weeping Lovegrass	Ermelo	2
Panicum maximum	Buffalo Grass	Gatton	4
Panicum maximum	Buffalo Grass	PUK 8	4
Ehrhartacalycina	Common Ehrharta	Mission	3

*The seeding rates used are as prescribed by Agricol (2007).
#Pelleted seeds.

Table 3. The seasonal dry matter content (%) for the period summer 2010 to spring 2011, of perennial sub-tropical grass cultivars planted during March 2010.

Cultivars	Summer	Autumn	Winter	Spring
Wollie	-	42.3^{abcd}	.	.
Brachiaria	21.7^{de}	25.6^{e}	28.1^{cd}	31.4^{f}
Gayanda	-	-	.	.
Katambora	20.3^{ef}	31.0^{cde}	27.4^{cd}	24.2^{de}
Katambora#	24.1^{de}	31.0^{cde}	28.8^{c}	23.9^{de}
Bermuda	23.0^{de}	30.4^{cde}	.	.
Vaquero	16.9^{f}	27.8^{de}	.	.
Irene	25.2^{d}	34.1^{bcde}	26.9^{cd}	25.7^{d}
Irene#	25.9^{d}	32.9^{bcde}	27.8^{cd}	25.6^{d}
PUK E436	37.5^{b}	45.7^{abc}	33.7^{b}	37.7^{b}
Ermelo#	43.2^{a}	50.2^{a}	40.1^{a}	41.7^{a}
Agpal	35.9^{bc}	48.1^{ab}	43.0^{a}	38.0^{b}
Ermelo	39.6^{ab}	50.3^{a}	40.1^{a}	40.1^{a}
Gatton	23.4^{de}	29.3^{de}	25.1^{de}	22.1^{f}
PUK 8	22.9^{de}	30.8^{cde}	26.5^{cde}	22.8^{ef}
Mission	32.2^{c}	30.5^{cde}	23.6^{e}	29.8^{c}
***LSD (0.05)¹**	4.25	15.72	3.35	1.86
****LSD (0.05)²**	8.066			

abcde Means with no common superscript, differ significantly (P<0.05);
LSD = Least Significant Difference; #Pelleted seed; *LSD (0.05)¹ = Compare within seasons;
**LSD (0.05)² = Compare over seasons.

Table 4. The seasonal dry matter production rate (kg DM ha^{-1} day^{-1}) for the period summer 2010 to spring 2011, of perennial sub-tropical grass cultivars planted during March 2010.

Cultivars	Summer	Autumn	Winter	Spring
Wollie	0^{f}	1.41^{f}	0^{f}	0^{f}
Brachiaria	22.6^{cde}	54.7^{ab}	2.65^{ef}	19.6^{e}
Gayanda	-	-	-	-
Katambora	49.9^{a}	62.7^{a}	8.72^{cd}	44.3^{bc}
Katambora#	49.3^{a}	65.4^{a}	11.0^{c}	55.4^{ab}
Bermuda	0^{f}	2.54^{f}	0^{f}	0^{f}
Vaquero	0.10^{f}	1.00^{f}	0^{f}	0^{f}
Irene	14.8^{ef}	32.7^{de}	1.77^{f}	62.1^{a}
Irene#	16.2^{def}	35.3^{de}	1.49^{f}	67.6^{a}
PUK E436	40.8^{ab}	43.6^{cd}	24.8^{b}	54.5^{ab}
Ermelo#	38.1^{abc}	37.6^{de}	9.14^{cd}	61.3^{a}
Agpal	22.1^{cde}	27.0^{e}	6.55^{de}	37.5^{cd}
Ermelo	30.5^{bcde}	37.3^{de}	10.9^{c}	55.5^{ab}
Gatton	29.9^{bcde}	49.1^{bc}	9.77^{cd}	44.3^{bc}
PUK 8	17.9^{de}	51.1^{bc}	9.71^{cd}	37.6^{cd}
Mission	32.2^{bcd}	6.53^{f}	40.0^{a}	23.9^{de}
***LSD (0.05)^{1}**	16.773	11.037	4.329	13.744
****LSD(0.05)^{2}**	11.112			

^{abcde} Means with no common superscript, differ significantly ($P<0.05$);
LSD = Least Significant Difference; #Pelleted seed; *LSD (0.05)^{1} = Compare within seasons;
**LSD (0.05)^{2} = Compare over seasons.

Table 5. The seasonal and total dry matter production (kg DM ha^{-1}) for the period summer 2010 to spring 2011, of perennial sub-tropical grass cultivars planted during March 2010.

Cultivars	Summer	Autumn	Winter	Spring	Total DM production
Wollie	0^{f}	152^{f}	0^{f}	0^{f}	152^{g}
Brachiaria	2075^{cde}	5912^{ab}	403^{ef}	1647^{e}	10037^{ef}
Gayanda	.	.	.	.	.
Katambora	4589^{a}	6776^{a}	1326^{cd}	3724^{bc}	16412^{abc}
Katambora#	4533^{a}	7064^{a}	1677^{c}	4655^{ab}	17929^{a}
Bermuda	42^{f}	274^{f}	0^{f}	0^{f}	315^{g}
Vaquero	9^{f}	108^{f}	0^{f}	0^{f}	114^{g}
Irene	1360^{ef}	3536de	270^{f}	5214^{a}	10380^{ef}
Irene#	1492^{def}	3807de	227^{f}	5677^{a}	11202^{def}
PUK E436	3753^{ab}	4709^{cd}	3768^{b}	4576^{ab}	16806^{ab}
Ermelo#	3501^{abc}	4064de	1390^{cd}	5149^{a}	14104^{bcd}
Agpal	2028^{cde}	2912^{e}	996de	3151^{cd}	9087^{f}
Ermelo	2805^{bcde}	4029de	1656^{c}	4658^{ab}	13147^{cde}
Gatton	2746^{bcde}	5299^{bc}	1486^{cd}	3719^{bc}	13250^{cde}
PUK 8	1623de	5523^{bc}	1475^{cd}	3159^{cd}	11779^{def}
Mission	2960^{bcd}	705^{f}	6078^{a}	2007de	11749^{def}
***LSD (0.05)^{1}**	1543.0	1191.8	657.9	1154.5	3270.8
****LSD(0.05)^{2}**	1048.8				

^{abcde} Means with no common superscript, differ significantly ($P<0.05$);
LSD = Least Significant Difference; #Pelleted seed; *LSD (0.05)^{1} = Compare within seasons;
**LSD (0.05)^{2} = Compare over seasons.

Table 6. The seasonal dry matter content (%) for the period spring 2011 to winter 2012, of perennial sub-tropical grass cultivars planted during November 2010.

Cultivars	Spring	Summer	Autumn	Winter
Wollie	-	14.8^{b}	27.6^{efg}	11.9^{gh}
Brachiaria	40.9^{a}	38.0^{ab}	22.8^{g}	38.1^{abcde}
Gayanda	-	28.4^{ab}	32.7^{cd}	25.2^{defgh}
Katambora	26.3^{ab}	30.3^{ab}	31.3^{cde}	33.6^{abcdef}
Katambora#	27.6^{ab}	31.8^{ab}	27.9^{def}	32.1^{bcdef}
Bermuda	14.3^{b}	30.0^{ab}	36.2^{c}	16.4^{fgh}
Vaquero	-	14.9^{b}	33.2^{c}	11.1^{h}
Irene	21.4^{ab}	34.1^{ab}	32.0^{cde}	-
Irene#	24.2^{ab}	32.5^{ab}	31.8^{cde}	-
PUK E436	37.2^{ab}	46.0^{a}	43.1^{b}	41.5^{abcd}
Ermelo#	27.3^{ab}	32.8^{ab}	49.3^{a}	50.5^{a}
Agpal	39.5^{a}	46.0^{a}	45.1^{ab}	47.6^{ab}
Ermelo	41.1^{a}	51.1^{a}	44.9^{ab}	46.5^{abc}
Gatton	28.8^{ab}	28.9^{ab}	27.1^{efg}	29.1^{cdefg}
PUK 8	27.9^{ab}	31.6^{ab}	25.8^{fg}	30.3^{bcdef}
Mission	18.4^{ab}	13.1^{b}	27.7^{efg}	22.2^{efgh}
***LSD (0.05)¹**	24.719	25.844	4.974	17.436
****LSD (0.05)²**	19.599			

abcde Means with no common superscript, differ significantly (P<0.05);
LSD = Least Significant Difference; #Pelleted seed; *LSD (0.05)¹ = Compare within seasons;
**LSD (0.05)² = Compare over seasons.

Table 7. The seasonal dry matter production rate (kg DM ha^{-1} day^{-1}) for the period spring 2011 to winter 2012, of perennial sub-tropical grass cultivars planted during November 2010.

Cultivars	Spring	Summer	Autumn	Winter
Wollie	0^{f}	0.33^{g}	1.17^{f}	0.11^{fg}
Brachiaria	1.42^{ef}	18.4^{efg}	50.6^{a}	0.74^{efg}
Gayanda	0^{f}	1.42^{g}	17.8^{e}	0.25^{fg}
Katambora	12.1^{bc}	76.2^{a}	47.2^{ab}	2.74^{def}
Katambora#	14.3^{ab}	76.4^{a}	38.1^{bc}	3.16^{cde}
Bermuda	4.98^{def}	5.32^{fg}	16.8^{e}	0.32^{fg}
Vaquero	0^{f}	1.77^{g}	16.6^{e}	0.22^{fg}
Irene	0.69^{ef}	37.7^{cde}	26.6^{de}	0.00^{g}
Irene#	0.73^{ef}	44.3^{cd}	26.3^{de}	0.00^{g}
PUK E436	19.6^{a}	45.4^{bcd}	42.3^{abc}	13.9^{a}
Ermelo#	0.56^{ef}	29.3^{de}	31.7^{cd}	3.69^{cd}
Agpal	3.25^{def}	51.5^{bc}	37.6^{bcd}	5.42^{cd}
Ermelo	7.74^{cd}	65.4^{ab}	45.9^{ab}	5.86^{bc}
Gatton	14.0^{ab}	35.8^{cde}	40.6^{abc}	5.20^{cd}
PUK 8	17.7^{ab}	23.6^{ef}	38.3^{bc}	4.48^{cd}
Mission	6.59^{cde}	4.00^{fg}	1.40^{f}	8.50^{b}
***LSD (0.05)¹**	6.232	20.206	11.479	2.702
****LSD(0.05)²**	11.853			

abcde Means with no common superscript, differ significantly (P<0.05);
LSD = Least Significant Difference; #Pelleted seed; *LSD (0.05)¹ = Compare within seasons;
**LSD (0.05)² = Compare over seasons.

Table 8. The seasonal and total dry matter production (kg DM ha^{-1}) for the period spring 2011 to winter 2012, of perennial sub-tropical grass cultivars planted during November 2010.

Cultivars	Spring	Summer	Autumn	Winter	Total DM production
Wollie	0^{f}	28^{g}	128^{f}	14^{fg}	170^{f}
Brachiaria	128^{ef}	1530^{efg}	5510^{a}	96^{efg}	7264^{cd}
Gayanda	0^{f}	118^{g}	1940^{e}	32^{fg}	2089^{ef}
Katambora	1088^{bc}	6321^{a}	5142^{ab}	353^{def}	12904^{a}
Katambora#	1286^{ab}	6342^{a}	4155^{bc}	408^{cde}	12192^{a}
Bermuda	448^{def}	441^{fg}	1835^{e}	41^{fg}	2766^{e}
Vaquero	0^{f}	147^{g}	1809^{e}	28^{fg}	1983^{ef}
Irene	62^{ef}	3129^{cde}	2902^{de}	0^{g}	6092^{d}
Irene#	66^{ef}	3677^{cd}	2861^{de}	0^{g}	6603^{d}
PUK E436	1768^{a}	3766^{bcd}	4608^{abc}	1791^{a}	11932^{a}
Ermelo#	50^{ef}	2431^{de}	3456^{cd}	476^{cd}	6413^{d}
Agpal	293^{def}	4271^{bc}	4102^{bcd}	699^{cd}	9365^{bc}
Ermelo	696^{cd}	5426^{ab}	4999^{ab}	756^{bc}	11877^{ab}
Gatton	1258^{ab}	2971^{cde}	4425^{abc}	671^{cd}	9323^{bc}
PUK 8	1592^{ab}	1961^{ef}	4177^{bc}	578^{cd}	8309^{cd}
Mission	593^{cde}	332^{fg}	153^{f}	1096^{b}	2174^{ef}
***LSD (0.05)[1]**	560.9	1677.1	1251.1	348.6	2557.7
****LSD(0.05)[2]**	1077.2				

[abcde] Means with no common superscript, differ significantly ($P<0.05$);
LSD = Least Significant Difference; #Pelleted seed; *LSD (0.05)[1] = Compare within seasons;
**LSD (0.05)[2] = Compare over seasons.

7. The production potential of Italian and Westerwolds ryegrasses planted at different planting dates

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Introduction

The seasonal variation in growth and nutritional value of perennial pastures restrict animal production. The fodder-flow programme for dairy and beef cattle production units in the coastal region of the southern Cape in South Africa, consists mainly of combinations of perennial pastures such as lucerne (*Medicago sativa*), kikuyu (*Pennisetum clandestinum*), perennial ryegrass (*Lolium multiflorum*) and clover species (*Trifolium repens* en *T. pratense*). The growth rates of these crops differ during spring, summer and autumn, but reach a mutual low during winter (Van Heerden *et al*,. 1989).

In an effort to overcome the problem of pasture shortages during winter, seasonal variation in growth and pasture quality, farmers in the southern Cape plant annual ryegrass (Lolium multiflorum spp.) in pure stands, in mixtures with other annual grasses or as crops over-sown into perennial pastures. Data regarding the production potential of annual ryegrass planted at different planting dates is inadequate to assist in accurate fodder-flow planning. The aim of this study was to determine the pasture production potential of Italian and Westerwolds ryegrasses planted at different planting dates.

Materials and Methods

The study was carried out between 2009 and 2011 on the Outeniqua Research Farm near George (Altitude 201 m, 33° 58' 38" S, 22° 25' 16" E, rainfall 729 mm year^{-1}) in the Western Cape Province of South Africa. The area has a temperate climate, with mean minimum and maximum air temperatures varying between 7°C -15°C and 18°C - 25°C, respectively. The study was a small-plot trial carried out on an Estcourt soil type (Soil Classification Workgroup 1991) under irrigation. The grasses were sown in 150 mm rows at a seeding rate of 20 kg ha^{-1} for the diploid and 25 kg ha^{-1} for the tetraploid cultivars. Plot size for each cultivar was 10,5 m^2. Irrigation was applied by means of a permanent overhead sprinkler system in one or two applications per week, at rates of 10-15 mm, based on tensiometer readings. Irrigation commenced at a tensiometer reading of -25 kPa and was terminated at a reading of -10 kPa. Annual ryegrass (*L. multiflorum*) varieties, i.e. Italicum (Italian ryegrass) and westerwoldicum (westerwolds ryegrass) were evaluated. The data of four Italian and four Westerwolds ryegrass cultivars planted in separate plots were pooled and the production rate and total production calculated. The varieties, ploid and cultivars combined and used as treatments, are given in Table 1.

Prior to planting, fertiliser was applied according to the soil analysis to raise soil phosphorous (P) level to 35 mg kg^{-1} (citric acid), potassium (K) level to 80 mg kg^{-1} and pH (KCl) to 5.5. Nitrogen (N) was applied to the grass and grass-legume pastures at a rate of 50 kg N ha^{-1} month^{-1}.

All the treatments were planted in 24 consecutive months from May 2009 until April 2011 in a well-prepared seedbed. The dry matter (DM) production was estimated by cutting the treatments by means of a sickle bar mover set to a height of 50 mm, at an interval of 28-35 days, when the ryegrasses had reached the three leave stage or when overshadowing of the growing points of grasses had started to occur (Fulkerson & Donaghy 2001). Samples were dried at 60ºC for 72 hours to a constant mass and weighed to determine DM content (%) and dry matter (DM) production.

The trial was a randomised complete block design with 184 treatment combinations randomly replicated in two blocks. Two factors, planting dates and cultivars, were used in the factorial treatment design. An appropriate analysis of variance (ANOVA) was performed, using SAS/STAT software, Version 9.2 (SAS, 2008). The Shapiro-Wilk test (Shapiro & Wilk, 1965) was performed to test normality of residuals. A Student LSD (least significant difference) (Ott, 1993) was calculated at a 5% significance level to compare treatment means.

The two treatments evaluated during the trial according to annual ryegrass variety, ploidy and cultivar combinations are given in Table 1.

Table 1. The two treatments evaluated during the trial according to annual ryegrass (*L. multiflorum*) variety, ploidy and cultivar combinations.

Treatment	Variety	ploidy	Cultivar
1	Italian	Diploid	Agriton
	Italian	Diploid	Enhancer
	Italian	Tetraploid	Jeanne
	Italian	Tetraploid	Parfait
2	Westerwolds	Diploid	Agri-Hilton
	Westerwolds	Tetraploid	Archie
	Westerwolds	Tetraploid	Energa
	Westerwolds	Tetraploid	Jivet

Results and discussion

Figures 1a – 12a show the annual combined monthly growth rate (kg DM ha-1 day^{-1}) over two years of Italian and Westerwolds ryegrass cultivars planted at different planting dates.

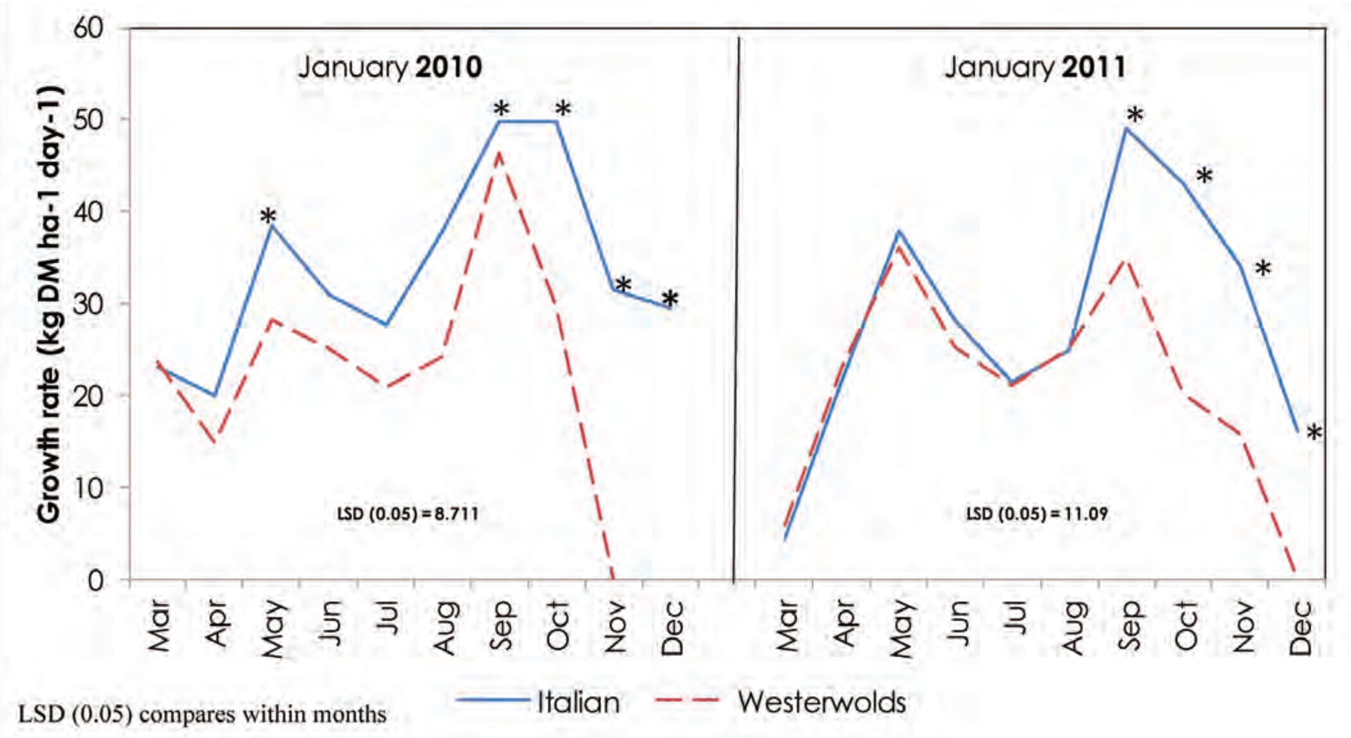

Figure 1a. Monthly growth rate of Italian and Westerwolds ryegrass planted during January 2010 and January 2011.

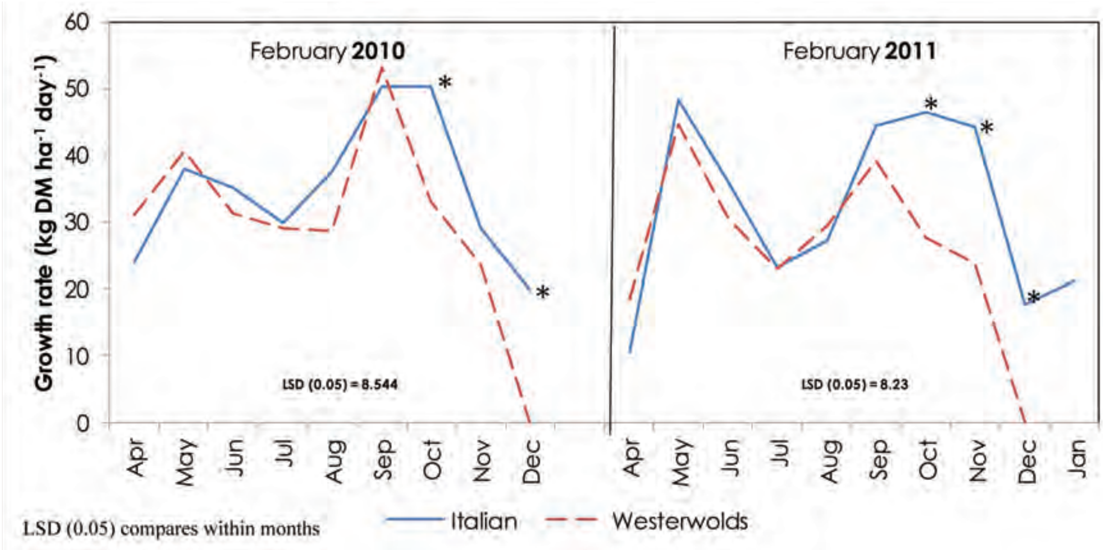

Figure 2a. Monthly growth rate of Italian and Westerwolds ryegrass planted during February 2010 and February 2011.

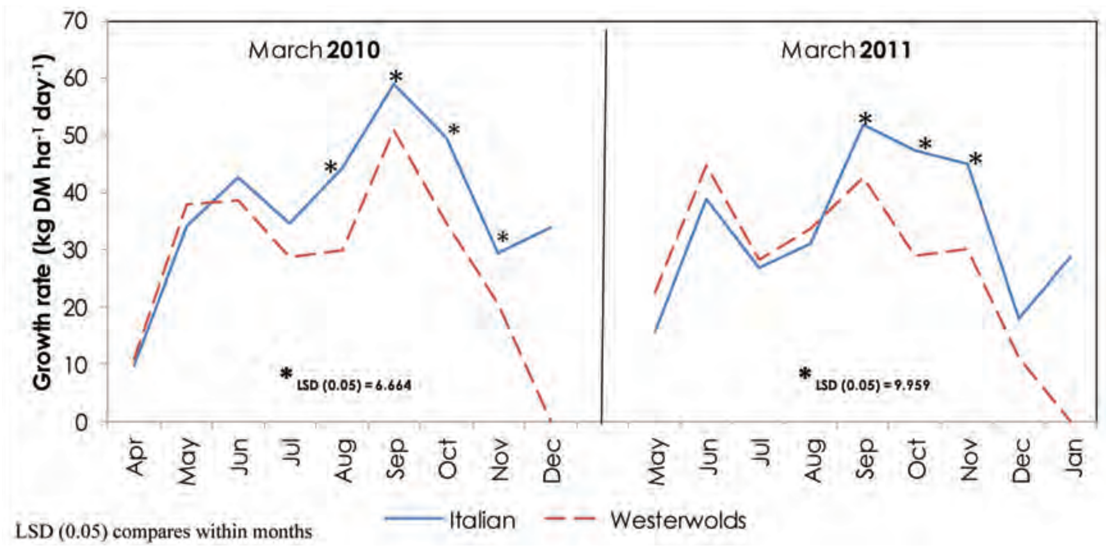

Figure 3a. Monthly growth rate of Italian and Westerwolds ryegrass planted during March 2010 and March 2011.

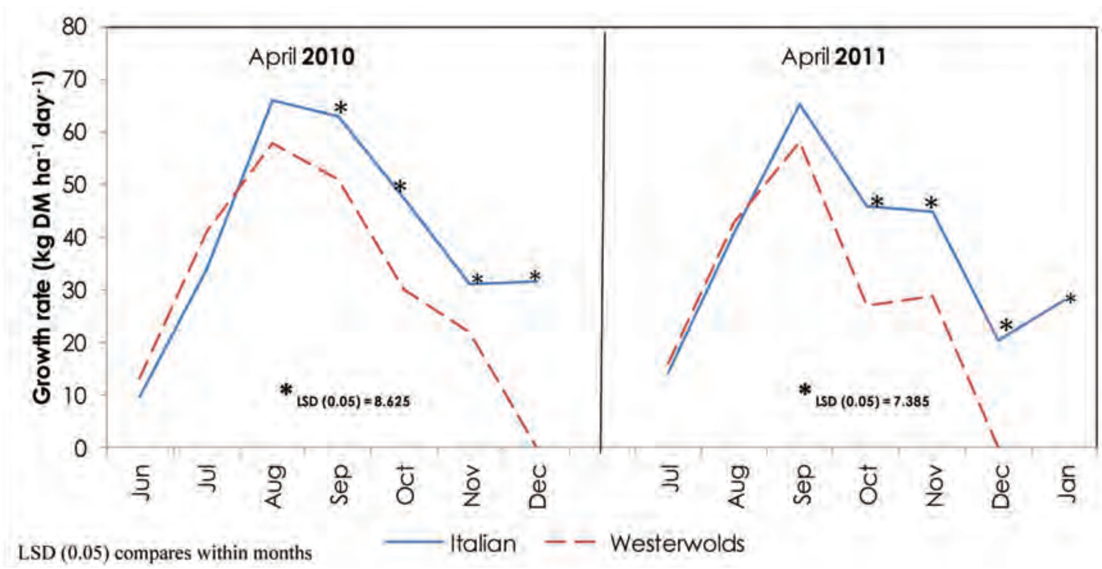

Figure 4a. Monthly growth rate of Italian and Westerwolds ryegrass planted during April 2010 and April 2011.

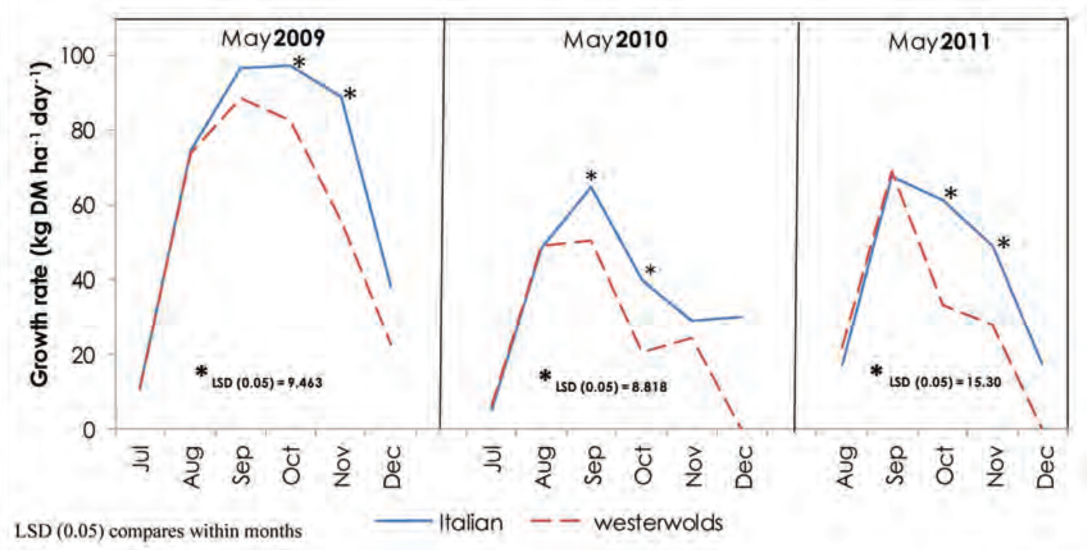

Figure 5a. Monthly growth rate of Italian and Westerwolds ryegrass planted during May 2009, May 2010, and May 2011.

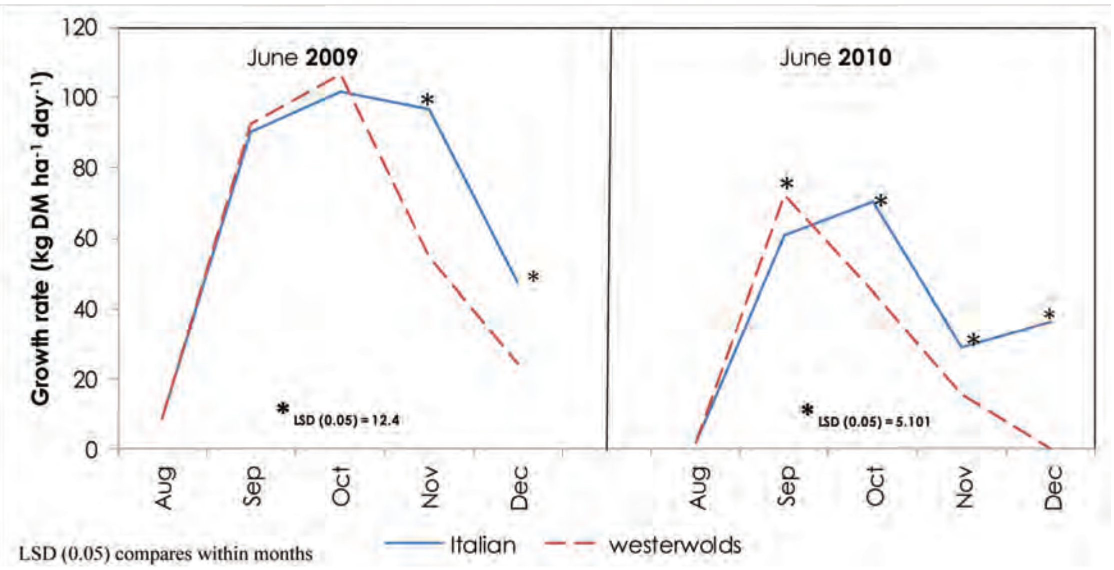

Figure 6a. Monthly growth rate of Italian and Westerwolds ryegrass planted during June 2009 and June 2010.

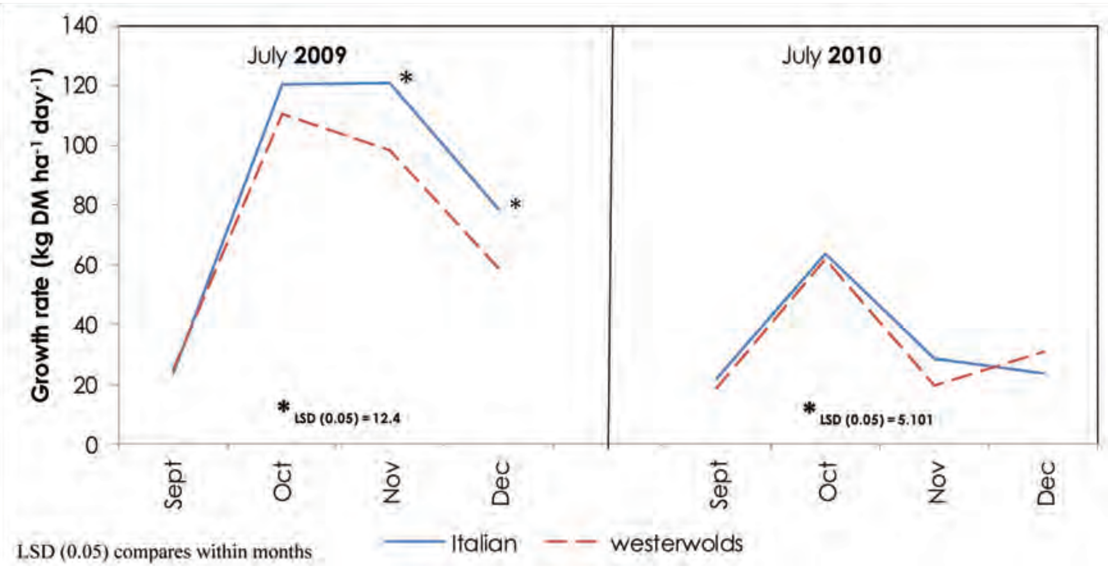

Figure 7a. Monthly growth rate of Italian and Westerwolds ryegrass planted during July 2009 and July 2010.

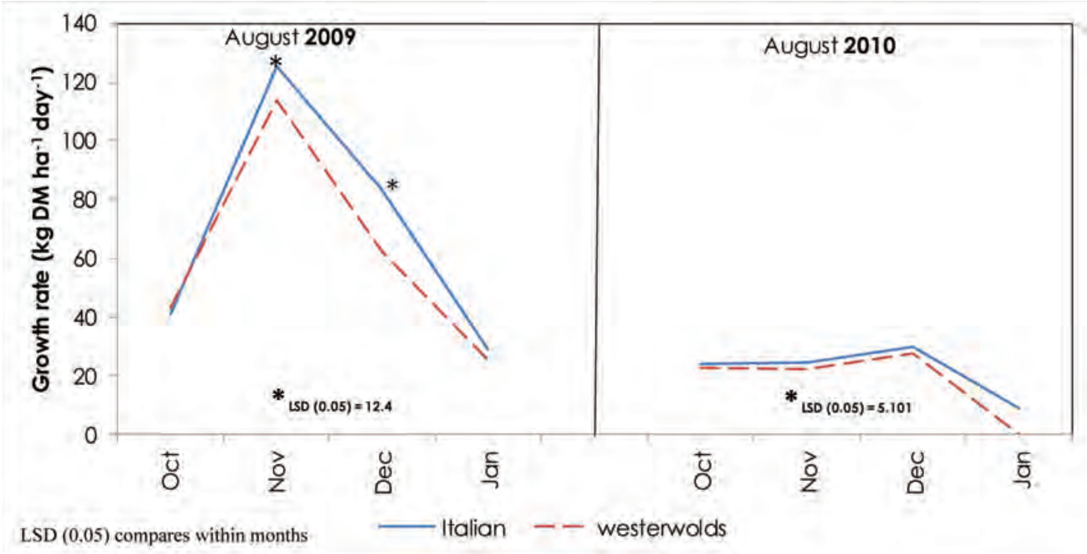

Figure 8a. Monthly growth rate of Italian and Westerwolds ryegrass planted during August 2009 and August 2010.

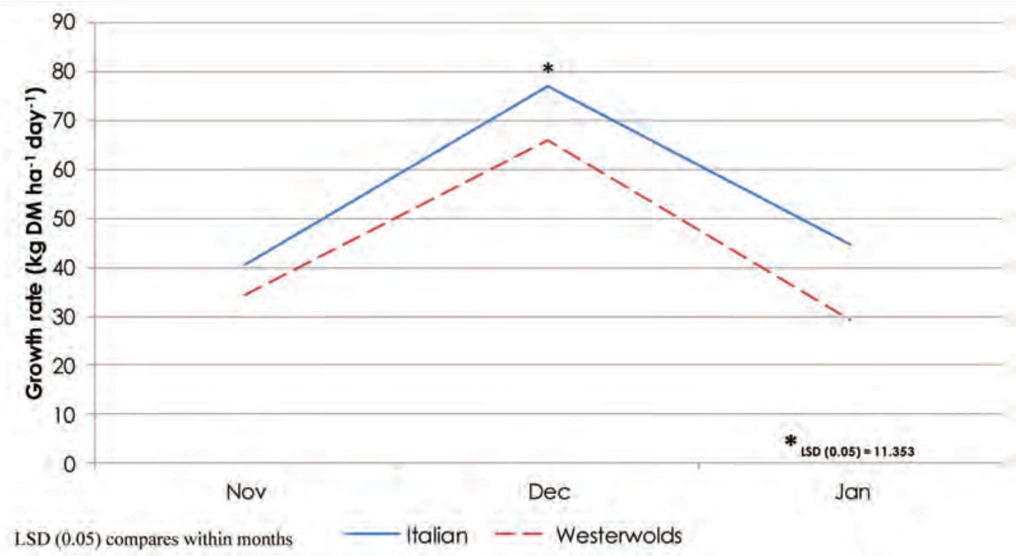

Figure 9a. Monthly growth rate of Italian and Westerwolds ryegrass planted during September 2009.

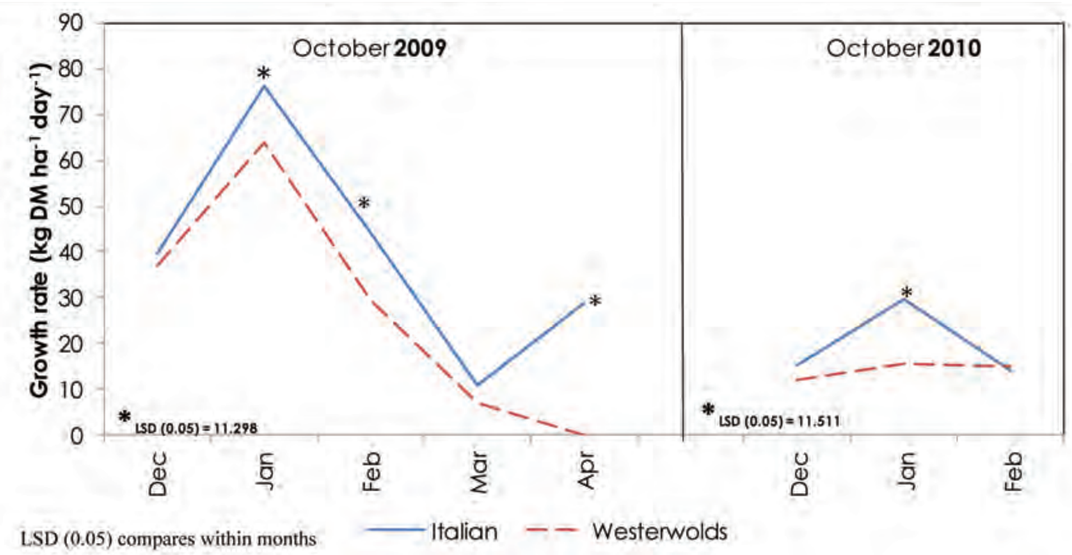

Figure 10a. Monthly growth rate of Italian and Westerwolds ryegrass planted during October 2009 and October 2010.

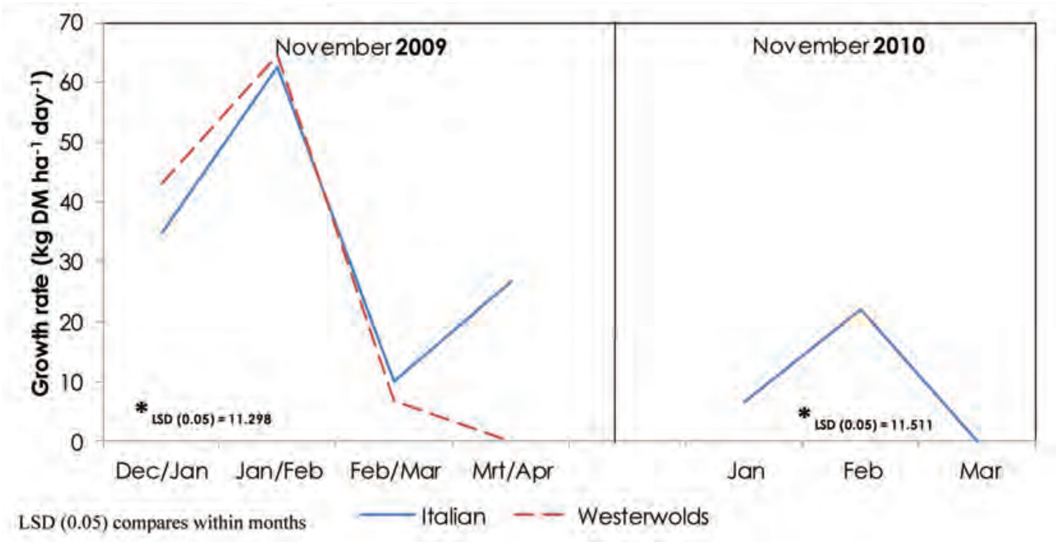

Figure 11a. Monthly growth rate of Italian and Westerwolds ryegrass planted during November 2009 and November 2010.

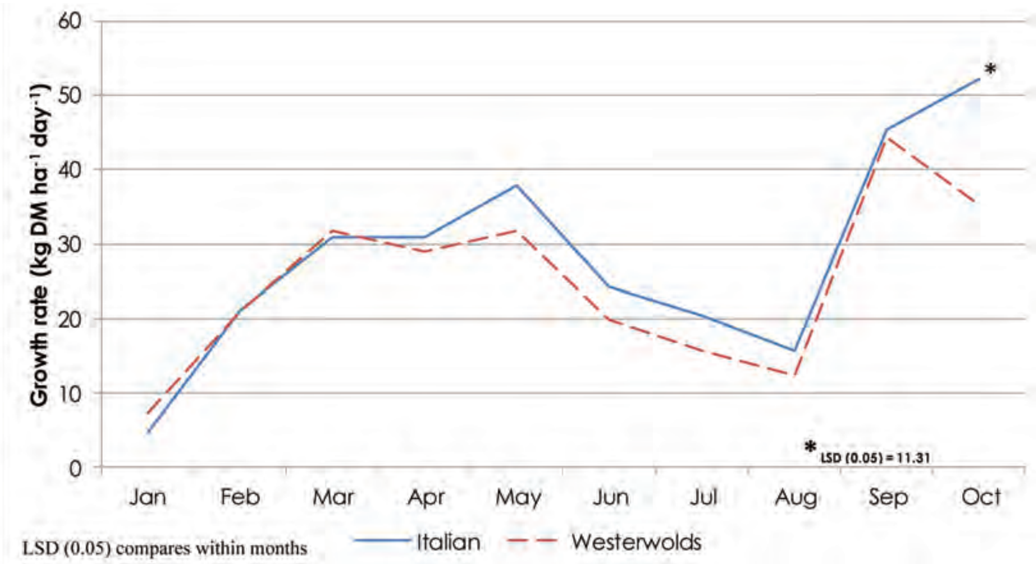

Figure 12a. Monthly growth rate of Italian and Westerwolds ryegrass planted during December 2009.

The growth rate (kg DM ha^{-1} day^{-1}) and number of harvests differ (P<0.05) over planting dates. The growth rates of Italian and Westerwolds ryegrasses planted during January until July were similar (P>0.05) in the beginning of the growth cycle. However, as the growth season prolonged, the growth rate of Westerwolds ryegrass decreased – in the latter part of the growth cycle it was lower (P<0.05) than that of Italian ryegrass. The growth rate of Italian ryegrass was higher than westerwolds ryegrass during peak production when planted in August, September and October, but did not differ (P>0.05) when planted during November and December.

The data also indicated that the seasonal growth rate of Italian and westerwolds ryegrass over years can vary or be similar depending on the planting date. The growth rate of Italian and Westerwolds ryegrass over years was similar when planted during February, March and April, but varied when planted from May until November. This was mainly due to climatic factors like temperature and rainfall and the effect they have on weed invasion from August until November. It can be expected that high rainfall during spring and early summer will have a pronounced effect on the invasion of weeds like Yellow nutsedge (*Cyperus esculentus*) (Afr. uintjies) and crab finger grass (*Digitaria sanguinalis*) (Afr. kruisgras) than during warmer and drier seasons.

Figures 1b – 10b show the average (two years) monthly growth rate (kg DM ha^{-1} day^{-1}) of Italian and Westerwolds ryegrasses planted at different planting dates over the trial period.

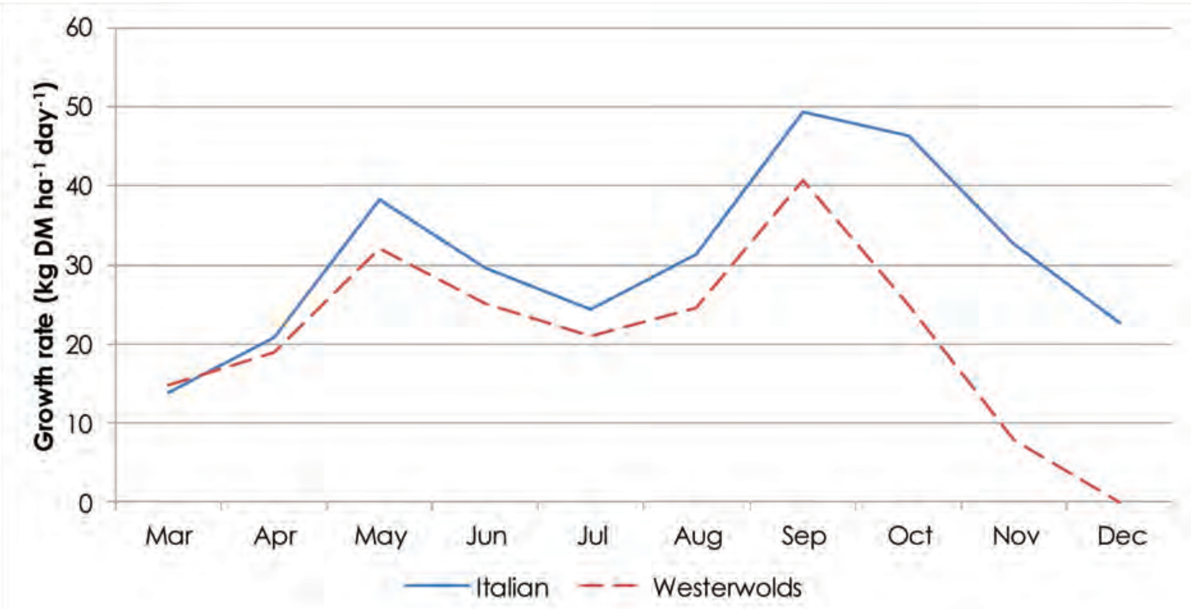

Figure 1b. Mean monthly growth rate of ryegrass planted during January.

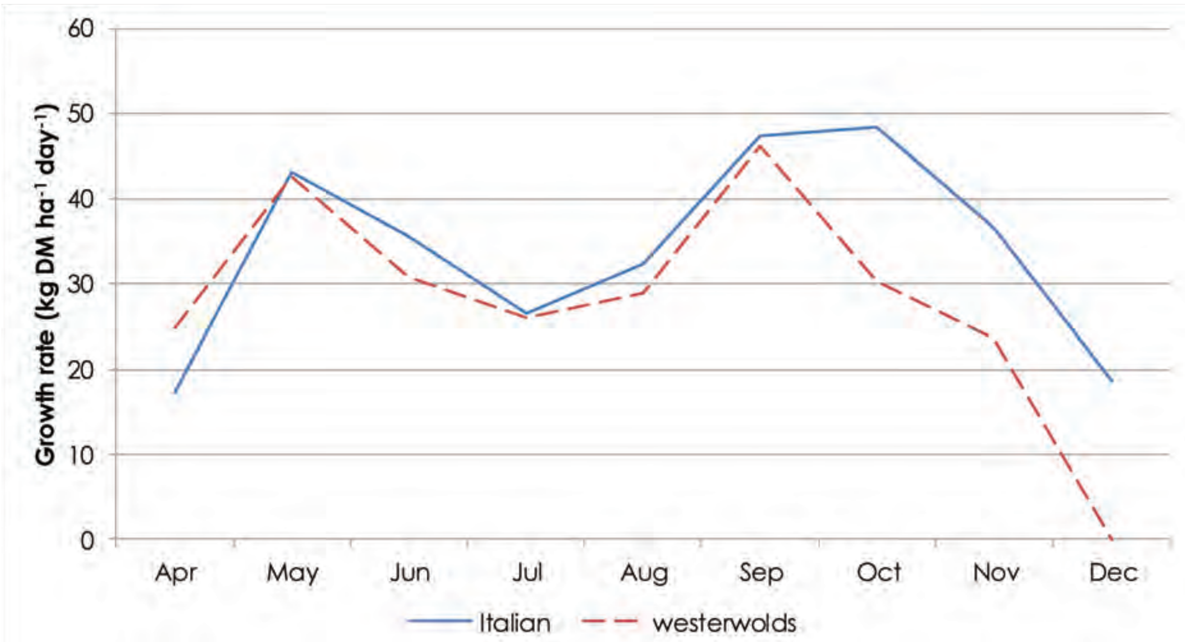

Figure 2b. Mean monthly growth rate of Italian and Westerwolds ryegrass planted during February.

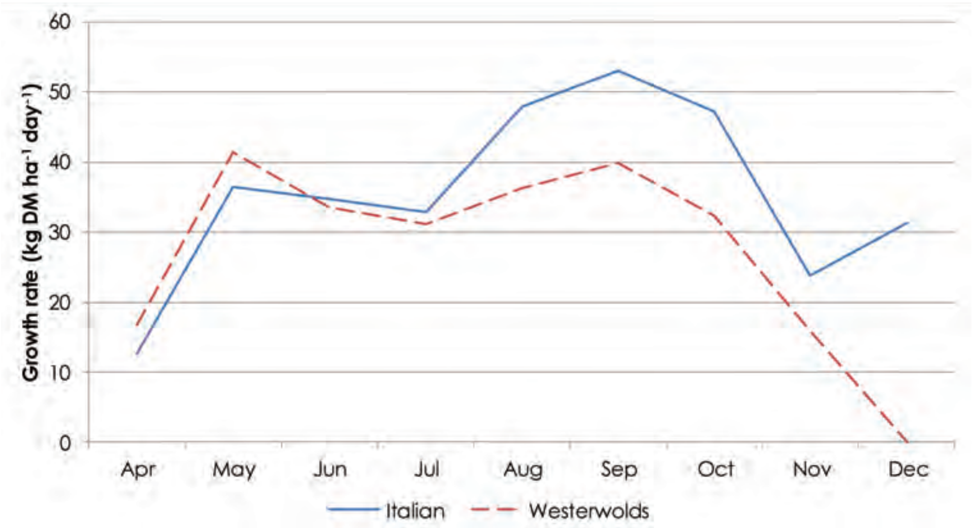

Figure 3b. Mean monthly growth rate of Italian and Westerwolds ryegrass planted during March.

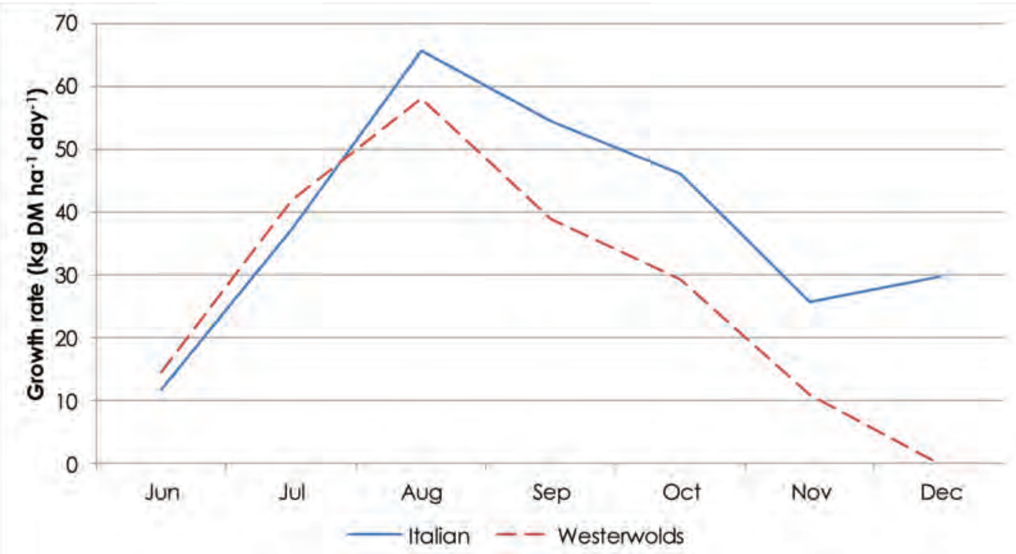

Figure 4b. Mean monthly growth rate of Italian and Westerwolds ryegrass planted during April.

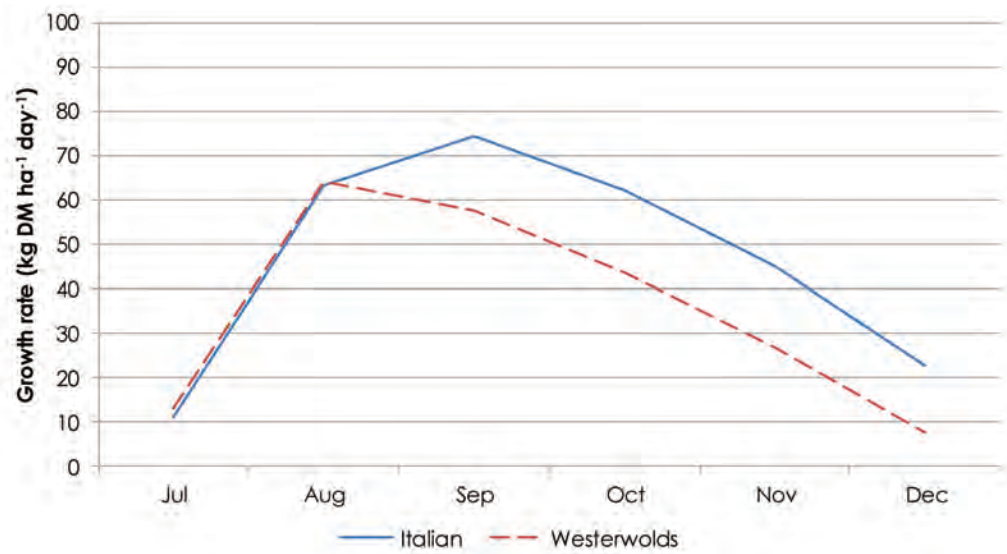

Figure 5b. Mean monthly growth rate of Italian and Westerwolds ryegrass planted during May.

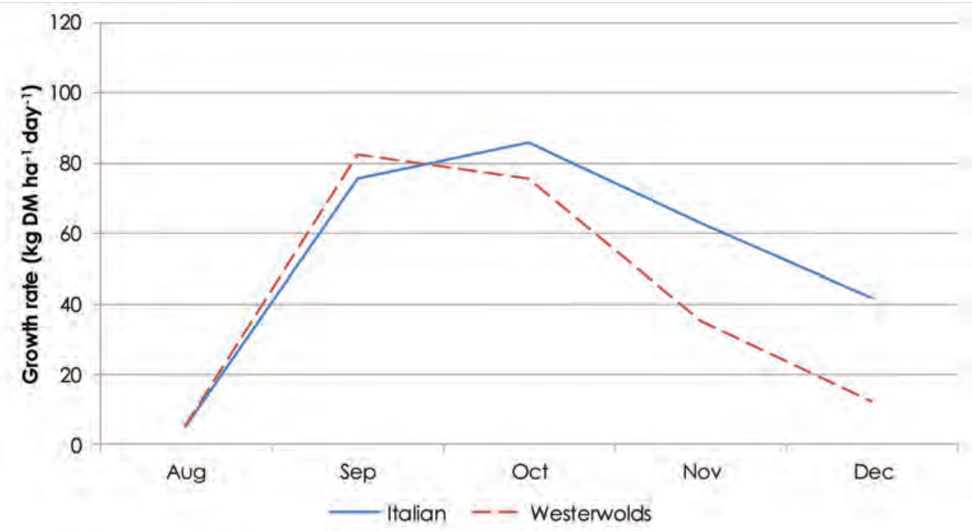

Figure 6b. Mean monthly growth rate of Italian and Westerwolds ryegrass planted during June.

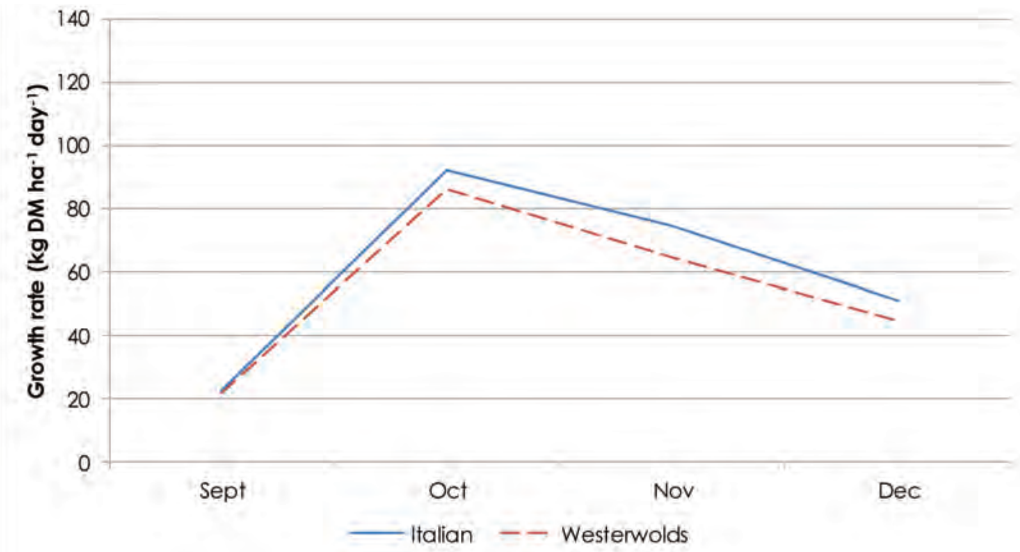

Figure 7b. Mean monthly growth rate of Italian and Westerwolds ryegrass planted during July.

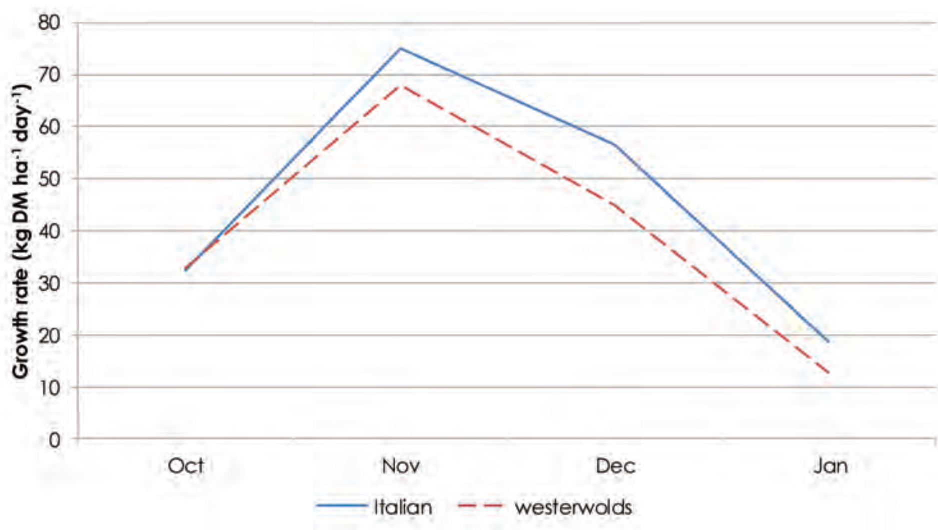

Figure 8b. Mean monthly growth rate of Italian and Westerwolds ryegrass planted during August.

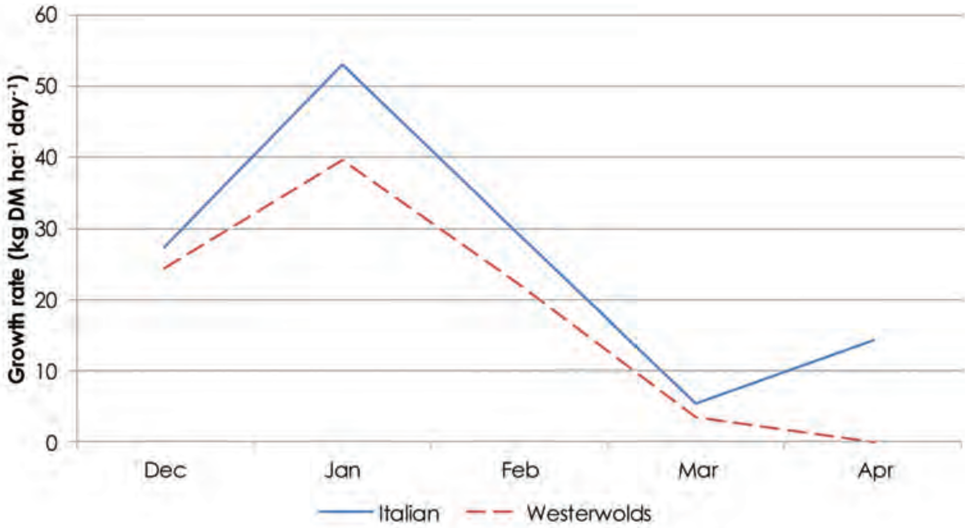

Figure 10b. Mean monthly growth rate of Italian and Westerwolds ryegrass planted during October.

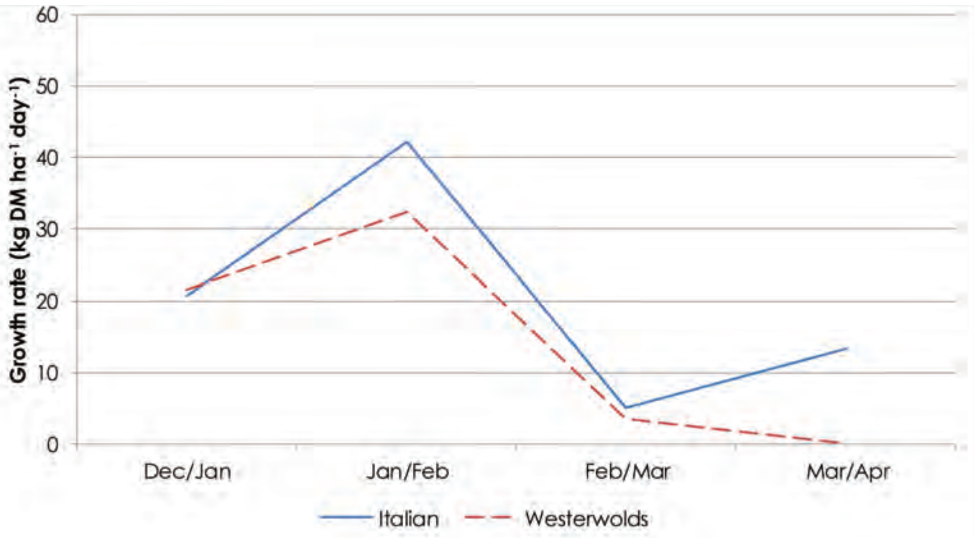

Figure 11b. Mean monthly growth rate of Italian and Westerwolds ryegrass planted during October.

The average combined growth rate over two years for the two ryegrass varieties shows that Italian ryegrass had similar or higher growth rates than Westerwolds ryegrass at all planting dates. Italian ryegrass also had a more protracted growth pattern than Westerwolds ryegrass if planted from December until June. Planting dates from July until November shows that the monthly growth between Italian and Westerwolds ryegrass differ less and that the total productive months for both varieties decline.

Table 2 shows the monthly growth rate (kg DM ha^{-1} day^{-1}) and total dry matter production (ton DM ha^{-1}) of Italian ryegrass planted at different planting dates. (Refer to Table 2)

Italian ryegrass was harvested up to ten times if planted during January, February or March with a total DM production (Table 4) of 9,7, 10,1 and 9,9 ton DM ha^{-1} respectively. Total harvests decreased monthly from 7 to 3 harvests if planted from April until September. The total DM production (Table 4) decreased during the same period from 8,7 to 5,5 ton DM ha^{-1}. The December planting date was also harvested ten times but the monthly growth rate from June until September and the total DM production (8,5 to DM ha^{-1}) were lower ($P<0.05$) than the January, February and March planting dates for this critical winter period.

If the aim in a fodder-flow programme is to provide feed from May until November, which include the critical winter months (June, July and August), it is better to plant Italian ryegrass during January, February or March. The production will be spread over nine to ten harvests with growth rates from 13 and 53 kg DM ha^{-1} day^{-1} and a total production of 9,7 to 10,1 ton DM ha^{-1}.

If the aim is to produce optimum spring and early summer (August to December) fodder, Italian ryegrass should be planted during April, May or June. The ryegrass will be productive for 5 to 7 months and the total DM production can vary between 8 and 9 ton DM ha^{-1}. However, Italian ryegrass planted from July until November will result in short periods (2-3 months) of high production (up to 92 kg DM ha^{-1} day^{-1}) but the total DM production over the growth period will be low and can vary between 3,9 and 7,7 ton DM ha^{-1}.

Table 3 shows the monthly growth rate (kg DM ha^{-1} day^{-1}) of Westerwolds ryegrass planted at different planting dates. (Refer to Table 3)

The Westerwolds ryegrass was harvested nine times if planted during January and eight times if planted during February or March, with a total DM production of 7,0, 8,3 and 7,8 ton DM ha^{-1} respectively. The amount of harvests decreased monthly from 6 to 3 harvests if planted from April until September. The total DM production (Table 4) varied between 7,0 and 8,3 ton DM ha^{-1} when planted during January and February respectively but could be as low as 3,7 and 4,1 ton DM ha^{-1} if planted during October or November.

The December planting date produced 10 harvests, but although the March, April and May growth rates were similar ($P>0.05$), they were higher ($P<0.05$) than the June, July and August planting dates. The total DM production (Table 4) of the December planting date (7,6 ton DM ha^{-1}) was also higher ($P<0.05$) than the total DM production (ton DM ha^{-1}) of the April, September, October and November planting dates, but similar ($P>0.05$) to those of the other planting dates. If planted during December it can be expected that Westerwold ryegrass, as a pasture, will not be productive from November onwards. This will have an adverse effect on the fodder-flow programme, since this data also shows that the September until November planting dates are the worst period to establish Italian or Westerwolds ryegrass and feed shortages could be expected.

If the aim is to plant Westerwolds ryegrass as fodder from May until November, which include the winter months (June, July and August), it is better to plant Westerwolds ryegrass during January, February or March. The production will be spread over 8-9 harvests, varied between 15 and 46 kg DM ha^{-1} day^{-1} and a total DM production (Table 4) of between 7,0 and 8,3 ton DM ha^{-1}.

If the aim is to produce optimum spring (September until November) and early summer (December) fodder from Westerwolds ryegrass, it is better to plant during May and June for spring and July or August for early summer production. The ryegrass will be productive between 3 and 6 months and the total DM production (Table 4) will vary between 3,7 and 7,6 ton DM ha^{-1}.

Westerwolds ryegrass planted from August until November will only be productive for short periods (mostly 2 – 4 months) producing up to 68 kg DM ha^{-1} day^{-1} but the total production will be low and can vary between 3,7 and 6 ton DM ha^{-1}.

Table 4 compares the total DM production (ton DM ha^{-1}) of Italian and Westerwolds ryegrass planted at different planting dates. (Refer to Table 4)

The total DM production (ton DM ha^{-1}) of the Italian ryegrass for the December until June planting dates, was higher ($P<0.05$) than that of the Westerwolds ryegrass. The total DM production of both the Italian and Westerwolds ryegrasses during the August, September and November planting dates were low and the difference in DM production between the two varieties were less than 1 ton DM ha^{-1}. This data shows that Italian ryegrasses have a higher total DM content when planted between December and June, and are thus more productive than Westerwold ryegrass. The best plantings dates, depending on the requirements within the fodder-flow programme, are between December and July.

Table 2. The monthly growth rate (kg DM $ha^{-1}day^{-1}$) of Italian ryegrass planted at different planting dates.

Plant	Monthly growth rate (kg DM ha^{-1} day)															
date	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**
Dec	5^{G}	21^{yzAB}	31^{qrstuv}	31^{qrstuv}	38^{mnop}	24^{wxyz}	20^{zBA}	16^{BCDE}	45^{ijkl}	52^{fgh}						
Jan			14^{CDE}	21^{yzAB}	38^{mnop}	30^{rstuvw}	25^{wxyz}	31^{qrstuv}	50^{fghij}	46^{hijkl}	33^{qprst}	23^{xyzA}				
Feb				17^{ABCD}	43^{klm}	36^{opqr}	27^{uvwxy}	32^{pqrstu}	47^{ghijk}	49^{fghijk}	37^{nopq}	19^{ABC}	21^{yzAB}			
Mar				13^{CDE}	37^{opq}	35^{opqrs}	33^{qprst}	48^{ghijk}	53^{fg}	47^{ghijk}	25^{wxyz}	33^{qprst}				
Apr						12^{DE}	38^{mnop}	66^{d}	55^{ef}	46^{hijkl}	26^{vwxyz}	30^{rstuvw}				
May							11^{EF}	64^{d}	74^{c}	62^{d}	45^{ijkl}	37^{nopq}				
Jun								5^{GF}	76^{c}	86^{b}	63^{d}	43^{klmn}				
July									23^{xyzA}	92^{a}	75^{c}	51^{fghi}				
Aug										32^{pqrstu}	75^{c}	60^{de}	25^{wxyz}			
Sep											41^{lmno}	77^{c}	45^{jkl}			
Oct												27^{tuvwx}	61^{d}	34^{qprs}	11^{EF}	29^{stuvwx}
Nov													29^{stuvw}	54^{ef}	10^{EFG}	26^{vwxyz}

LSD (0.05) = 6.0673 compares over months
^{abcd} means with no common superscript, differs significantly

Table 3. The monthly growth rate (kg DM $ha^{-1}day^{-1}$) of Westerwolds ryegrass planted at different planting dates.

Plant date	Monthly growth rate (kg DM ha^{-1} day)														
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**
Dec	7^{H}	21^{ABCDE}	32^{qrstuv}	$29^{stuvwxyz}$	$32^{qrstuvw}$	20^{ABCDE}	16^{DEFG}	12^{GH}	44^{hij}	$35^{mnopqrs}$					
Jan			15^{FG}	19^{BCDEFG}	32^{pqrstu}	$25^{vwxyzAB}$	21^{ABCDE}	25^{xyzAB}	$41^{hijklmn}$	25^{wxyzAB}	16^{DEFG}				
Feb				25^{xyzAB}	43^{hijkl}	$31^{qrstuvwx}$	26^{vwxyzA}	$29^{stuvwxyz}$	46^{hi}	$30^{qrstuvwxy}$	24^{yzAB}				
Mar				17^{CDEFG}	41^{hijklm}	34^{opqrs}	$31^{qrstuvwx}$	$36^{lmnopqr}$	$40^{ijklmno}$	32^{pqrstu}	19^{BCDEFG}				
Apr						15^{FG}	42^{hijklm}	58^{def}	39^{klmnop}	$29^{rstuvwxyz}$	21^{ABCD}				
May							13^{GH}	64^{cde}	58^{ef}	44^{hijk}	$37^{klmnopq}$	8^{zABC}			
Jun								5^{l}	82^{ab}	76^{b}	42^{hijklm}	24^{xyzAB}			
July									22^{ABCD}	86^{a}	59^{def}	53^{fg}			
Aug										33^{pqrst}	68^{c}	47^{gh}	$26^{uvwxyzAB}$		
Sep											35^{nopqrs}	66^{c}	$29^{stuvwxyz}$		
Oct												25^{xyzAB}	54^{fg}	$26^{tuvwxyzA}$	7^{HI}
Nov													43^{hijkl}	65^{cd}	7^{HI}

LSD (0.05) = 6.9089 compares over months
^{abcd} means with no common superscript, differs significantly

Table 4. The total DM production (ton ha^{-1}) of Italian and Westerwolds ryegrass planted at different planting dates.

Ryegrass variety	Planting date and total DM production (ton DM ha^{-1})											
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Italian	**8.5^{cde}**	**9.7^{ab}**	**10.1^{a}**	**9.9^{a}**	**8.7^{cd}**	**9.0^{bc}**	**8.2^{defg}**	**7.7^{fgh}**	**6.6^{ij}**	**5.5^{jk}**	**5.2^{lm}**	**3.9^{n}**
Westerwolds	**7.6^{fgh}**	**7.0^{hi}**	**8.3^{def}**	**7.8^{efg}**	**6.7^{ij}**	**7.6^{gh}**	**7.0^{hi}**	**7.0^{hi}**	**6.0^{jk}**	**4.5^{mn}**	**3.7^{n}**	**4.1^{n}**

LSD (0.05) = 0.7516 compares over months
^{abcd} means with no common superscript, differs significantly

Conclusion

Planting date influenced the production potential of both Italian and Westerwolds ryegrasses. The combined average growth rate over two years of the two varieties shows that Italian ryegrass, planted from December until June, is more productive than Westerwolds ryegrass.

The variation in growth rate during spring and early summer over years at similar planting dates is an indication that climatic factors and the presence of weeds can influence the production potential of these temperate grasses. This can be a risk for farmers and an important reason for selecting planting dates in such a way to ensure that the crops are productive, have the potential to overcome climatic changes and the ability to compete with spring and summer weeds.

If the aim, from a fodder-flow perspective, is to provide fodder from May until November, which also includes the critical winter months (June, July and August), Italian ryegrass is a better option than Westerwolds ryegrass, if planted during February or March. If the aim is to produce optimum spring and early summer (September to December) fodder, Italian ryegrass should be planted during May or June.

Italian or Westerwolds ryegrasses should not be planted later than June. This will result in short productive periods (3-4 months) and the total production will be low.

MESSAGE TO THE FARMER

Planting date has a pronounced effect on the production potential of Italian and Westerwolds ryegrass. Both these species should be planted at specific planting dates to provide feed within a fodder-flow programme from May until November. The production potential of Italian or Westerwolds ryegrass planted from September until November is low – it will probably not be cost-effective under irrigation if fertilised with nitrogen. December as a planting date for Westerwolds ryegrass is risky and could result in fodder shortage during winter, spring and early summer. Based on growth rate and total production, Italian ryegrass is a better option than Westerwolds ryegrass, if not strategically over-sown into perennial pasture.

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8. Production of *Brassica, Beta, Raphanus* and *Cichorium* species in the southern Cape of South Africa

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Introduction

Grass and legume pastures are widely used as fodder for dairy and beef cattle in the southern Cape. The periods of low production in the fodder flow are filled with a variety of grains – but there is still a need for a high-quality crop that can produce sufficient amounts of dry matter (DM) during summer and autumn. A possible alternative is annual forage crops – which include forage rape (*Brassica napus*), forage turnip (*B. rapa*), kales (*B. oleracea*), swedes (*B. napobrassica*), fodder beet (*Beta vulgaris*), Japanese radish (*Raphanus sativus*), and chicory (*Cichorium intybus*). Unfortunately, limited or no information is available on the production potential of these crop species in the southern Cape.

Annual forage-crop species are mainly used as fodder in the summer-rainfall areas of South Africa (Kynoch Pasture Handbook, 2004) – given the reliable rainfall and favorable temperatures during the growth period in these areas (Kynoch Pasture Handbook, 2004). These species are quick to establish and produce large amounts of forage during summer and autumn for cattle and sheep (Hall & Jung, 1994; Ayres, 2002; Kynoch Pasture Handbook, 2004; Hogh-Jensen *et al.*, 2006; Khogali *et al.*, 2011). Leaves, stems and/or bulbs can be used as forage, depending on the species (Bartholomew & Underwood n.d.; Hall & Jung, 1994; Krall *et al.*, 1996; Wilson *et al.*, 2004; Hall & Jung, 2005; Turki & Khogali 2011). As forage, these crops are palatable, digestible, can provide energy, and also contain a high level of protein (Hall & Jung, 1994; Reid *et al.*, 1994; Ayres, 2002; Hall & Jung, 2005; Hogh-Jensen *et al.*, 2006; Khogali *et al.*, 2011).

The aim of this study was to evaluate the DM production potential and the appropriate planting date for forage rape, forage turnip, Kales, Swedes, fodder beet, fodder radish, and Chicory cultivars.

Materials and Methods

This study was carried out at the Outeniqua Research Farm near George (altitude 201 m, 33º 58' 38" S; 22º 25' 16'' E; rainfall 728 mm p.a.) in the Western Cape Province of South Africa. The study was done under sprinkler irrigation, on a Witfontein soil form. Irrigation scheduling was done according to tensiometer readings – commencing at –25 kPa, and terminating at –10 kPa (Botha, 2002). Fertiliser was applied to raise and balance the soil-nutrient levels, to soil-analysis recommendations. Phosphorous (P) and potassium (K) will be applied before planting – to raise soil-nutrient levels in accordance with the soil-analysis report.

The trial was planted on 26 November 2011. Two randomised replicates were planted on 26 January 2012 and 26 March 2012. Lands were shallowly tilled with a konskilde, and a seedbed was created. Seed was planted into the soil and then plots were rolled with a land roller.

The trial consisted of 17 cultivars (treatments) and each treatment was replicated three times. The experimental design was a randomised block design with 17 treatments randomly allocated in 3 blocks. Plot size was 2.1 m x 6 m (12.6 m^2). Plots were sampled by species, when the species reached maturity. Each treatment was harvested destructively.

- In the case of the forage rapes, kales and chicory, a strip of pasture (1.5 m x 4 m = 6 m^2) was cut at a height of 100 mm – to be used for pasture sampling. The weight of the cut strip was determined, after which approximately 500 g of the sample was placed in a brown paper bag and then weighed wet and dry to determine DM content. The sample was dried in an oven at 60ºC for 72 hours, in order to determine dry weight.

- The forage turnips, swede, fodder beet, and fodder radish, were completely removed by hand. A pasture strip (1.5 m x 4 m = 6 m^2) was used and the total weight of the sample was determined. The plants were divided into roots and above-ground plant material, and each fraction was weighed separately. Approximately 500 g of each of the fractions were placed in a brown paper bag, and then weighed wet and dry to determine DM content. Samples were dried in an oven at 60ºC for 72 hours, in order to determine dry weight.

An appropriate analysis of variance was performed, with the assumption of normality of the residuals tested to ensure valid and reliable results (Shapiro & Wilk, 1965). A Student LSD (least significant difference)-test, at 5% significance level, was done to compare the treatment means (Ott, 1998). The STATS module of SAS version 9.2 was used to analyse the data (SAS institute Inc., 2008).

Results and discussion

Table 2 indicates the dry matter (DM) production rate, DM content, DM production, and days from planting to harvesting of different plant fractions of annual fodder-crop species planted during November 2011.

- *Bulbs*
  Invitation and T-Raptor had the highest ($P<0.05$) bulb DM content. Dynamo had a similar ($P>0.05$) bulb DM production rate to Invitation and Barkant, but was higher ($P<0.05$) than the other bulb-producing cultivars. Invitation had the highest ($P<0.05$) bulb DM production.

- *Stems and leaves*
  KR6099 had a similar ($P>0.05$) stem/leaf DM content to KR7872, Interval, Sovereign, and Barnapoli, but was higher ($P<0.05$) than all the other cultivars. Interval and Nooitgedacht had a similar ($P>0.05$) stem/leaf DM production rate to Barkant, T-Raptor, Barnapoli, KR6099, and Dynamo, but was higher ($P<0.05$) than the other cultivars. KR6099 had a similar ($P>0.05$) stem/leaf DM production to Interval, but was higher ($P<0.05$) than the other cultivars.

- *All plant fractions*
  KR6099 had a similar ($P>0.05$) mean DM content to KR7872, Interval, Sovereign, and Barnapoli, but was higher ($P<0.05$) than the other cultivars. Barkant had a similar ($P>0.05$) mean DM production rate to Nooitgedacht, Dynamo, Interval and T-Raptor, but was higher ($P<0.05$) than the other cultivars. KR6099 had a similar ($P>0.05$) total DM production to Interval, Invitation, Nooitgedacht and Dynamo, but was higher ($P<0.05$) than the other cultivars.

Table 3 indicates the dry matter (DM) production rate, DM content, DM production, and days from planting to harvesting for different plant fractions of annual fodder-crop species planted during January 2012.

- *Bulbs*
  Invitation had the highest ($P<0.05$) bulb DM content. Invitation and Brigadier had the highest ($P<0.05$) bulb DM production rate, and the highest ($P<0.05$) bulb DM production.

- *Stems and leaves*
  KR6099 had a similar ($P>0.05$) stem/leaf DM content to Brigadier, Barnapoli, Sovereign, KR7872, Invitation, Interval, Chico, Purple Top, and Spitfire, but was higher ($P<0.05$) than the other cultivars. Interval had a similar ($P>0.05$) stem/leaf DM production rate to KR7872, Spitfire, Barnapoli and KR6099, but was higher ($P<0.05$) than the other cultivars. KR6099 had a similar ($P>0.05$) stem/leaf DM production to Sovereign, but was higher ($P<0.05$) than the other cultivars.

- *All plant fractions*
  KR6099, Invitation, Barnapoli, Sovereign, KR7872, and Interval, had a similar (P>0.05) mean DM content to Chico, Spitfire and Brigadier, but were higher (P<0.05) than the other cultivars. Interval, KR7872, and Spitfire, had a similar (P>0.05) mean DM production rate to Nooitgedacht, Barnapoli, KR6099, Invitation, Brigadier and Sovereign, but were higher (P<0.05) than the other cultivars. KR6099, Brigadier, Invitation, and Sovereign, had the highest (P<0.05) total DM production.

Table 4 indicates the dry matter (DM) production rate, DM content, DM production, and days from planting to harvesting for different plant fractions of annual fodder-crop species planted during March 2012.

- *Bulbs*
  Invitation and Brigadier had the highest (P<0.05) bulb DM content, the highest (P<0.05) bulb DM production rate, and the highest (P<0.05) bulb DM production.

- *Stems and leaves*
  Invitation had the highest (P<0.05) stem/leaf DM content. Nooitgedacht, Purple Top and Dynamo had a similar (P>0.05) stem/leaf DM production rate to Barkant, but were higher (P<0.05) than the other cultivars. Sovereign had a similar (P>0.05) DM production to KR6099, but was higher (P<0.05) than the other cultivars.

- *All plant fractions*
  Invitation had the highest (P<0.05) mean DM content. Dynamo and Nooitgedacht had a similar (P>0.05) mean DM production rate to Barkant, but were higher than the other cultivars. Brigadier had a similar (P>0.05) DM production to Invitation, but was higher (P<0.05) than the other cultivars.

Conclusion

The forage turnip cultivar dynamo, the forage rape cultivar Interval, the kale cultivar KR6099, the swede cultivar Invitation, and the fodder radish cultivar Nooitgedacht, were the most productive cultivars during the November planting date. The kale cultivars KR6099 and Sovereign, the Swede cultivar Invitation, and the fodder beet cultivar Brigadier, were the most productive cultivars during the January planting date. The Swede cultivar Invitation and the fodder beet cultivar Brigadier were the most productive cultivars during the March planting date.

For the November, January and March planting dates, the Swede cultivar Invitation had the highest or near highest bulb DM content, bulb DM production rate, and bulb DM production. The Kale cultivar KR6099 had – for the November and January planting date – the highest or near highest stem/leaf DM content, stem/leaf DM production rate, and stem/leaf DM production.

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Table 1. Species, common name, cultivar, usage, and growth period, of the different *Brassica*, *Beta*, *Raphanus* and *Cichorium* species, to be evaluated in the trial at Outeniqua Research Farm.

Species	Common name	Cultivar(s)	Usage			Seeding rate
			Roots	Stems	Leaves	
Brassica rapa	Forage turnip	Dynamo Barkant Green Globe KR7809 Purple Top T-Raptor	X	X	X	3
B. napus	Forage rape	Barnapoli KR7872 Interval Spitfire		X	X	5
B. oleracea	Kale	Caledonian KR6099 Sovereign		X	X	5
B. napobrassica	Swede	Invitation	X	X	X	1.5
Beta vulgaris	Fodder beet	Brigadier	X	X	X	6
Raphanus sativus	Japanese radish	Nooitgedacht	X	X	X	6
Cichorium intybus	Chicory	Chico		X	X	5

(Bartholomew & Underwood n.d.; Hall & Jung, 1994; Krall *et al.*, 1996; Hall & Jung, 2005).

Table 2. The dry matter (DM) production rate, DM content, DM production, and days from planting to harvesting of different plant fractions of annual fodder-crop species planted during November 2011, on the Outeniqua Research Farm.

Treatment	Days from planting to harvesting	Bulbs			Stems and leaves			All plant fractions		
		DM production rate (Kg DM ha^{-1} day^{-1})	DM content (%)	DM production (Kg DM ha^{-1})	DM production rate (Kg DM ha^{-1} day^{-1})	DM content (%)	DM production (Kg DM ha^{-1})	Mean DM production rate (Kg DM ha^{-1} day^{-1})	Mean DM content (%)	Total DM production (Kg DM ha^{-1})
Dynamo	**76**	22.9^{a}	5.99^{bc}	1736^{bc}	46.7^{abc}	8.74^{gh}	3547^{cde}	69.5^{abc}	7.36^{f}	5283^{abc}
Barkant	**76**	20.9^{ab}	5.36^{bc}	1588^{bc}	52.3^{ab}	8.46^{gh}	3975^{cd}	73.2^{a}	6.91^{f}	5563^{bc}
Green Globe*	**76**	.	.	.	.	.	.	.	.	.
KR7809	**76**	11.6^{bc}	4.76^{c}	884^{bc}	37.7^{bcd}	9.79^{fgh}	2868^{cde}	49.4^{bcdef}	7.28^{f}	3751^{bcde}
Purple Top	**76**	9.43^{c}	6.87^{b}	717^{bc}	36.4^{bcd}	9.83^{fgh}	2769^{de}	45.9^{cdef}	8.35^{f}	3485^{cde}
T-Raptor	**76**	5.78^{c}	10.0^{a}	440^{c}	47.7^{abc}	8.69^{gh}	3627^{cde}	53.5^{abcde}	9.32^{ef}	4066^{bcde}
Barnapoli	**97**	.	.	.	47.5^{abc}	14.1^{abcd}	4610^{bcd}	47.5^{cdef}	14.1^{abcd}	4610^{bcde}
KR7872	**97**	.	.	.	40.7^{bcd}	15.4^{ab}	3948^{cd}	40.7^{defg}	15.4^{ab}	3948^{bcde}
Interval	**97**	.	.	.	62.7^{a}	14.9^{abc}	6085^{ab}	62.7^{abcd}	14.9^{abc}	6085^{ab}
Spitfire	**97**	.	.	.	36.3^{bcd}	13.2^{bcde}	3519^{cde}	36.3^{efgh}	13.2^{bcd}	3519^{cde}
Caledonian	**163**	.	.	.	21.4^{def}	12.3^{cdef}	3483^{cde}	21.4^{gh}	12.3^{cd}	3483^{cde}
KR6099	**163**	.	.	.	47.4^{abc}	16.1^{a}	7723^{a}	47.4^{cdef}	16.1^{a}	7723^{a}
Sovereign	**163**	.	.	.	29.3^{cde}	14.8^{abcd}	4778^{bcd}	29.3^{fgh}	14.8^{abcd}	4778^{bcd}
Invitation	**163**	22.3^{ab}	11.1^{a}	3637^{a}	11.3^{ef}	12.8^{bcde}	1843^{ef}	33.6^{efgh}	11.9^{de}	5480^{abc}
Brigadier	**163**	11.4^{bc}	6.22^{bc}	1860^{b}	2.11^{f}	10.9^{efg}	344^{f}	13.5^{h}	8.57^{f}	2204^{e}
Nooitgedacht	**76**	8.11^{c}	5.78^{bc}	616^{bc}	63.5^{a}	7.28^{h}	4823^{bc}	71.6^{ab}	6.53^{f}	5440^{abc}
Chico	**97**	.	.	.	29.0^{cde}	12.0^{def}	2813^{cde}	29.0^{fgh}	12.0^{de}	5813^{de}
LSD (0.05)		**10.916**	**1.921**	**1341.9**	**20.137**	**2.909**	**2042.5**	**23.732**	**2.860**	**2443.1**

abcde Means with no common superscript, differ significantly ($P<0.05$); LSD = Least Significant Difference;
*Green Globe failed to germinate and emerge.

Table 3. The dry matter (DM) production rate, DM content, DM production, and days from planting to harvesting of different plant fractions of annual fodder-crop species planted during January 2012 on the Outeniqua Research Farm.

Treatment	Days from planting to harvesting	Bulbs			Stems and leaves			All plant fractions		
		DM production rate (Kg DM ha^{-1} day^{-1})	DM content (%)	DM production (Kg DM ha^{-1})	DM production rate (Kg DM ha^{-1} day^{-1})	DM content (%)	DM production (Kg DM ha^{-1})	Mean DM production rate (Kg DM ha^{-1} day^{-1})	Mean DM content (%)	Total DM production (Kg DM ha^{-1})
Dynamo	**75**	5.10^{b}	5.33^{c}	383^{b}	16.5^{e}	10.3^{bcd}	1234^{fg}	21.6^{de}	7.82^{cd}	1616^{fg}
Barkant	**75**	3.84^{b}	4.74^{c}	288^{b}	12.4^{e}	9.58^{cd}	929^{g}	16.2^{e}	7.16^{de}	1216^{g}
Green Globe*	**75**	.	.	.	.	.	.	.	.	.
KR7809	**75**	3.67^{b}	4.50^{c}	275^{b}	110^{e}	9.19^{d}	828^{g}	14.7^{e}	6.85^{de}	1103^{g}
Purple Top	**75**	1.93^{b}	6.34^{c}	145^{b}	12.4^{e}	10.5^{abcd}	932^{fg}	14.4^{e}	8.40^{de}	1077^{g}
T-Raptor	**75**	2.33^{b}	9.99^{b}	145^{b}	14.5^{e}	9.00^{d}	1091^{fg}	16.9^{e}	9.50^{bc}	1265^{g}
Barnapoli	**97**	.	.	.	41.6^{ab}	12.0^{ab}	4038^{d}	41.6^{ab}	12.0^{a}	4038^{cd}
KR7872	**97**	.	.	.	44.0^{ab}	11.7^{ab}	4264^{cd}	44.0^{a}	11.7^{a}	4264^{cd}
Interval	**97**	.	.	.	47.8^{a}	11.6^{ab}	4637^{cd}	47.8^{a}	11.6^{a}	4637^{c}
Spitfire	**97**	.	.	.	43.3^{ab}	10.7^{abcd}	4203^{d}	43.3^{a}	10.7^{ab}	4203^{cd}
Caledonian	**159**	.	.	.	32.7^{cd}	9.55^{cd}	5198^{bc}	32.7^{bc}	9.55^{bc}	5198^{bc}
KR6099	**159**	.	.	.	41.6^{ab}	12.4^{a}	6610^{a}	41.6^{ab}	12.4^{a}	6610^{a}
Sovereign	**159**	.	.	.	38.6^{bc}	11.7^{ab}	6137^{ab}	38.6^{ab}	11.7^{a}	6137^{ab}
Invitation	**159**	24.8^{a}	12.5^{a}	3944^{a}	15.5^{e}	11.6^{ab}	2460^{e}	40.3^{ab}	12.0^{a}	6404^{a}
Brigadier	**159**	28.4^{a}	9.08^{b}	4518^{a}	12.0^{e}	12.0^{ab}	1909^{ef}	40.4^{ab}	10.5^{ab}	6427^{a}
Nooitgedacht	**75**	4.32^{b}	5.14^{c}	324^{b}	37.6^{bc}	5.95^{e}	2821^{e}	41.9^{ab}	5.54^{e}	3145^{de}
Chico	**97**	.	.	.	28.4^{d}	11.2^{abc}	2759^{e}	28.4^{cd}	11.2^{ab}	2759^{ef}
LSD (0.05)		**4.507**	**2.048**	**674.8**	**8.209**	**1.998**	**989.6**	**9.540**	**2.000**	**1174.4**

abcde Means with no common superscript, differ significantly ($P<0.05$); LSD = Least Significant Difference;
*Green Globe failed to germinate and emerge.

Table 4. The dry matter (DM) production rate, DM content, DM production. and days from planting to harvesting of different plant fractions of annual fodder-crop species planted during March 2012 on the Outeniqua Research Farm.

Treatment	Days from planting to harvesting	Bulbs			Stems and leaves			All plant fractions		
		DM production rate (Kg DM ha^{-1} day^{-1})	DM content (%)	DM production (Kg DM ha^{-1})	DM production rate (Kg DM ha^{-1} day^{-1})	DM content (%)	DM production (Kg DM ha^{-1})	Mean DM production rate (Kg DM ha^{-1} day^{-1})	Mean DM content (%)	Total DM production (Kg DM ha^{-1})
Dynamo	**64**	5.46^{b}	7.34^{c}	349^{b}	51.0^{ab}	7.76^{efg}	3262^{cd}	56.4^{ab}	7.55^{fgh}	36.11^{d}
Barkant	**64**	6.45^{b}	6.92^{c}	413^{b}	54.7^{a}	7.60^{efg}	3498^{cd}	61.1^{a}	7.26^{fgh}	3911^{cd}
Green Globe	**64**	.	.	.	.	.	.	.	.	.
KR7809	**64**	5.84^{b}	7.27^{c}	374^{b}	42.0^{bcd}	6.73^{gh}	2690de	47.9^{bcde}	7.00^{gh}	3065de
Purple Top	**64**	4.15^{b}	10.2^{b}	266^{b}	45.5^{abc}	6.35^{gh}	2912de	49.6^{bcd}	8.26^{efg}	3177de
T-Raptor	**64**	.	.	.	35.7^{cd}	7.62^{efg}	2282^{e}	35.7^{fg}	7.62^{fgh}	2282^{e}
Barnapoli	**93**	.	.	.	42.1^{bcd}	9.35^{cd}	3912^{c}	42.1^{defg}	9.35^{ef}	3912^{cd}
KR7872	**93**	.	.	.	42.1^{bcd}	8.34^{def}	3914^{c}	42.1^{defg}	8.34^{ef}	3914^{cd}
Interval	**93**	.	.	.	42.6^{bc}	8.34^{def}	3961^{bc}	42.6^{cdefg}	8.34^{ef}	3961^{cd}
Spitfire	**93**	.	.	.	37.7^{cd}	7.31^{fgh}	3505^{cd}	37.7^{efg}	7.31^{fgh}	3505^{d}
Caledonian	**148**	.	.	.	23.6^{ef}	10.1^{c}	3493^{cd}	23.6^{h}	10.1^{cd}	3493^{d}
KR6099	**148**	.	.	.	32.7^{de}	11.7^{b}	4839^{a}	32.7^{gh}	11.7^{b}	4839^{bc}
Sovereign	**148**	.	.	.	32.5^{de}	12.1^{b}	4806^{ab}	32.5^{gh}	12.1^{b}	4806^{bc}
Invitation	**148**	20.6^{a}	13.6^{a}	3049^{a}	22.9^{ef}	13.6^{a}	3390^{cd}	43.5^{cdef}	13.6^{a}	6439^{a}
Brigadier	**148**	18.4^{a}	13.4^{a}	2718^{a}	19.0^{fg}	8.99^{cde}	2812de	37.4^{efg}	11.2^{bc}	5530^{ab}
Nooitgedacht	**64**	3.11^{b}	7.02^{c}	199^{b}	49.6^{ab}	5.90^{h}	3177^{cd}	52.8^{abc}	6.46^{h}	3376^{d}
Chico	**93**	.	.	.	10.7^{g}	9.36^{cd}	994^{f}	10.7^{i}	9.36^{de}	994^{f}
LSD (0.05)		**3.574**	**1.513**	**486.5**	**9.89**	**1.430**	**858.6**	**10.54**	**1.297**	**970.2**

abcde Means with no common superscript differ significantly ($P<0.05$); LSD = Least significant difference;
*Green Globe failed to germinate and emerge.

9. The evaluation of annual legume cultivars for the southern Cape

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Introduction

Many cool-season annual, forage legume cultivars are available in South Africa. Such forage legumes are valued for their high forage quality (Wasserman, 1981) and their ability to fix nitrogen through their association with *Rhizobium* bacteria in root nodules (Strijdom *et al.*, 1980). Annual cool-season legumes provide forage from autumn to spring – except if winter temperatures are too low, which can impede growth (Donaldson, 2001). Forage legumes produce a higher quality pasture than pure grass stands, and are therefore sown in a mixture with grass (Bartholomew, 2005). The legume component contributes greatly to nutritional value, palatability, digestibility, and intake of such grass-legume pastures (Wasserman, 1981; Botha, 2008).

Annual legumes refer to plants having a lifespan of one year or less (Bartholomew, 2005). The forage legumes included in this trial are: arrowleaf clover (*Trifolium vesiculosum*), balansa clover (*T. michelianum* Savi.), berseem clover (*T. alexandrinum* L.), biserrula (*Biserrula pelecinus*), barrel medic (*Medicago trancatula*), burr clover (*M. polymorpha*), Sub-clover (*T. subterraneun*), Persian clover (*T. resupinatum*), pink serradella (*O. sativus*), and grazing vetch (*Vicia dasycarpa*).

The aim of this study was to evaluate the production potential of 22 annual, cool-season forage legume cultivars.

Materials and Methods

The study was carried out at the Outeniqua Research Farm, near George (Altitude 201 m, 33° 58' 38'' S, 22° 25' 16'' E; rainfall 728 mm year^{-1}) in the Western Cape Province of South Africa, on a Witfontein soil form (Soil Classification Workgroup, 1991). The study area was under permanent overhead sprinkler irrigation – with irrigation scheduling undertaken by means of a tensiometer. Irrigation commenced at a tensiometer reading of -25 kPa, and was terminated at a reading of -10 kPa (Botha, 2002).

Soil samples were taken prior to establishment, to a depth of 150 mm, and analysed for Ca, Mg, Na, K, P, Cu, Zn, Mn, B, S, and C levels. Fertiliser was applied according to the soil analysis – to raise soil P level to 35 mg kg^{-1}, K level to 80 mg kg^{-1}, and pH (KCl) to 5.5 (Beyers, 1973).

A total of 22 cultivars were evaluated in the form of a randomised block design, with three replicates per cultivar (total of 54 plots). The scientific name, common name, cultivar name, and seeding rate of the annual legumes evaluated, are given in Table 1.

Table 1. The scientific name, common name, cultivar name, and seeding rate (kg ha^{-1}) of annual legumes evaluated during the study.

	Scientific name	Common name	Cultivar name	Seeding rate
1	*Trifolium alexandrinum*	Berseem	Calipso	10
2	*Trifolium alexandrinum*	Berseem	Elite II	10
3	*Trifolium vesiculosum*	Arrowleaf	Zulu	15
4	*Trifolium vesiculosum*	Arrowleaf	Cefalo	15
5	*Trifolium michelianum*	Balansa	Viper	4
6	*Trifolium michelianum*	Balansa	Taipan	4

7	*Trifolium subterranean*	Subterranean	Losa	15
8	*Trifolium subterranean*	Subterranean	Dalkeith	15
9	*Trifolium subterranean*	Subterranean	Woogenellup	15
10	*Trifolium subterranean*	Subterranean	Campeda	15
11	*Trifolium resipunatum*	Persian	Morbulk	10
12	*Trifolium resipunatum*	Persian	Laser	10
13	*Trifolium resipunatum*	Persian	Maral	10
14	*Vicia dasaycarpa*	Vetch	Max	35
15	*Vicia dasaycarpa*	Vetch	Capello	35
16	*Medicago truncutula*	Barrel medic	Paraggio	15
17	*Medicago truncutula*	Barrel medic	Parabinga	15
18	*Medicago polymorpha*	Burr medic	Jaguar	15
19	*Medicago polymorpha*	Burr medic	Santiago	15
20	*Medicago polymorpha*	Burr medic	Scimitar	15
21	*Ornithopus sativus*	Pink serradella	Emena	25
22	*Ornithopus sativus*	Pink serradella	Margurita	25

The trial was established on 18 April 2011. The trial area was sprayed with herbicide, tilled with a disk harrow and kongskilde, and rolled with a light landroller to create a firm seedbed and to eradicate any weeds. The various cultivars/species were planted according to commercially recommended seeding rates, and were adapted for germination percentages. Plots were 2.1 m x 6 m per treatment (12.6 m^2), with 14 rows that were 15 cm apart. All seed was inoculated with species-specific *Rhizobium* – a maximum of 2 hours before planting – and was kept in a cool place until it could be planted. Seed was also treated with pesticide and fungicide prior to establishment. Immediately after establishment, each plot was raked lightly, in order to cover seeds and maintain inoculant activity.

Plots were harvested every 28 days using quadrats – to determine growth rate (kg DM ha^{-1} day^{-1}) and dry matter (DM) production (kg DM ha^{-1}). Three quadrats of 0.25 m^2 were randomly placed per plot, and were cut to a height of 50 mm. The samples were pooled and weighed. A grab sample of approximately 500 g green material was taken from the pooled sample, weighed, dried at 60°C for 72 hours, and then weighed to determine DM content. After sampling, plots were cut to a uniform height of 50 mm above ground level using a Honda Lawnmower. Plots were only fertilised when deficiency symptoms became apparent, or if deficiencies were identified in the soil analysis. Weed control was done mainly by mechanical means.

A Student least significant difference (LSD), at 5 % significance level, was performed to compare the treatment means (Ott, 1998). The STATS module of SAS version 9.2 (2008) was used to analyse the data.

Results and discussion

The mean monthly growth rate of annual legumes is shown in Table 2. The growth rate of species varied over months, with different cultivars achieving the highest growth rate during different months. The following cultivars could be harvested four times (the rest could only be harvested three times):

- Both berseem cultivars (Calipso and Elite II)
- Both balansa cultivars (Viper and Taipan)
- Both serradella cultivars (Emena and Margurita)
- All three Persian clover cultivars (Morbulk, Laser and Maral)
- The arrowleaf cultivar Zulu
- The subterranean cultivars (Woogenellup and Campeda)

All medic and Vetch cultivars were only harvested three times.

The total seasonal and annual dry matter (DM) production of the annual legumes evaluated, is given in Table 3. The annual legumes were only productive during winter and spring. During winter, the barrel medic cultivar Parragio and the serradella cultivar Emena, had similar (P>0.05) DM production to the berseem cultivar Calipso, barrel medic cultivar Parabinga, and the serradella cultivar Margurita – but were higher (P<0.05) than the rest. The spring DM production of the Serradella cultivar Emena was similar (P>0.05) to that of the other Serradella cultivar Margurita, and the Berseem clover cultivar Elite II, but was higher than the rest. The highest (P<0.05) annual dry matter production was for the Serradella cultivar Emena, with only the other Serradella cultivar, Margurita, having a similar (P>0.05) production.

The highest producing cultivars (in terms of annual DM production) for each species, are listed below. The highest producing cultivar is listed first, and any similar (P>0.05) producing cultivars thereafter:

- Berseem clover: Both cultivars had similar (P>0.05) DM production
- Arrowleaf clover: Both cultivars had similar (P>0.05) DM production
- Balansa cover: Both cultivars had similar (P>0.05) DM production
- Subterranean clover: Woogenellup, with similar (P>0.05) from Losa
- Persian clover: Three cultivars had similar (P>0.05) DM production
- Vetch: Both cultivars had similar (P>0.05) DM production
- Medics: Barrel medic cultivars Parragio and Parabinga
- Serradella: Both cultivars had similar (P>0.05) DM production

Conclusions

1. Temperate annual legumes that are established during autumn will produce a maximum of four harvests/grazings – providing forage primarily from mid-winter to early spring.
2. The Serradella cultivars Emena and Margurita, were the most productive during this study – for the region.

MESSAGE TO THE FARMER

- Annual legumes can be established to provide high quality forage during mid-winter and early spring.
- The selection of the annual legume species/cultivar should be based on the seasonal DM production of the species/cultivar, the specific fodder-flow shortage it is required to fill, the local climatic conditions, and the prevalent pests and diseases.

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Table 2. Mean monthly growth rate (kg DM ha^{-1} day^{-1}) of annual ryegrass cultivars, during 2011.

Species	Cultivar	July	Aug	Sept	Oct	Nov
Berseem	Calipso	6.51^{e}	48.9^{abc}	36.2^{bcde}	37.3^{bcd}	18.1^{ab}
Berseem	Elite II	2.75^{gh}	38.6^{cde}	37.8^{bcde}	65.0^{a}	32.8^{a}
Arrowleaf	Zulu	0.77^{h}	13.8^{ghi}	27.3^{efgh}	37.9^{bcd}	29.1^{a}
Arrowleaf	Cefalo	2.83^{gh}	5.30^{i}	9.58^{hi}	47.9^{abc}	-
Balansa	Viper	0.69^{h}	20.1^{fgh}	28.0^{efgh}	37.4^{bcd}	10.6^{ab}
Balansa	Taipan	0.29^{h}	17.4^{fgh}	24.2^{efgh}	39.5^{bcd}	3.53^{b}
Subterranean	Losa	3.77^{fg}	40.0^{cd}	40.3^{bcde}	29.4^{def}	-
Subterranean	Dalkeith	1.36^{gh}	30.0^{def}	11.8^{ghi}	1.07^{g}	-
Subterranean	Woogenellup	2.28^{gh}	43.6^{bcd}	55.6^{b}	35.7^{cd}	3.70^{b}
Subterranean	Campeda	0.98^{h}	25.9^{efg}	42.3^{bcde}	33.0^{cde}	2.58^{b}
Persian	Morbulk	2.08^{gh}	13.5^{ghi}	31.2^{defgh}	36.4^{bcd}	19.0^{ab}
Persian	Laser	1.17^{h}	13.3^{ghi}	24.0^{efgh}	35.6^{d}	13.1^{ab}
Persian	Maral	1.31^{gh}	14.9^{ghi}	34.7^{bcdef}	35.3^{cd}	12.0^{ab}
Vetch	Max	9.92^{bc}	20.9^{fgh}	45.1^{bcde}	12.1^{fg}	-
Vetch	Capello	9.74^{bcd}	21.9^{fgh}	26.1^{efgh}	7.55^{g}	-
Barrel medic	Paraggio	7.20^{de}	59.2^{a}	52.9^{bcd}	16.8^{efg}	-
Barrel medic	Parabinga	5.79^{ef}	56.9^{ab}	39.0^{bcde}	9.42^{g}	-
Burr Medic	Jaguar	12.0^{ab}	22.7^{fgh}	33.2^{cdefg}	6.08^{g}	-
Burr Medic	Santiago	1.72^{gh}	9.32^{hi}	1.32^{i}	3.52^{g}	-
Burr Medic	Scimitar	1.06^{h}	11.8^{hi}	13.6^{fghi}	1.69^{g}	-
Serradella	Emena	13.0^{a}	36.6^{cde}	90.5^{a}	43.0^{bcd}	20.1^{ab}
Serradella	Margurita	1.36^{gh}	49.0^{abc}	54.9^{bc}	53.5^{ab}	25.3^{ab}
LSD (0.05)		2.541	13.81	22.20	17.66	25.30

LSD (0.05) compares within month and over cultivars.
^{abc} Means with no common superscript, differ significantly.
*Growth rate from establishment to first harvest.

Table 3. Total seasonal and annual dry matter production (kg DM ha^{-1}) of annual legume cultivars, during 2011.

Species	Cultivar	Winter	Spring	Annual
Berseem	Calipso	2065^{abc}	2385^{cde}	4450^{bcd}
Berseem	Elite II	1376^{ef}	3468^{ab}	4844^{bc}
Arrowleaf	Zulu	468^{hi}	1961^{defgh}	2429^{ghi}
Arrowleaf	Cefalo	250^{i}	1194^{ghijk}	1444^{ijk}
Balansa	Viper	612^{ghi}	1677^{defghi}	2289^{hij}
Balansa	Taipan	497^{hi}	1849^{defghi}	2346^{hij}
Subterranean	Losa	1523^{de}	1979^{defgh}	3502^{defg}
Subterranean	Dalkeith	984^{fg}	351^{kl}	1335^{jk}
Subterranean	Woogenellup	1465^{de}	2651^{bcd}	4116^{cde}
Subterranean	Campeda	829^{gh}	1845^{defghi}	2674^{fgh}
Persian	Morbulk	600^{ghi}	2232^{def}	2832^{fgh}
Persian	Laser	499^{hi}	1914^{defghi}	2413^{ghij}
Persian	Maral	555^{ghi}	2185^{defg}	2740^{fgh}
Vetch	Max	1646^{cde}	1614^{efghi}	3260^{efgh}
Vetch	Capello	1654^{cde}	948^{ijkl}	2602^{fgh}
Barrel medic	Paraggio	2428^{a}	1967^{defgh}	4395^{cd}
Barrel medic	Parabinga	2211^{ab}	1365^{fghij}	3576^{def}
Burr Medic	Jaguar	1916^{bcd}	1106^{hijkl}	3022^{fgh}
Burr Medic	Santiago	383^{hi}	139^{l}	476^{k}
Burr Medic	Scimitar	405^{hi}	413^{jkl}	818^{k}
Serradella	Emena	2418^{a}	3943^{a}	6362^{a}
Serradella	Margurita	2228^{ab}	3291^{abc}	5520^{ab}
LSD (0.05)		457.7	998.5	1093

LSD (0.05) compares within month and over cultivars.
^{abc} Means with no common superscript, differ significantly.

10. The production potential of fescue, *Festulolium* hybrids, and ryegrass cultivars in the southern Cape

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Introduction

There has been a recent call for forage cultivars with increased resistance to biotic stresses, and abiotic stresses such as heat, drought and cold due to climate change (Kopecky *et al.*, 2005). The complementary agronomic characteristics of ryegrass (*Lolium* spp.) and fescues (*Festuca* spp.) – namely high forage quality and stress tolerance respectively – has led to various attempts to combine these characteristics through hybridisation of these species (Kopecky *et al.*, 2005; Akgun *et al.*, 2008). The resultant hybrids are commonly referred to as *Festulolium*X spp. So far, 23 amphidiploid *Festulolium* cultivars have been registered internationally. An additional 18 cultivars resulting from introgression of tall fescue and perennial or Italian ryegrass, are also available (Ghesquire *et al.*, 2010).

Three different hybrid varieties are commonly available. *Festulolium pabulare* is a cross between Tall Fescue (*Festuca arundinacea*) and Italian ryegrass (*Lolium multiflorum* var. *italicum*), and *Festulolium braunii* is a cross between meadow fescue (*Festuca pratensis*) and Italian ryegrass. Both these crosses are then back-crossed with either their fescue or ryegrass parent species, to obtain, respectively – festucoid and loloid varieties.

There are currently no scientific data describing the production potential of such *Festulolium* varieties, compared to ryegrass and fescue under irrigation in the southern Cape. The aim of this study was thus to determine and compare the production potential of various Festulolium cultivars, relative to that of ryegrass and fescue. Some 13 Festulolium cultivars, 7 fescue cultivars, and 4 ryegrass cultivars were compared in terms of seasonal and annual dry matter (DM) production, over a three year period. The trial was established during May 2011, and the first year of data are here discussed.

Materials and Methods

The study was carried out at the Outeniqua Research Farm near George (Altitude 201 m, 33° 58' 38" S; 22° 25' 16" E; rainfall 728 mm year^{-1}) in the Western Cape Province of South Africa, on an Estcourt soil type (Soil Classification Workgroup, 1991). The study area was under permanent overhead sprinkler irrigation, with irrigation scheduling done by means of a tensiometer. Irrigation commenced at a tensiometer reading of -25 kPa, and was terminated at a reading of -10 kPa (Botha, 2002).

Prior to establishment, soil samples were taken to a depth of 150 mm and analysed for Ca, Mg, Na, K, P, Cu, Zn, Mn, B, S, and C levels. Fertiliser was applied according to the soil analysis, to raise the soil P level to 35 mg kg^{-1}, K level to 80 mg kg^{-1}, and the pH (KCl) to 5.5 (Beyers, 1973).

The scientific name, *Festuca* parent, *Lolium* parent, Backcross species, and cultivar name of species that were evaluated – are shown in Table 1. A total of 24 cultivars were evaluated in the form of a randomised design, with three replicates per cultivar (total of 72 plots).

The trial was established on 11 May 2011, on a paddock previously planted to perennial ryegrass-clover pastures. The paddock was sprayed with a contact herbicide during January, and tilled during February to remove the existing sward. Monthly herbicide applications (up to establishment) were aimed at eradicating emerging weeds. The trial area was tilled prior to establishment with a disk harrow and kongskilde, and rolled with a light landroller to create a firm seedbed and eradicate any remaining weeds. The various cultivars/species were planted according to commercially recommended seeding rates for fescue (20 kg ha^{-1}), Italian ryegrass (25 kg ha^{-1}), and perennial ryegrass (20 kg ha^{-1}). The Festuloliums were planted at 20 kg ha^{-1}. Plots were 2.1 m x 6 m, per treatment (12.6 m^2), with 14 rows spaced 15 cm apart. After establishment, plots were raked lightly to cover seeds.

Plots were harvested every 28 days to determine growth rate (kg DM ha^{-1} day^{-1}) and total DM production (kg DM ha^{-1}), by means of quadrats. Three quadrats of 0.25 m^2 were randomly placed per plot, and cut to a height of 50 mm. The samples were pooled and weighed. A grab sample of approximately 400 g was taken from the pooled sample, weighed, dried at 60°C for 72 hours, and then re-weighed to determine DM content. After sampling, plots were cut to a uniform height of 50 mm, using a Honda Lawnmower. All plots receive a topdressing of 50 kg N ha^{-1} and 50 kg K ha^{-1} – after each harvest (ARC, 2005). Plots are sprayed with herbicide, as required, to control weeds.

A Student least significant difference (LSD) test, at 5 % significance level, was preformed to compare the treatment means (Ott, 1998). The STATS module of SAS version 9.2 (2008) was used to analyse the data. Data were analysed as follows:

- The mean growth rates, seasonal DM production, and annual DM production of the different species were compared with each other.
- All cultivars were compared with each other.
- Festulolium cultivars were compared with each other.

The production potential of Festulolium cultivars will be discussed in general, and in comparison with the parent lines (fescue and ryegrass species used in crosses) and the commonly used perennial grass species in the area (perennial ryegrass).

Table 1. The scientific name, *Festuca* parent, *Lolium* parent, back-cross species, and cultivar name of species, being evaluated.

	Scientific name	Festuca parent	Lolium parent	Back-cross species	Cultivar name
1	*F. arundinacea*	-	-	-	Kora
2	*F. arundinacea*	-	-	-	Tuscany
3	*F. arundinacea*	-	-	-	Baroptima
4	*F. arundinacea*	-	-	-	Verdant
5	*F. arundinacea*	-	-	-	Jenna
6	*F. pratensis*	-	-	-	Laura
7	*F. pratensis*	-	-	-	Jamaica
8	*Fest. pabulare*	*F. arundinacea*	*L. multiflorum*	*F. arundinacea*	Felina
9	*Fest. pabulare*	*F. arundinacea*	*L. multiflorum*	*F. arundinacea*	Hykor
10	*Fest. pabulare*	*F. arundinacea*	*L. multiflorum*	*F. arundinacea*	Mahulena
11	*Fest. pabulare*	*F. arundinacea*	*L. multiflorum*	*F. arundinacea*	Rebab
12	*Fest. pabulare*	*F. arundinacea*	*L. multiflorum*	*F. arundinacea*	HZFLPC2
13	*Fest. pabulare*	*F. arundinacea*	*L. multiflorum*	*F. arundinacea*	Fojtan
14	*Fest. pabulare*	*F. arundinacea*	*L. multiflorum*	*L. multiflorum*	Becva
15	*Fest. pabulare*	*F. arundinacea*	*L. multiflorum*	*L. multiflorum*	Lofa
16	*Fest. braunii*	*F. pratensis*	*L. multiflorum*	*L. multiflorum*	Perun
17	*Fest. braunii*	*F. pratensis*	*L. multiflorum*	*L. multiflorum*	Perseus
18	*Fest. braunii*	*F. pratensis*	*L. multiflorum*	*L. multiflorum*	Hostyn

19	*Fest. braunii*	*F. pratensis*	*L. multiflorum*	*L. multiflorum*	Paulita
20	*Fest. braunii*	*F. pratensis*	*L. multiflorum*	*L. multiflorum*	Achilles
21	*L. perenne*	-	-	-	Bealy
22	*L. perenne*	-	-	-	Bronsyn
23	*L. multiflorum*	-	-	-	Jeanne
24	*L. multiflorum*	-	-	-	Parfait

Results and discussion

Species compared

The mean monthly growth rate (kg DM ha^{-1}) of tall fescue, meadow fescue, perennial ryegrass, Italian ryegrass and festulolium cultivars is shown in Table 2. The highest (P<0.05) growth rate was obtained by different species during different months. Perennial ryegrass had the highest (P<0.05) or similar (P>0.05) to highest growth rate during all the months – except January and April.

The total seasonal and annual dry matter production (kg DM ha^{-1}) of tall fescue, meadow fescue, perennial ryegrass, Italian ryegrass, and festulolium cultivars, is shown in Table 3. The highest (P<0.05) total annual DM production was achieved by Italian and perennial ryegrass, with a similar (P>0.05) production obtained by *Festulolium braunii.* The total annual DM production of Tall Fescue And Meadow Fescue did not differ (P>0.05).

The production potential of the different festulolium varieites will now be discussed relative to that of the parent species (*Festuca* spp. and *Lolium* spp.):

a) Festulolium pabulare loloid: Tall Fescue x Italian ryegrass x Italian ryegrass

Festulolium pabulare loloid (FPL) had a similar (P>0.05) growth rate to Italian ryegrass, from establishment until April, but its growth rate was lower (P<0.05) during May (Table 2). As a result, the seasonal DM production of FPL was similar (P>0.05) to that of Italian ryegrass during all seasons. Irrespective of this, the annual DM production of FPL was lower (P<0.05) than for Italian ryegrass (Table 3).

From establishment until October, the growth rate of FPL was higher (P<0.05) than or similar (P>0.05) to that of Tall Fescue, while from November until May the growth rate of FPL was similar (P>0.05) to or lower (P<0.05) than that of Tall Fescue. The seasonal dry-matter production of FPL was higher (P<0.05) than that of Tall Fescue during winter, but lower (P<0.05) during summer and autumn. The total annual DM production of fescue and FPF, was similar (P>0.05).

Festulolium pabulare loloid had the potential to match the growth rate of Italian ryegrass during the majority of the growth season and to have a higher growth rate during early establishment, than Tall Fescue.

b) Festulolium pabulare festucoid: Tall Fescue x Italian ryegrass x Italian ryegrass

The growth rate of *Festulolium pabulare* festucoid (FPF) was similar (P>0.05) to or higher (P<0.05) than that of Tall Fescue during all months except August. The seasonal dry-matter production of Tall Fescue and FPF was similar (P>0.05) during all seasons, except winter, when the DM production of FPF was lower (P<0.05). The total annual DM prodction of FPF and Tall Fescue was similar (P>0.05).

The growth rate of Italian ryegrass was higher (P<0.05) than that of FPF from July to August, but was lower (P<0.05) than or similar (P>0.05) to FPF from November to May. During winter and spring the total seasonal DM production of Italian ryegrass was (P<0.05) higher than that of FPF – with the annual DM production of Italian ryegrass also being higher (P<0.05).

The annual production potential of FPL (P<0.05) was lower than that of Italian ryegrass, – but similar (P>0.05) to that of Tall Fescue. Thus, FPF, like Tall Fescue, is slower to establish than ryegrass.

c) *Festulolium braunii loloid: Meadow Fescue x Italian ryegrass x Italian ryegrass*

The growth rate of *Festulolium braunii* loloid (FBL) was similar (P>0.05) to or higher (P<0.05) than that of Meadow Fescue during all months. The seasonal dry-matter production of FBL was higher (P<0.05) than Meadow Fescue during winter and autumn, and similar (P>0.05) during spring and summer. The annual DM production FBL was higher (P<0.05) than that of meadow fescue.

Festulolium braunii loloid (FBL) had a similar (P>0.05) growth rate to Italian ryegrass during all months except July and February – when that of Italian ryegrass was higher (P<0.05). The seasonal dry matter production of FBL was similar (P>0.05) to that of Italian ryegrass during spring, summer and autumn, but lower (P<0.05) during winter. The total annual dry matter production of FBL and italian ryegrass was similar (P>0.05).

The FBL variety had a higher growth during establsihment than Meadow Fescue, and a similar growth rate to ryegrass from spring to autumn – making it quicker to establish than fescue, but slightly slower than Italian ryegrass.

Both *Festulolium pabulare* varieties had a similar (P>0.05) annual production potential to their fescue parent (tall fescue) – but lower (P<0.05) than that of Italian ryegrass (Table 3). *Festulolium braunii* had a higher production potential than its fescue parent (meadow fescue) and similar to Italian ryegrass. Of the Festulolium varieties, FBL had the highest total annual DM production, with a similar (P>0.05) production obtained by FPL.

Festulolium cultivars compared

The mean monthly growth rate of the Festulolium cultivars evaluated is shown in Table 4. The cultivar with the highest growth rate varied between months. The FPL cultivar Perun, and the FBL cultivars Becva, had the highest (P<0.05) or similar (P>0.05) to the highest growth rate from July to October. The FPF cultivar Mahulena had the highest (P<0.05) or similar (P>0.05) to highest growth rate from October to May.

The total seasonal and annual DM production of the Festulolium cultivars evaluated is shown in Table 5. The FPL cultivar Becva, and the FBL cultivar Hostyn had similar (P>0.05) DM production to the highest producing cultivars during all seasons. The highest (P<0.05) total annual DM production was for the FBL cultivars Perun and Hostyn – with similar productions (P>0.05) obtained by the FPF cultivar Mahulena, FPL cultivar Becva, and the FBL cultivars Paulita and Achilles.

All cultivars compared

The mean, monthly growth rate of fescue, Festulolium and ryegrass cultivars evaluated during the study, is shown in Table 6. The highest monthly growth rate was obtained by different cultivars, during the various months.

The total seasonal and annual DM production of fescue, festulolium and ryegrass cultivars, is shown in Table 7. The annual DM production of the perennial ryegrass cultivar Bealy was similar (P>0.05) to that of the tall fescue cultivar Verdant, but higher (P<0.05) than the rest. Verdant had the highest (P<0.05) seasonal DM production during winter. From spring to autumn, the Tall Fescue cultivar Jenna, perennial ryegrass cultivar Bealy, and festulolium cultivars Mahulena, Hostyn, and Paulita – had the highest (P<0.05) or similar (P>0.05) to the highest seasonal DM production.

a) *Festulolium cultivars compared to Italian ryegrass*

The Italian ryegrass cultivars, Parfait and Jeanne did not differ in terms of total annual DM production. Parfait will be used to compare the seasonal and annual dry-matter production of Festulolium cultivars – to that of the ryegrass parent. Parfait had a similar (P>0.05) total annual dry-matter production to the cultivars Becva, Perun, Hostyn and Paulita, but was higher (P<0.05) than the remaining Festulolium cultivars. During winter the FPL cultivar Becva, and the FBL cultivar Perun, were the only Festulolium cultivars that had a similar (P>0.05) seasonal dry-matter production to Parfait – with that of the remaining festulolium cultivars lower (P<0.05). During summer all the Festulolium cultivars had a similar (P>0.05) dry-matter production to

Parfait. During spring and summer the only Festulolium cultivars that had a lower (P<0.05) dry-matter production than Parfait, were Felina (FPF) and Lofa (FPL), respectively.

b) Festulolium cultivars compared to fescue

The fescue cultivar Verdant had the highest (P<0.05) total annual DM production of the fescue cultivars, and will be used as the fescue parent in order to compare the production potential of Festulolium cultivars. During winter, the DM production of Verdant was higher (P<0.05) than all the Festulolium cultivars. Verdant had a (P<0.05) lower dry-matter production than all the FBL cultivars, as well as the FPL cultivar Becva, and the FPF cultivar Mahulena, during spring – but it was similar (P>0.05) to the rest of the Festulolium cultivars. The DM production of Verdant was higher (P<0.05) than Lofa and Perun during summer, but similar (P>0.05) to the rest of the festulolium cultivars. The autumn production of the Festulolium cultivars was similar (P>0.05) to that of Verdant, except for Lofa and Felina, for which it was lower(P<0.05). The total annual dry-matter production of Verdant was similar (P>0.05) to Becva (FPL), Perun (FBL), Hostyn (FBL) and Paulita (FBL) – but higher (P<0.05) than the rest.

Of the Festulolium cultivars, Hostyn had the highest annual DM production, with similar (P>0.05) dry-matter production achieved by Mahulena, Becva, Perun, Hostyn and Paulita. Hostyn also had a similar production to the Tall Fescue cultivars Verdant, Kora and Jenna, as well as the two Italian ryegrass cultivars.

Conclusions

1. Both *Festulolium pabulare* varieties had a similar annual dry-matter production potential to their fescue parent (Tall Fescue), but these were lower than for Italian ryegrass.
2. When comparing the two *Festulolium pabulare* varieties, the loloid variety showed a superior winter and spring production, while the festucoid variety had a higher summer production.
3. The *Festulolium brauni* variety was the only Festulolium variety that had a similar total annual dry-matter production to Italian ryegrass, and a higher total annual dry-matter production than its fescue parent (Meadow Fescue).
4. When compared with each other, the *Festulolium braunii* variety had a higher total annual dry-matter production than the *Festulolium pabulare* festucoid variety, but it was similar to the *Festulolium pabulare* loloid variety. It would thus appear that loloid types have the ability to establish more rapidly than festucoid types, and, as result, are higher yielding in the first year.
5. Based on the first year of data, the recommended Festulolium cultivars are all loloid types: Becva (FPL), Perun (FBL), Hostyn (FBL), and Paulita (FBL). All these cultivars had a similar annual dry-matter production to the Tall Fescue cultivar Verdant, and the Italian ryegrass cultivar Parfait. Of the festucoid varieties, Mahulena had the highest production during the first year.
6. Bealy, a perennial ryegrass, was the highest yielding cultivar during year one, with none of the Festulolium cultivars out-yielding it during this time.
7. Further evaluation of Festulolium cultivars in successive years is required to determine if they demonstrate superior persistence to annual and perennial ryegrass in this region.
8. Festuloliums will have to be evaluated under animal grazing conditions to determine whether they show a higher palatability and intake compared to fescue.

MESSAGE TO THE FARMER

- New perennial grasses are available and can be included in fodder-flow programmes.
- Care must be taken when selecting cultivars and species to utilise in a system – with selection based on seasonal production potential.
- Further evaluation of Festuloliums is required in this region, in order to determine persistence, grazing tolerance, and palatability.

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Table 2. Mean monthly growth rate (kg DM ha^{-1} day^{-1})of Tall Fescue, Meadow Fescue, perennial ryegrass, Italian ryegrass, and Festulolium varieties during year 1.

Species	July*	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
TF	9.52^{cd}	42.0^{b}	75.4^{cd}	68.6^{c}	34.3^{ab}	62.0^{bc}	56.0^{ab}	17.1^{b}	50.2^{a}	43.0^{a}	29.3^{ab}
MF	5.45^{d}	48.8^{ab}	83.8^{bc}	73.0^{bc}	26.8^{bc}	58.6^{bc}	52.6^{abc}	14.1^{bc}	31.9^{c}	40.4^{ab}	26.7^{b}
IR	21.3^{a}	49.3^{ab}	100^{a}	78.6^{ab}	21.9^{cd}	60.2^{bc}	36.9^{d}	15.4^{c}	46.4^{b}	36.1^{ab}	34.0^{a}
PR	15.8^{ab}	55.3^{a}	92.4^{ab}	83.3^{a}	29.9^{abc}	74.9^{a}	43.1^{bcd}	18.3^{ab}	44.9^{ab}	34.1^{b}	29.4^{ab}
FPL	15.6^{ab}	47.0^{ab}	98.8^{a}	74.7^{abc}	16.6^{d}	51.7^{c}	43.3^{bcd}	9.05^{c}	37.7^{bc}	37.8^{ab}	27.1^{b}
FPF	4.72^{d}	32.6^{c}	64.1^{d}	72.1^{bc}	38.6^{a}	60.6^{bc}	61.1^{a}	23.5^{a}	49.4^{a}	39.1^{ab}	27.8^{ab}
FBL	14.3^{bc}	48.8^{ab}	89.3^{abc}	82.3^{a}	23.4^{cd}	62.7^{b}	40.6^{cd}	17.1^{ab}	46.6^{ab}	37.5^{ab}	31.1^{ab}
LSD	5.842	8.628	14.01	9.070	9.468	10.63	13.62	6.421	9.702	7.874	6.462

LSD (0.05) compares within month. ^{abc} Means with no common superscript, differ significantly.
TF: Tall Fescue, MF: Meadow Fescue, FPF: *Festulolium pabulare* festucoid (Tall Fescue x Italian ryegrass x Tall Fescue),
FPL: *Festulolium pabulare* loloid (Tall Fescue x Italian ryegrass x Italian ryegrass),
FBL: *Festulolium braunii* loloid (Meadow Fescue x Italian ryegrass x Italian ryegrass), PR: Perennial ryegrass, IR: Italian ryegrass.

Table 3. Total seasonal and annual dry matter production (kg DM ha^{-1}) of Tall Fescue, Meadow Fescue, perennial ryegrass, Italian ryegrass, and Festulolium varieties during year 1.

Species	Winter	Spring	Summer	Autumn	Annual
TF	2405^{cd}	4965^{cd}	3845^{ab}	3437^{a}	14652^{bc}
MF	2193^{de}	5121^{bcd}	3566^{abc}	2761^{c}	13642^{c}
IR	3908^{a}	5618^{ab}	3210^{cd}	3247^{ab}	16010^{a}
PR	3512^{ab}	5738^{a}	3891^{ab}	3048^{abc}	16188^{a}
FPL	3216^{ab}	5441^{abc}	2966^{d}	2871^{bc}	14384^{bc}
FPF	1441^{e}	4847^{d}	4128^{a}	3267^{ab}	13683^{c}
FBL	3141^{bc}	5331^{abcd}	3434^{bcd}	3235^{ab}	15251^{ab}
LSD (0.05)	762.4	509.5	582.2	436.5	1057

LSD (0.05) compares within month. ^{abc} Means with no common superscript, differ significantly.
TF: Tall Fescue, MF: Meadow Fescue, FPF: *Festulolium pabulare* festucoid (Tall Fescue x Italian ryegrass x Tall Fescue),
FPL: *Festulolium pabulare* loloid (Tall Fescue x Italian ryegrass x Italian ryegrass),
FBL: *Festulolium braunii* loloid (Meadow Fescue x Italian ryegrass x Italian ryegrass), PR: Perennial ryegrass, IR: Italian ryegrass.

Table 4. The mean monthly growth rates (kg DM ha^{-1} day^{-1}) of festulolium cultivars during year 1.

Species	Cultivar	July[4]	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
FPF[1]	Felina	1.52^{e}	25.8^{d}	49.8^{g}	69.9^{bc}	36.3^{abcd}	62.7^{abc}	60.9^{abc}	17.1^{de}	48.0^{a}	35.7^{a}	22.9^{b}
FPF	Hykor	8.15^{cde}	32.9^{bcd}	70.8^{cdef}	78.7^{abc}	27.8^{bcde}	66.8^{ab}	53.4^{abcd}	16.5^{de}	52.1^{a}	35.5^{a}	27.8^{ab}
FPF	Mahulena	3.7^{e}	41.6^{abc}	72.0^{cdef}	73.3^{abc}	43.3^{a}	60.5^{abc}	64.5^{ab}	26.8^{abc}	46.7^{a}	40.9^{a}	34.8^{a}
FPF	Rebab	3.06^{e}	31.2^{cd}	59.5^{fg}	68.7^{bc}	44.7^{a}	64.2^{ab}	52.6^{abcd}	31.1^{a}	50.5^{a}	43.3^{a}	31.9^{ab}
FPF	HZFLPC2	3.83^{e}	30.7^{cd}	68.4^{defg}	68.2^{c}	40.6^{ab}	57.8^{abc}	72.7^{a}	21.7^{bcd}	51.6^{a}	36.1^{a}	23.4^{b}
FPF	Fojtan	6.26^{de}	33.6^{bcd}	64.1^{efg}	73.6^{abc}	38.9^{abc}	51.9^{bc}	62.8^{ab}	27.9^{ab}	50.4^{a}	43.1^{a}	26.2^{ab}
FPL[2]	Lofa	11.5^{cd}	45.7^{a}	83.1^{bcde}	81.3^{abc}	19.2^{e}	46.5^{c}	36.2^{cd}	7.9^{f}	33.7^{a}	35.8^{a}	26.2^{ab}
FPL	Becva	19.6^{ab}	48.3^{a}	114^{a}	68.1^{c}	14.1^{e}	57.0^{abc}	50.3^{abcd}	10.2^{ef}	41.6^{a}	39.8^{a}	28.0^{ab}
FBL[3]	Perun	20.7^{a}	47.2^{a}	98.9^{ab}	79.9^{abc}	24.6^{de}	57.6^{abc}	32.2^{d}	14.6^{def}	48.3^{a}	40.3^{a}	32.4^{ab}
FBL	Perseus	11.7^{cd}	43.7^{ab}	88.1^{bcd}	84.3^{ab}	23.4^{de}	63.5^{ab}	35.5^{cd}	14.1^{def}	39.1^{a}	36.8^{a}	32.4^{ab}
FBL	Hostyn	15.2^{abc}	50.1^{a}	88.5^{bc}	81.2^{abc}	22.2^{e}	72.3^{a}	46.4^{bcd}	19.2^{cd}	48.4^{a}	41.0^{a}	35.1^{a}
FBL	Paulita	12.4^{bcd}	49.9^{a}	84.6^{bcd}	86.5^{a}	25.7^{cde}	66.2^{ab}	45.5^{bcd}	21.6^{bcd}	52.4^{a}	33.2^{a}	31.6^{ab}
FBL	Achilles	11.5^{cd}	53.2^{a}	86.3^{bcd}	79.6^{abc}	20.9^{e}	54.0^{bc}	443.5^{bcd}	16.1^{de}	44.9^{a}	36.2^{a}	23.9^{b}
		7.692	11.65	19.95	16.01	13.86	16.7	25.88	8.042	19.65	14.76	10.03

[1] FPF: *Festulolium pabulare* festucoid (Tall Fescue x Italian ryegrass x Tall fescue)
[2] FPL: *Festulolium pabulare* loloid (Tall Fescue x Italian ryegrass x Italian ryegrass)
[3] FBL: *Festulolium braunii* loloid (Meadow Fescue x Italian ryegrass x Italian ryegrass)
[4] Growth rate from establishment in May to first harvest
LSD (0.05) compares over cultivars within month
[abc] Means with no common superscript, differ significantly

Table 5. Total seasonal and annual dry-matter production (kg DM ha^{-1}) of festulolium cultivars during year 1.

Species	Cultivar	Winter	Spring	Summer	Autumn	Annual
FPF[1]	Felina	960^{f}	4312^{c}	4002^{ab}	2911^{ab}	12185^{e}
FPF	Hykor	1957de	4927^{abc}	3893^{abc}	3248^{ab}	14025^{bcd}
FPF	Mahulena	1505^{ef}	5235^{ab}	4309^{a}	3434^{ab}	14483^{abcd}
FPF	Rebab	1247^{ef}	4787^{bc}	4205^{ab}	3526^{a}	13764de
FPF	HZFLPC2	1425^{ef}	4923^{abc}	4317^{a}	3124^{ab}	13788de
FPF	Fojtan	1554^{ef}	4900^{abc}	4044^{ab}	3359^{ab}	13856^{cde}
FPL[2]	Lofa	2744^{cd}	5123^{abc}	2583^{d}	2679^{b}	13129de
FPL	Becva	3689^{ab}	5540^{ab}	3349^{abcd}	3063^{ab}	15641^{ab}
FBL[3]	Perun	3770^{a}	5688^{a}	2977^{cd}	3397^{ab}	15833^{a}
FBL	Perseus	2690^{cd}	5463^{ab}	3227^{bcd}	3033^{ab}	14413^{abcd}
FBL	Hostyn	3277^{abc}	5358^{ab}	3932^{abc}	3494^{ab}	16061^{a}
FBL	Paulita	2977^{bc}	5485^{ab}	3797^{abc}	3300^{ab}	15559^{abc}
FBL	Achilles	2990^{abc}	5215^{ab}	3236^{bcd}	2950^{ab}	14390^{abcd}
LSD (0.05)		789.8	817.0	986.5	828.0	1761

[1] FPF: *Festulolium pabulare* festucoid (Tall Fescue x Italian ryegrass x Tall Fescue)
[2] FPL: *Festulolium pabulare* loloid (Tall Fescue x Italian ryegrass x Italian ryegrass)
[3] FBL: *Festulolium braunii* loloid (Meadow Fescue x Italian ryegrass x Italian ryegrass)
LSD (0.05) compares over cultivars within season
[abc] Means with no common superscript, differ significantly

Table 6. The mean monthly growth rate (kg DM ha^{-1} day^{-1}) of festulolium, fescue and ryegrass cultivars, during year 1.

Species	Cultivar	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March	April	May
TF[1]	Kora	5.5^{efg}	40.6^{efgh}	79.9^{cdefg}	81.6^{abcde}	42.6^{a}	67.1^{bc}	40.6^{def}	14.8^{efghi}	50.4^{ab}	44.6^{ab}	31.6^{abcd}
TF	Tuscany	4.6^{fg}	27.4^{i}	63.7^{fgh}	65.4^{gh}	44.0^{a}	56.5^{bcd}	59.7^{abcde}	25.2^{abc}	46.1^{abcde}	45.0^{a}	25.6^{bcd}
TF	Baroptima	3.9^{fg}	36.7^{fghi}	60.9^{gh}	70.6^{cdefgh}	46.7^{a}	66.8^{bc}	49.4^{bcdef}	15.7^{efgh}	48.2^{abcd}	44.9^{ab}	25.0^{bcd}
TF	Verdant	25.2^{a}	61.3^{a}	84.8^{bcde}	57.6^{h}	12.9^{g}	65.3^{bc}	66.7^{ab}	8.1^{hi}	54.6^{ab}	38.6^{abc}	35.9^{a}
TF	Jenna	8.4^{def}	44.1^{cdefg}	87.9^{bcd}	67.7^{fgh}	25.3^{def}	54.2^{cd}	63.7^{abc}	21.5^{bcde}	51.7^{ab}	42.0^{abc}	28.3^{abcd}
MF[2]	Laura	6.9^{defg}	50.1^{abcde}	80.6^{cdefg}	68.6^{efgh}	23.2^{efg}	55.0^{cd}	52.6^{abcdef}	15.4^{efghi}	32.5^{de}	37.1^{abc}	23.6^{cd}
MF	Jamaica	4.0^{fg}	47.5^{bcdef}	86.9^{bcd}	$77.3^{abcdefg}$	30.3^{bcde}	62.3^{bcd}	52.6^{abcdef}	12.8^{fghi}	31.3^{e}	43.7^{ab}	29.7^{abcd}
FPF[3]	Felina	1.5^{g}	25.8^{i}	49.8^{h}	69.9^{defgh}	36.3^{abcd}	62.7^{bc}	60.9^{abcd}	17.1^{defg}	45.0^{abcde}	35.7^{abc}	22.9^{d}
FPF	Hykor	8.1^{def}	32.9^{ghi}	70.8^{defgh}	$78.7^{abcdefg}$	27.8^{cde}	66.8^{bc}	53.4^{abcdef}	16.5^{defg}	52.1^{ab}	35.5^{abc}	27.8^{abcd}
FPF	Mahulena	3.7^{fg}	41.6^{defgh}	72.0^{defg}	73.3^{bcdefg}	43.3^{a}	60.5^{bcd}	64.5^{abc}	26.8^{abc}	46.7^{abcde}	40.9^{abc}	34.8^{ab}
FPF	Rebab	3.1^{fg}	31.2^{hi}	59.5^{gh}	68.7^{efgh}	44.7^{a}	64.2^{bc}	52.6^{abcdef}	31.1^{a}	50.5^{ab}	43.3^{ab}	31.9^{abcd}
FPF	HZ	3.8^{fg}	30.7^{hi}	68.4^{defgh}	68.2^{efgh}	40.6^{ab}	57.8^{bcd}	72.7^{a}	21.7^{bcde}	51.6^{ab}	36.1^{abc}	23.4^{d}
FPF	Fojtan	6.3^{defg}	33.6^{ghi}	64.2^{efgh}	73.6^{bcdefg}	38.9^{abc}	51.9^{cd}	62.8^{abcd}	27.9^{ab}	50.4^{ab}	43.1^{ab}	26.2^{abcd}
FPL[4]	Lofa	11.5^{cde}	45.7^{bcdef}	83.1^{bcdef}	81.3^{abcdef}	19.2^{efg}	46.5^{d}	36.2^{f}	7.9^{i}	33.7^{cde}	35.8^{abc}	26.2^{abcd}
FPL	Becva	19.6^{ab}	48.3^{bcdef}	115^{a}	68.1^{efgh}	14.1^{fg}	57.0^{bcd}	50.3^{bcdef}	10.2^{ghi}	41.6^{abcde}	39.8^{abc}	28.0^{abcd}
FBL[5]	Perun	20.7^{ab}	47.2^{bcdef}	98.9^{abc}	79.9^{abcdef}	24.6^{defg}	57.6^{bcd}	32.2^{f}	14.6^{efghi}	48.3^{abcd}	40.3^{abc}	32.4^{abcd}
FBL	Perseus	11.7^{cde}	43.7^{cdefg}	88.1^{bcd}	84.3^{abc}	23.4^{efg}	63.5^{bc}	35.5^{f}	14.1^{efghi}	39.1^{bcde}	36.8^{abc}	32.3^{abcd}
FBL	Hostyn	15.2^{bc}	50.1^{abcde}	88.5^{bcd}	81.2^{abcdef}	22.2^{efg}	72.3^{b}	46.4^{bcdef}	19.2^{cdef}	48.4^{abcd}	41.0^{abc}	35.1^{ab}
FBL	Paulita	12.4^{cd}	49.9^{abcde}	84.6^{bcdef}	86.5^{ab}	25.7^{def}	66.1^{bc}	45.5^{bcdef}	21.6^{bcde}	52.4^{ab}	33.2^{abc}	31.6^{abcd}
FBL	Achilles	11.5^{cde}	53.2^{abcd}	86.3^{bcd}	79.6^{abcdef}	20.9^{efg}	54.0^{cd}	43.5^{cdef}	16.1^{efg}	44.9^{abcde}	36.2^{abc}	23.9^{cd}
PR[6]	Bealy	20.1^{ab}	53.7^{abc}	97.8^{abc}	75.9^{bcdefg}	30.1^{bcde}	88.6^{a}	51.8^{abcdef}	24.0^{abcd}	57.5^{a}	39.8^{abc}	32.3^{abcd}
PR	Bronsyn	11.4^{cde}	56.9^{ab}	87.1^{bcd}	90.8^{a}	29.8^{bcde}	61.2^{bcd}	34.4^{f}	12.5^{fghi}	32.3^{de}	28.5^{c}	26.6^{abcd}
IR[7]	Jeanne	22.8^{a}	45.9^{bcdef}	96.6^{abc}	83.2^{abcd}	24.7^{defg}	52.3^{bcd}	37.8^{ef}	9.3^{ghi}	44.0^{abcde}	31.3^{bc}	34.3^{ab}
IR	Parfait	19.9^{ab}	52.7^{abcd}	104^{ab}	74.0^{bcdefg}	19.1^{efg}	63.1^{bc}	36.1^{f}	21.4^{bcde}	48.9^{abc}	40.9^{abc}	33.8^{abc}
LSD (0.05)		6.28	11.60	21.14	13.74	12.00	16.03	22.31	7.78	16.16	13.60	10.25

[1] TF: Tall Fescue, [2] MF: Meadow Fescue, [3] FPF: *Festulolium pabulare* festucoid (Tall Fescue x Italian ryegrass x Tall Fescue),
[4] FPL: *Festulolium pabulare* loloid (Tall Fescue x Italian ryegrass x Italian ryegrass),
[5] FBL: *Festulolium braunii* loloid (Meadow Fescue x Italian ryegrass x Italian ryegrass), [6]PR: Perennial ryegrass, [7]IR: Italian ryegrass
LSD (0.05) compares over cultivars within month
^{abc} Means with no common superscript, differ significantly

Table 7. Total seasonal and annual dry-matter production (kg DM ha^{-1}) of festulolium, fescue and ryegrass cultivars, during year 1.

Species	Cultivar	Winter	Spring	Summer	Autumn	Annual
TF[1]	Kora	1926^{ijk}	5672^{ab}	3494^{bcdef}	3553^{abc}	14646^{defghi}
TF	Tuscany	1397^{kl}	4800^{cd}	4019^{abcd}	3269^{abcde}	13485^{hij}
TF	Baroptima	1632^{jkl}	4936^{bcd}	3763^{bcdef}	3309^{abcd}	13639^{hij}
TF	Verdant	4721^{a}	4364^{d}	3990^{abcd}	3629^{ab}	16705^{ab}
TF	Jenna	2349^{fghij}	5054^{abcd}	3956^{abcde}	3424^{abc}	14783^{cdefgh}
MF[2]	Laura	2391^{fghi}	4818^{cd}	3498^{bcdef}	2605^{ef}	13313^{hij}
MF	Jamaica	1995^{ghijk}	5425^{abc}	3634^{bcdef}	2917^{cdef}	13970^{ghi}
FPF[3]	Felina	960^{l}	4312^{d}	4002^{abcd}	2911^{cdef}	12184^{j}
FPF	Hykor	1957^{hijk}	4927^{bcd}	3893^{abcde}	3248^{abcde}	14025^{fghi}
FPF	Mahulena	1505^{kl}	5235^{abc}	4309^{ab}	3434^{abc}	14483^{defghi}
FPF	Rebab	1247^{kl}	4787^{cd}	4205^{abc}	3526^{abc}	13764^{hij}
FPF	HZ	1425^{kl}	4923^{bcd}	4317^{ab}	3124^{abcdef}	13788^{hij}
FPF	Fojtan	1554^{kl}	4900^{bcd}	4044^{abcd}	3359^{abc}	13856^{hi}
FPL[4]	Lofa	2744^{efg}	5123^{abcd}	2583^{g}	2679^{def}	13129^{ij}
FPL	Becva	3689^{bcd}	5540^{abc}	3349^{cdefg}	3063^{abcdef}	15641^{bcdef}
FBL[5]	Perun	3770^{bc}	5688^{ab}	2977^{fg}	3397^{abc}	15833^{bcde}
FBL	Perseus	2690^{efgh}	5463^{abc}	3227^{defg}	3033^{abcdef}	14413^{efghi}
FBL	Hostyn	3277^{bcde}	5358^{abc}	3932^{abcde}	3494^{abc}	16061^{bcd}
FBL	Paulita	2977^{def}	5485^{abc}	3797^{abcdef}	3300^{abcd}	15559^{bcdefg}
FBL	Achilles	2990^{def}	5215^{abc}	3236^{defg}	2950^{bcdef}	14390^{efghi}
PR[6]	Bealy	3927^{b}	5695^{ab}	4692^{a}	3648^{a}	17961^{a}
PR	Bronsyn	3096^{cdef}	5780^{a}	3090^{efg}	2449^{f}	14414^{efghi}
IR[7]	Jeanne	3952^{b}	5715^{ab}	2981^{fg}	3082^{abcdef}	15729^{bcde}
IR	Parfait	3864^{b}	5521^{abc}	3439^{bcdefg}	3467^{abc}	16291^{bc}
LSD (0.05)		750.4	819.9	898.7	679.2	1626

[1] TF: Tall Fescue, [2] MF: Meadow Fescue, [3] FPF: *Festulolium pabulare* festucoid (Tall Fescue x Italian ryegrass x Tall Fescue),
[4] FPL: *Festulolium pabulare* loloid (Tall Fescue x Italian ryegrass x Italian ryegrass),
[5] FBL: *Festulolium braunii* loloid (Meadow Fescue x Italian ryegrass x Italian ryegrass), [6]PR: Perennial ryegrass, [7]IR: Italian ryegrass
LSD (0.05) compares over cultivars within month
[abc] Means with no common superscript, differ significantly

11. The evaluation of annual ryegrass cultivars in the southern Cape: 2010 to 2011

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Introduction

Dairy and beef production in the southern Cape is based primarily on planted pastures. Annual ryegrass varieties – such as Italian ryegrass (*Lolium multiflorum* var. *italicum*) and westerwolds ryegrass (*L. multiflorum* var. *westerwoldicum*) – are established in both pure swards and are strategically over-sown into kikuyu to provide high quality fodder for animals (Botha *et al.*, 2008; Botha & Gerber, 2008: Van der Colf, 2010), and form an important part of fodder-flow systems in the southern Cape. New cultivars are continuously being made available and their evaluation in terms of seasonal and annual dry-matter production potential is needed, in order to assist farmers select the species/cultivar best suited to a specific pasture system. The aim of this study was to evaluate the production potential of annual ryegrass cultivars in the southern Cape.

Materials and Methods

This study was carried out in association with the Agricultural Research Council (ARC) – with two separate trials established during May 2010 and April 2011, respectively. Similar methods were utilised during both years/studies. The species, ploidy and cultivar name of the annual ryegrass cultivars evaluated during 2010 and 2011, are given in Table 1 and Table 2, respectively.

The studies were carried out at the Outeniqua Research Farm, near George (Altitude 201 m; 33º 58' 38'' S, 22º 25' 16'' E; rainfall 728 mm p.a.) in the Western Cape Province of South Africa, under sprinkler irrigation and on a Witfontein soil form. Irrigation scheduling was done according to tensiometer readings – commencing at –25 kPa and terminating at –10 kPa (Botha, 2002). Prior to establishment, soil samples were taken to a depth of 150 mm and were analysed for Ca, Mg, Na, K, P, Cu, Zn, Mn, B, S, and C levels. Fertiliser was applied according to the soil analysis, in order to raise the soil P level to 35 mg kg^{-1}, the K level to 80 mg kg^{-1}, and the pH (KCl) to 5.5 (Beyers, 1973). Treatments received 50 kg N ha^{-1} and 50 kg K ha^{-1} after each harvest.

The trial area was tilled with a konskilde prior to establishment, to create a seedbed and to mechanically eradicate weeds. Treatments were established in rows on 2.1 m x 6 m plots, at a seeding rate of 25 kg ha-1 for diploids, and 30 kg ha^{-1} for tetraploids. Both trials consisted of a randomised block design, with three replicates per treatment. Plots were harvested on a 28-day cycle. A strip of pasture (1.27 m x 4.8 m = 6.1 m^2) was cut to a height of 50 mm above ground level, and weighed. Approximately 500 g of the sample was placed in a brown paper bag, weighed, dried at 60ºC for 72 hours, and then weighed again in order to determine dry-matter content.

Table 1. Species, ploidy and cultivar name of annual ryegrass cultivars, evaluated during 2010

Species	Ploidy	Cultivar
Westerwolds ryegrass	Diploid	Mispah
Westerwolds ryegrass	Diploid	Performer
Westerwolds ryegrass	Diploid	Bruiser
Westerwolds ryegrass	Tetraploid	Archie
Westerwolds ryegrass	Tetraploid	Captain
Westerwolds ryegrass	Tetraploid	Primora
Westerwolds ryegrass	NA	K2W2
Westerwolds ryegrass	NA	K2W1

Italian ryegrass	Diploid	Agriton
Italian ryegrass	Diploid	Tabu
Italian ryegrass	Diploid	Dargle
Italian ryegrass	Diploid	Supreme Q
Italian ryegrass	Diploid	Agriboost
Italian ryegrass	Diploid	Sustainer
Italian ryegrass	Diploid	Warrior
Italian ryegrass	Diploid	Enhancer
Italian ryegrass	Tetraploid	Feast II
Italian ryegrass	NA	K2I1
Italian ryegrass	NA	K2I2
Mixture	NA	Voyager
Mixture	NA	Voyager 12
Mixture	NA	Voyager 31

Table 2. Species, ploidy and cultivar name of annual ryegrass cultivars, evaluated during 2011

Species	Ploidy	Cultivar
Westerwolds ryegrass	Diploid	Mispah
Westerwolds ryegrass	Diploid	Performer
Westerwolds ryegrass	Diploid	Bruiser
Westerwolds ryegrass	Tetraploid	Archie
Westerwolds ryegrass	Tetraploid	Captain
Westerwolds ryegrass	Tetraploid	Primora
Italian ryegrass	Diploid	Agriton
Italian ryegrass	Diploid	Tabu
Italian ryegrass	Diploid	Dargle
Italian ryegrass	Diploid	Supreme Q
Italian ryegrass	Diploid	Agriboost
Italian ryegrass	Diploid	Sustainer
Italian ryegrass	Diploid	Warrior
Italian ryegrass	Tet	Feast II
Mixture	Mix	Voyager
Mixture	Mix	Voyager 12
Mixture	Mix	Voyager 31

An appropriate analysis of variance was performed on monthly growth rate, total seasonal dry-matter production, and annual dry-matter production. The assumption of normality of the residuals (Shapiro & Wilk, 1965) was fulfilled. Therefore, the results are statistically sound. A Student least significant difference (LSD), at 5 % significance level, was done to compare the treatment means (Ott, 1998). The STATS module of SAS version 9.2 (SAS institute Inc., 2008) was used to analyse the data.

Results and discussion

Year 2010

The mean monthly growth rate (kg DM ha^{-1} day^{-1}) of annual ryegrass cultivars evaluated during 2010, is shown in Table 3. The Italian ryegrass cultivar Tabu, was the only cultivar that had the highest (P<0.05) or similar (P>0.05) to highest growth rate from July to December.

The total seasonal and annual DM production (kg DM ha^{-1}) of annual ryegrass cultivars evaluated during 2010, is shown in Table 4. The Italian ryegrass cultivars Tabu, Supreme Q, Agriboost and Enhancer, had the highest (P<0.05) or similar (P>0.05) to highest seasonal DM production during all seasons. The highest (P<0.05) annual DM production was achieved by the Italian ryegrass cultivar Tabu, with similar (P>0.05) production obtained from the Italian ryegrass cultivars Supreme Q, Agriboost, Warrior, and Enhancer – as well as the Westerwolds ryegrass cultivars Performer and K2W2.

Year 2011

The mean monthly growth rate of annual ryegrass cultivars evaluated during 2011, is shown in Table 5. The Italian ryegrass cultivar Warrior, was the only cultivar that had the highest (P<0.05) or similar (P>0.05) to highest growth rate from June to December. From June to August (winter), the Westerwold ryegrass cultivars Mispah and Performer, and the Italian ryegrass cultivars Dargle, Supreme Q and Warrior, had the highest (P<0.05) or similar (P>0.05) to highest growth rates during all months. From September to November (spring), the Italian ryegrass cultivars Tabu and Warrior were the only cultivars that had the highest (P<0.05) or similar (P>0.05) to highest growth rate during all months.

The total seasonal and annual species, ploidy, and cultivar name of annual ryegrass cultivars evaluated during DM production of annual ryegrass cultivars during 2011, is shown in Table 6. The highest (P<0.05) annual DM production was for the Italian ryegrass cultivar Warrior, with similar (P>0.05) production obtained by the Italian ryegrass cultivars Tabu and Agriboost, and the Westerwolds ryegrass cultivar Performer. The Westerwolds ryegrass cultivar Performer and the Italian ryegrass cultivar Warrior, were the only cultivars that had the highest (P<0.05) or similar (P>0.05) to highest seasonal dry-matter production throughout all seasons.

Conclusions

1. The growth rate and seasonal production differed between cultivars.
2. The Italian ryegrass cultivars Tabu, Agriboost and Warrior – as well as the westerwolds ryegrass cultivar Performer – were among the most productive cultivars during both 2010 and 2011.
3. The seasonal spread of growth and dry-matter production should be considered when deciding on which ryegrass cultivar to use in a pasture system.

MESSAGE TO THE FARMER

The choice of which annual ryegrass cultivar or variety to use should be based on the specific purpose of the pasture to be established (for example, short-term winter feed, planting with companion species, high spring production, silage production, or extended growth season), and also the seasonal spread of production.

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Table 3. Mean monthly growth rate (kg DM ha^{-1} day^{-1}) of annual ryegrass cultivars, during 2010.

Species	Ploidy	Cultivar	July	August	Sept	Oct	Nov	Dec
Westerwolds	Dip	Mispah	10.3^{b}	49.8^{abcd}	40.3^{ab}	25.2^{defg}	20.7^{def}	$24.4^{cdefghi}$
Westerwolds	Dip	Performer	13.8^{a}	52.7^{ab}	34.3^{bcde}	30.7^{bcde}	31.1^{a}	26.0^{cdefgh}
Westerwolds	Dip	Bruiser	12.0^{ab}	48.9^{abcde}	35.4^{abcd}	17.2^{fg}	14.6^{gh}	11.8^{j}
Westerwolds	Tet	Archie	12.2^{ab}	43.2^{defg}	31.4^{cde}	25.3^{defg}	18.8^{efg}	18.6^{ghij}
Westerwolds	Tet	Captain	13.3^{a}	54.8^{a}	36.9^{abc}	16.4^{fg}	22.4^{cde}	$23.7^{cdefghi}$
Westerwolds	Tet	Primora	12.6^{ab}	44.9^{cdefg}	34.3^{bcde}	29.3^{cde}	22.0^{cdef}	15.9^{hij}
Westerwolds	NA	K2W2	11.1^{ab}	46.3^{bcdef}	40.6^{ab}	38.4^{abc}	26.5^{abc}	$28.8^{abcdefg}$
Westerwolds	NA	K2W1	11.3^{ab}	41.4^{fg}	36.0^{abcd}	31.9^{bcde}	20.6^{def}	19.1^{fghij}
Italian	Dip	Agriton	12.8^{ab}	46.0^{bcdef}	39.7^{ab}	29.3^{cde}	22.2^{cde}	30.5^{abcde}
Italian	Dip	Tabu	13.2^{ab}	48.7^{abcde}	41.1^{ab}	42.7^{ab}	28.1^{ab}	38.8^{a}
Italian	Dip	Dargle	11.2^{ab}	48.2^{abcdef}	38.2^{abc}	27.0^{cdef}	20.8^{def}	$23.7^{cdefghi}$
Italian	Dip	Supreme Q	12.7^{ab}	49.0^{abcde}	35.5^{abcd}	44.6^{a}	25.2^{bcd}	30.7^{abcde}
Italian	Dip	Agriboost	12.4^{ab}	47.0^{bcdef}	42.4^{a}	31.7^{bcde}	24.7^{bcd}	31.6^{abcd}
Italian	Dip	Sustainer	11.4^{ab}	43.1^{defg}	37.8^{abc}	30.8^{bcde}	17.2^{fg}	20.8^{efgij}
Italian	Dip	Warrior	12.3^{ab}	45.4^{cdef}	35.3^{abcd}	35.7^{abcd}	28.9^{ab}	37.8^{ab}
Italian	Dip	Enhancer	13.6^{a}	50.2^{abc}	37.3^{abc}	37.5^{abc}	25.5^{bcd}	34.0^{abc}
Italian	Tet	Feast II	11.7^{ab}	45.7^{bcdef}	33.5^{bcde}	35.8^{abcd}	26.3^{abc}	29.8^{abcdef}
Italian	NA	K2I1	12.0^{ab}	42.5^{efg}	41.1^{ab}	44.5^{a}	25.1^{bcd}	28.0^{bcdefg}
Italian	NA	K2I2	11.4^{ab}	38.4^{g}	33.8^{bcd}	37.1^{abcd}	24.4^{bcd}	14.9^{ij}
Mix	NA	Voyager	13.5^{a}	47.2^{bcdef}	28.3^{def}	29.4^{cde}	27.4^{ab}	31.2^{abcde}
Mix	NA	Voyager 12	13.6^{a}	52.6^{ab}	26.7^{ef}	13.5^{g}	12.1^{h}	23.2^{defghi}
Mix	NA	Voyager 31	12.0^{ab}	48.1^{abcdef}	23.3^{f}	22.0^{efg}	18.9^{efg}	$21.8^{defghij}$
LSD (0.05)			2.891	7.003	7.813	12.08	4.884	10.74

LSD (0.05) compares within month.
^{abc} Means with no common superscript, differ significantly.

Table 4. Total seasonal and annual dry-matter production (kg DM ha^{-1}) of annual ryegrass cultivars, during 2010.

Species	Ploidy	Cultivar	Winter	Spring	Summer	Annual
Westerwolds	Dip	Mispah	2666^{bcdef}	2430^{cde}	$1049^{cdefghi}$	6145^{cdefg}
Westerwolds	Dip	Performer	3006^{ab}	2721^{abcd}	1120^{cdefgh}	6848^{abc}
Westerwolds	Dip	Bruiser	2736^{abcdef}	1887^{fg}	509^{j}	5132^{g}
Westerwolds	Tet	Archie	2523^{defg}	2252^{def}	799^{ghij}	5575^{efg}
Westerwolds	Tet	Captain	3056^{a}	2102^{ef}	$1019^{cdefghi}$	6177^{cdef}
Westerwolds	Tet	Primora	2619^{bcdefg}	2419^{cde}	681^{hij}	5719^{efg}
Westerwolds	NA	K2W2	2569^{defg}	2989^{ab}	$1238^{abcdefg}$	6795^{abcd}
Westerwolds	NA	K2W1	2392^{fg}	2513^{bcde}	822^{fghij}	5727^{efg}
Italian	Dip	Agriton	2671^{abcdef}	2574^{bcde}	1312^{abcde}	6557^{bcde}
Italian	Dip	Tabu	2805^{abcde}	3177^{a}	1670^{a}	7652^{a}
Italian	Dip	Dargle	2654^{bcdefg}	2427^{cde}	$1019^{cdefghi}$	6100^{cdefg}
Italian	Dip	Supreme Q	2788^{abcde}	3006^{ab}	1320^{abcde}	7113^{abc}
Italian	Dip	Agriboost	2686^{abcdef}	2789^{abc}	1357^{abcd}	6833^{abc}
Italian	Dip	Sustainer	2462^{efg}	2441^{cde}	893^{efghij}	5797^{defg}
Italian	Dip	Warrior	2617^{cdefg}	2815^{abc}	1625^{ab}	7057^{abc}
Italian	Dip	Enhancer	2896^{abcd}	2843^{abc}	1460^{abc}	7199^{ab}
Italian	Tet	Feast II	2587^{defg}	2703^{abcd}	1283^{abcdef}	6572^{bcde}
Italian	NA	K2I1	2480^{efg}	3156^{a}	1205^{bcdefg}	6842^{abc}
Italian	NA	K2I2	2276^{g}	2705^{abcd}	640^{ij}	5621^{efg}
Mix	NA	Voyager	2768^{abcdef}	2387^{cde}	1343^{abcde}	6498^{bcde}
Mix	NA	Voyager 12	2992^{abc}	1465^{g}	997^{defghi}	5454^{fg}
Mix	NA	Voyager 31	2704^{abcdef}	1808^{fg}	$938^{defghij}$	5450^{fg}
LSD (0.05)			388.4	494.9	461.6	1014

LSD (0.05) compares within month.
abc Means with no common superscript, differ significantly.

Table 5. Mean monthly growth rate (kg DM ha^{-1} day^{-1}) of annual ryegrass cultivars, during 2011.

Species	Ploidy	Cultivar	June	July	August	Sept	Oct	Nov	Dec
Westerwolds	Dip	Mispah	24.4^{abcd}	45.0^{a}	49.2^{abc}	45.5^{bcd}	26.3^{efgh}	47.9^{abcde}	22.9^{abc}
Westerwolds	Dip	Performer	26.2^{abc}	51.7^{a}	51.8^{a}	51.8^{b}	40.7^{ab}	55.7^{ab}	23.0^{abc}
Westerwolds	Dip	Bruiser	27.1^{a}	42.5^{a}	37.8^{f}	22.4^{f}	18.4^{hi}	-	-
Westerwolds	Tet	Archie	22.9^{abcd}	39.1^{a}	42.3^{cdef}	36.8^{de}	22.2^{ghi}	31.4^{fgh}	10.3^{ef}
Westerwolds	Tet	Captain	26.4^{ab}	40.1^{a}	38.4^{ef}	23.9^{f}	15.1^{i}	25.0^{h}	8.63^{f}
Westerwolds	Tet	Primora	21.9^{bcd}	41.7^{a}	39.7^{def}	45.5^{bcd}	31.3^{cdef}	38.8^{defg}	13.6^{def}
Italian	Dip	Agriton	20.9^{d}	42.5^{a}	42.0^{def}	38.2^{de}	25.2^{fgh}	41.1^{cdef}	15.1^{cdef}
Italian	Dip	Tabu	21.8^{bcd}	43.3^{a}	42.4^{cdef}	68.5^{a}	39.1^{abc}	52.3^{abcd}	21.3^{abcd}
Italian	Dip	Dargle	26.6^{ab}	43.0^{a}	45.5^{abcd}	41.5^{cde}	23.1^{fghi}	42.9^{bcdef}	19.7^{bcd}
Italian	Dip	Supreme Q	22.7^{abcd}	42.1^{a}	43.4^{bcdef}	48.2^{bc}	29.5^{defg}	39.4^{cdefg}	13.8^{def}
Italian	Dip	Agriboost	20.8^{d}	49.5^{a}	45.6^{abcd}	52.5^{b}	34.3^{bcde}	52.8^{abc}	23.9^{abc}
Italian	Dip	Sustainer	27.1^{a}	44.9^{a}	39.9^{def}	33.3^{e}	21.1^{ghi}	35.1^{efgh}	17.9^{bcd}
Italian	Dip	Warrior	23.3^{abcd}	51.9^{a}	50.4^{ab}	63.4^{a}	42.8^{ab}	57.0^{a}	29.7^{a}
Italian	Tet	Feast II	21.4^{cd}	40.0^{a}	45.2^{abcde}	51.8^{b}	43.8^{a}	40.4^{cdefg}	16.2^{bcdef}
Mix	Mix	Voyager	23.5^{abcd}	44.7^{a}	40.7^{de}	41.8^{cde}	39.4^{abc}	42.4^{bcdef}	24.9^{ab}
Mix	Mix	Voyager 12	20.9^{d}	39.9^{a}	41.1^{def}	22.9^{f}	20.5^{hi}	26.9^{gh}	7.98^{f}
Mix	Mix	Voyager 31	22.7^{abcd}	42.8^{a}	40.3^{def}	34.9^{e}	36.2^{abcd}	42.7^{bcdef}	15.0^{cdef}
LSD (0.05)			4.91	15.54	7.105	8.749	8.736	13.66	9.134

LSD (0.05) compares within month.
^{abc} Means with no common superscript, differ significantly.

Table 6. Total seasonal and annual dry-matter production (kg DM ha^{-1}) of annual ryegrass cultivars, during 2011.

Species	Ploidy	Cultivar	Winter	Spring	Summer	Annual
Westerwolds	Dip	Mispah	5619^{abc}	3487^{def}	665^{abc}	9771^{bcde}
Westerwolds	Dip	Performer	6191^{a}	4303^{abc}	667^{abc}	11160^{ab}
Westerwolds	Dip	Bruiser	5312^{cde}	1207^{k}	-	6519^{i}
Westerwolds	Tet	Archie	4975^{de}	2642^{ghi}	298^{ef}	7916^{fghi}
Westerwolds	Tet	Captain	5140^{cde}	1863^{jk}	250^{f}	7254^{ghi}
Westerwolds	Tet	Primora	4997^{cde}	3373^{defg}	394^{def}	8765^{ef}
Italian	Dip	Agriton	5031^{cde}	3039^{fgh}	437^{cdef}	8507^{efgh}
Italian	Dip	Tabu	5145^{cde}	4681^{ab}	617^{abcd}	10442^{abc}
Italian	Dip	Dargle	5532^{bcd}	3137^{fgh}	572^{bcd}	9240^{cdef}
Italian	Dip	Supreme Q	5157^{cde}	3422^{def}	399^{def}	8979^{def}
Italian	Dip	Agriboost	5538^{bcd}	4067^{abcd}	692^{abc}	10297^{abcd}
Italian	Dip	Sustainer	5516^{bcd}	2607^{hi}	519^{bcde}	8642^{efg}
Italian	Dip	Warrior	5970^{ab}	4759^{a}	861^{a}	11590^{a}
Italian	Tet	Feast II	5014^{cde}	3963^{bcde}	469^{bcdef}	9446^{cde}
Mix	Mix	Voyager	5298^{cde}	3586^{cdef}	723^{ab}	9607^{cde}
Mix	Mix	Voyager 12	4857^{e}	2037^{ij}	231^{f}	7126^{hi}
Mix	Mix	Voyager 31	5122^{cde}	3289^{efgh}	434^{cdef}	8844^{ef}
LSD (0.05)			631.0	733.1	264.8	1411

LSD (0.05) compares within month.

[abc] Means with no common superscript, differ significantly.

12. The production and nutritional value of annual winter growing grass and legume species

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Abstract

The dry matter (DM) production and quality of ryegrass (*Lolium multiflorum* var. *westerwoldicum*), oats (*Avena sativa*), triticale (*Triticosecale*), serradella (*Ornithopus sativus*) and vetch (*Vicia dasycarpa*) as annual winter-growing (June, July and August) grasses and legumes, planted at different planting dates in either pure stands or as mixtures, was investigated. Planting date influenced winter DM production. The period until first grazing varied between 46-50 days if planted during February or March, and 61-77 days when planted during April or May. February and March were the best planting dates to plant annual crops for winter fodder production. The growth rate of oats (58-65 kg DM ha^{-1} day^{-1}) or oats-triticale (60-78 kg DM ha^{-1} day^{-1}), planted during February, was high, making it a suitable late autumn (May)- early winter (June) pasture crop. Annual ryegrass planted during February or March, had a higher or similar DM production rate during winter (45-89 kg DM ha^{-1} day^{-1}), compared to the other species evaluated. The mean CP content (>20%) and mean IVOMD (>70%) of the different annual-producing pasture crops was high, making these crops well-suited as winter pasture crops for high-producing animals like dairy cows.

Keywords: crude protein, *in vitro* organic matter digestibility, *Avena sativa, Triticosecale, Lolium multiflorum, Vicia dasycarpa, Ornithopus sativus.*

Introduction

The provision of nutritious, palatable fodder during winter is an essential feature of an efficient fodder-flow programme. The fodder-flow programme for dairy and beef cattle production units in the coastal region of the southern Cape of South Africa consists mainly of combinations of perennial pastures such as lucerne (*Medicago sativa*), kikuyu (*Pennisetum clandestinum*), and ryegrass- (*Lolium perenne* and *L. multiflorum*) and clover (*Trifolium repens* en *T. pratense*)species. The growth rates of these crops differ during spring, summer and autumn, but reach a mutual low during winter (Van Heerden *et al.*, 1989). The resultant excess of fodder during spring, summer and autumn, and shortages during winter (June, July and August), limits the production potential and profitability of milk or beef production from planted pastures (Dawe & Lattimore, 1986). In an effort to overcome the problem of low winter-grazing capacities of perennial, irrigated pastures (Van Heerden *et al.*, 1989), farmers in the southern Cape traditionally plant annual ryegrass (*Lolium multiflorum* spp.) or oats (*Avena sativa*), in pure stands or in mixtures, as winter pastures. Data regarding the production potential and nutritional value of winter-producing grasses and legumes, planted specifically as winter pasture (June, July and August) for high-producing dairy cattle, is inadequate to assist in accurate fodder-flow planning. The aim of this study was to determine the dry matter production and quality of different annual winter-growing grass and legume species, in pure stands and mixtures, at different planting dates.

Materials and Methods

The study was carried out over the winter periods during 2005 and 2006 on the Outeniqua Research

Farm near George (Altitude 201 m, 33° 58' 38" S, 22° 25' 16" E, rainfall 729 mm year^{-1}) in the Western Cape Province of South Africa. The area has a temperate climate, with mean minimum and maximum air temperatures varying between 7°C -15°C and 18°C - 25°C respectively. The study was a small-plot trial carried out on an Estcourt soil type (Soil Classification Workgroup, 1991) under irrigation, and grazed by Jersey cows. Plot sizes were 150 m^2 (10 m x 15 m). Irrigation was applied by means of a permanent overhead sprinkler system in one or two applications per week, at rates of 10 -15 mm, based on tensiometer readings. Irrigation commenced at a tensiometer reading of -25 kPa and terminated at a reading of -10 kPa. Annual ryegrass (*L. multiflorum* cv. Energa), oats (*A. sativa* cv. SSH421) and triticale (*Triticosecale* cv. Bacchus) were evaluated in pure stands or in mixtures with legumes such as serradella (Ornithopus sativus cv. Emena) and vetch (*Vicia dasycarpa* cv. Max). The species and cultivars used during the trial are given in Table 1. The treatments, species combinations, seeding rates and abbreviations used during the trial are given in Table 2. The legume seed was treated with insecticide (280 ml Dimethoate dissolved in 1500 ml water sprinkled over 45 kg seed) and inoculated with the specific strain of *Rhizobium* required for effective nodulation and nitrogen fixation (Staphorst & Strijdom, 1974; Allen & Allen, 1981; Langenhoven, 1986).

Prior to planting, fertiliser was applied according to the soil analysis to raise the soil phosphorous level to 35 mg kg^{-1}, potash level to 80 mg kg^{-1} (citric acid) and pH (KCl) to 5,5. Nitrogen (N) was applied to the grass and grass-legume pastures at a rate of 55 kg N ha^{-1} month^{-1}. Pure legume stands did not receive N fertilization. Four weeks after germination, a mixture of Molybdenum (Mo) and an insecticide (Ometoaat), in the form of a foliar application, was applied to the legume pastures at 130 gm ha^{-1} and 40 ml ha^{-1} respectively (Langenhoven, 1986; Lowther, 1987).

All the treatments (pure stands and mixtures) were planted at four different planting dates: 15 February, 15 March, 15 April and 15 May. No seedbed was prepared. Eragrostis teff was planted during November of the previous year and grazed throughout the summer by Jersey cows. Four weeks prior to planting the winter crops, the teff was grazed down to 30 mm and sprayed with an herbicide (glyphosate) at 3 l ha^{-1}. The different crops were then planted into the dead plant material and stubble with an Aitchison seeder, without prior working of the soil or preparing of seedbeds.

The crops were grazed down to a height of 50 mm at an interval of 28-35 days, when the ryegrasses had reached the three-leaf stage, or when overshadowing of the growing points of grasses had started to occur (Fulkerson & Donaghy, 2001). The dry matter (DM) production was estimated before grazing, by harvesting six 0,099 m^2 quadrats at a cutting height of 50 mm in each paddock. Samples were dried at 60ºC for 72 hours to a constant mass and weighed to determine DM content (%). The six samples were pooled to make up a two kg sample per treatment, milled (SWC Hammer mill, 1 mm sieve) and analysed for in vitro organic matter digestibility (IVOMD) (Tilley & Terry, 1963), crude protein (CP) content (AOAC, 2000) and neutral detergent fibre (NDF) content (Van Soest *et al.*, 1991).

The trial was a randomised complete block design with four main-plot treatments (sowing time – Feb, Mar, Apr and May) randomly allocated within each of the three block replicates. The 12 sub-plot treatments (cultivar and sowing density combinations) were randomly allocated within each main-plot. Standard univariate split-plot analysis of variance (ANOVA) was performed on all measurements, using SAS version 9.13 statistical software (SAS, 1999). The Shapiro-Wilk's test was performed on the residuals to test for deviations from normality (Shapiro and Wilk, 1965). Student's t-LSD (Least significant difference) was calculated at a 5% significance level to compare means of significant effects.

Table 1 shows the pasture species and cultivars used in the trial.

Table 1. The pasture species and cultivars used in the trial.

Pasture species	Cultivar
Ryegrass (*Lolium multiflorum* var. *westerwoldicum*)	Energa
Oats (*Avena sativa*)	SSH421
Triticale (*Triticosecale*)	Bacchus
Serradella (*Ornithopus sativus*)	Emena
Vetch (*Vicia dasycarpa*)	Max

Table 2 shows the different treatments, species, botanical composition of the treatments and seeding rate used in the trial.

Table 2. The different treatments, species, botanical composition of the treatments and seeding rate used in the trial.

Treatment	Species, botanical composition and seeding rate (kg ha^{-1})
1	Ryegrass (25)
2	Oats (100)
3	Triticale (130)
4	Ryegrass (15) + oats (60)
5	Ryegrass (15) + triticale (100)
6	Ryegrass (15) + serradella (10)
7	Ryegrass (15) + vetch (10)
8	Oats (50) + triticale (80)
9	Oats (50) + serradella (15)
10	Oats (50) + vetch (15)
11	Triticale (90) + serradella (15)
12	Triticale (90) + vetch (15)

Results and discussion

The monthly growth rate (kg DM ha-1 day-1) of different annual winter-growing pasture crops planted during February 2005 and February 2006 is shown in Table 3 and Table 4 respectively.

Table 3. The monthly dry matter production rate (kg DM ha^{-1} day^{-1}) of different annual winter-growing pasture crops planted during February 2005.

Treatment	31 Mar	3 May	7 Jun	13 Jul	17 Aug	22 Sep	25 Oct
ryegrass	28.1^{d}	57.8^{abc}	45.3^{ab}	56.4^{a}	74.3^{abc}	98.3^{a}	100.9^{a}
oats	57.7^{ab}	65.0^{ab}	36.9^{abc}	32.3^{ef}	54.2^{bcd}	48.9^{b}	20.4^{c}
triticale	40.4^{bcd}	48.8^{bc}	19.3^{d}	33.6^{def}	27.7^{ef}	3.1^{c}	0^{c}
ryegrass/oats	33.2^{cd}	50.7^{bc}	49.6^{a}	51.6^{ab}	72.1^{abc}	87.1^{a}	67.7^{b}
ryegrass/triticale	34.3^{cd}	57.7^{abc}	38.2^{abc}	51.9^{ab}	75.8^{ab}	87.6^{a}	80.2^{ab}
ryegrass/serradella	35.4^{cd}	46.1^{bc}	42.2^{abc}	38.4^{cdef}	88.8^{a}	91.9^{a}	71.1^{ab}
ryegrass/vetch	27.0^{d}	55.5^{abc}	35.9^{abcd}	45.3^{abc}	61.2^{bcd}	89.2^{a}	72.8^{ab}
oats/triticale	60.2^{a}	78.1^{a}	42.0^{abc}	44.0^{bcd}	56.3^{bcd}	54.6^{b}	23.6^{c}
oats/serradella	51.3^{abc}	56.4^{abc}	30.0^{bcd}	34.5^{cdef}	45.5^{de}	38.6^{b}	17.8^{c}
oats/vetch	44.1^{abcd}	54.7^{abc}	40.7^{abc}	39.7^{cde}	49.0^{cde}	53.3^{b}	19.6^{c}
triticale/serradella	30.3^{d}	44.2^{bc}	26.9^{cd}	27.1^{f}	12.2^{f}	3.7^{c}	0^{c}
triticale/vetch	39.2^{cd}	36.1^{c}	40.3^{abc}	35.0^{cdef}	27.2^{ef}	5.9^{c}	0^{c}
LSD (0.05)	**18.20**	**26.25**	**17.90**	**11.33**	**25.99**	**19.95**	**29.96**

^{abcde} Means with no common superscript in columns, differed significantly (P<0.05)
LSD (0.05) compares within columns

The first grazing, following a February planting, occurred after 46 days (31 March 2005) and 50 days (4 April 2006). During 2005, the growth rate of oats/triticale, from planting to the first grazing, was higher (P<0.05) than that of ryegrass, triticale and mixtures containing ryegrass or triticale. The trend continued during 2006, with the growth rate of pure stands of oats, triticale, or mixtures containing oats or triticale highest from planting to first grazing. During both years (2005 and 2006), the growth rate of ryegrass was higher than (P<0.05), or similar to (P>0.05) that of any of the other species from May until November. The growth rate of the ryegrass mixtures varied monthly and was higher (P<0.05) from July onwards than the growth rate of oats, triticale or mixtures containing oats and triticale.

Table 4. The monthly dry matter production rate (kg DM ha^{-1} day^{-1}) of different annual winter-growing pasture crops planted during February 2006.

Treatment	4 Apr	8 May	12 Jun	13 Jul	17 Aug	21Sep	24 Oct	28 Nov
ryegrass	19.8^{c}	52.6^{ab}	60.0^{ab}	56.3^{a}	88.8^{a}	93.3^{ab}	87.7^{a}	54.3^{a}
oats	57.2^{a}	63.0^{a}	42.5^{abcd}	39.4^{b}	38.3^{c}	36.4^{cd}	59.3^{b}	7.46^{b}
triticale	58.2^{a}	21.0^{d}	31.4^{cd}	20.0^{cd}	22.9^{de}	16.3^{de}	13.3^{d}	2.48^{b}
ryegrass/oats	56.8^{a}	57.5^{ab}	65.9^{a}	70.2^{a}	89.9^{a}	75.4^{b}	88.8^{a}	50.3^{a}
ryegrass/triticale	51.8^{ab}	51.7^{abc}	61.2^{ab}	59.8^{a}	75.1^{b}	104.1^{a}	90.4^{a}	53.9^{a}
ryegrass/serradella	24.2^{c}	49.9^{abc}	53.8^{abc}	55.5^{a}	74.1^{b}	101.8^{a}	82.3^{a}	58.4^{a}
ryegrass/vetch	27.8^{c}	41.0^{bc}	60.5^{ab}	62.8^{a}	90.3^{a}	74.1^{b}	80.6^{a}	54.3^{a}
oats/triticale	59.3^{a}	46.4^{abc}	41.3^{bcd}	32.9^{bc}	37.6^{c}	48.2^{c}	44.0^{bc}	7.13^{b}
oats/serradella	49.0^{ab}	50.9^{abc}	42.1^{bcd}	32.3^{bc}	35.7^{c}	17.0^{de}	34.3^{c}	5.47^{b}
oats/vetch	52.7^{ab}	39.7^{bc}	42.3^{abcd}	36.0^{b}	34.6^{cd}	26.9^{de}	37.6^{c}	10.6^{b}
triticale/serradella	42.0^{b}	18.5^{d}	29.2^{d}	16.1^{d}	8.50^{f}	6.66^{e}	5.42^{d}	2.71^{b}
triticale/vetch	52.1^{ab}	33.6^{cd}	27.7^{d}	17.9^{cd}	19.3^{ef}	20.3^{de}	12.8^{d}	7.24^{b}
LSD (0.05)	**14.01**	**18.16**	**23.58**	**14.97**	**12.28**	**21.26**	**19.71**	**10.28**

abcde Means with no common superscript in columns, differed significantly (P<0.05)
LSD (0.05) compares within columns

The monthly growth rate (kg DM ha-1 day-1) of different annual winter-growing pasture crops planted during March 2005 and March 2006 is shown in Table 5 and Table 6 respectively.

Table 5. The monthly dry matter production rate (kg DM ha^{-1} day^{-1}) of different annual winter-growing pasture crops planted during March 2005.

Treatment	Apr	3 May	7 Jun	13 Jul	17 Aug	22 Sep	25 Oct
ryegrass	-	29.9^{d}	48.5^{a}	50.2^{ab}	63.2^{a}	84.0^{a}	49.1^{ab}
oats	-	49.1^{abc}	41.5^{a}	48.0^{ab}	37.6^{cd}	54.8^{b}	56.0^{a}
triticale	-	46.3^{abc}	43.7^{a}	39.2^{abc}	13.7^{e}	7.3^{c}	3.89^{cd}
ryegrass/oats	-	49.5^{ab}	40.3^{a}	35.7^{abc}	57.1^{ab}	84.2^{a}	65.3^{a}
ryegrass/triticale	-	38.8^{cd}	46.6^{a}	49.3^{ab}	54.1^{abc}	88.6^{a}	54.9^{a}
ryegrass/serradella	-	31.4^{d}	39.6^{a}	53.0^{a}	62.9^{a}	85.8^{a}	60.6^{a}
ryegrass/vetch	-	31.1^{d}	41.7^{a}	45.8^{abc}	57.7^{ab}	83.9^{a}	55.6^{a}
oats/triticale	-	52.3^{a}	39.7^{a}	44.7^{abc}	41.7^{bcd}	60.5^{b}	25.2^{bc}
oats/serradella	-	40.0^{bcd}	41.8^{a}	28.2^{bc}	33.8^{d}	45.3^{b}	23.3^{cd}
oats/vetch	-	39.3^{bcd}	37.4^{a}	33.6^{bc}	41.0^{bcd}	49.1^{b}	19.2^{cd}
triticale/serradella	-	49.2^{abc}	46.7^{a}	37.0^{abc}	12.4^{e}	3.7^{c}	0.4^{d}
triticale/vetch	-	46.7^{abc}	43.3^{a}	52.2^{ab}	27.1^{de}	3.5^{c}	5.0^{cd}
LSD (0.05)	-	**10.58**	**20.37**	**19.36**	**17.37**	**20.06**	**24.57**

abcde Means with no common superscript in columns, differed significantly (P<0.05)
LSD (0.05) compares within columns

The first grazing, following a March planting, occurred 49 days after planting on the 4th of May. The growth rate of oats and triticale from planting until the first grazing (May) was higher (P<0.05) than that of a pure ryegrass stand during both years. However, the growth rate of ryegrass from June onwards was higher than (P<0.05,) or similar to (P>0.05), that of the other species or mixtures. The growth rate of ryegrass or ryegrass mixtures during August 2005 and June 2006 was higher (P<0.05) than that of oats mixtures or triticale mixtures.

Table 6. The monthly growth rate (kg DM ha^{-1} day^{-1}) of different annual wintergrowing pasture crops planted during March 2006.

Treatment	Apr	4 May	6 Jun	10 Jul	14 Aug	20 Sep	23 Oct	27 Nov
ryegrass	-	34.6^{d}	54.4^{ab}	89.3^{a}	73.4^{abcd}	115.8^{a}	147.3^{a}	50.8^{ab}
oats	-	49.9^{abc}	35.0^{cde}	40.8^{c}	35.2^{def}	34.9^{cd}	64.0^{c}	15.0^{c}
triticale	-	54.4^{ab}	22.7^{ef}	38.6^{c}	20.1^{ef}	14.9^{de}	17.2^{de}	6.65^{c}
ryegrass/oats	-	53.2^{ab}	46.5^{bcd}	73.5^{ab}	88.4^{ab}	105.8^{ab}	151.2^{a}	48.2^{b}
ryegrass/triticale	-	55.8^{ab}	67.1^{a}	83.9^{ab}	79.8^{abc}	102.2^{ab}	166.6^{a}	68.6^{a}
ryegrass/serradella	-	32.4^{d}	56.9^{ab}	65.1^{b}	96.3^{a}	94.6^{ab}	148.3^{a}	55.0^{ab}
ryegrass/vetch	-	30.9^{d}	48.5^{cd}	76.7^{ab}	79.5^{abc}	90.3^{b}	99.3^{b}	49.6^{ab}
oats/triticale	-	59.9^{a}	30.9^{ef}	37.8^{c}	39.0^{cdef}	40.6^{c}	63.6^{c}	15.7^{c}
oats/serradella	-	46.4^{bc}	27.0^{def}	39.4^{c}	51.5^{bcde}	20.1^{cde}	42.7^{cd}	12.2^{c}
oats/vetch	-	49.9^{abc}	37.4^{cde}	36.5^{c}	27.0^{ef}	34.1^{cde}	53.6^{c}	18.6^{c}
triticale/serradella	-	40.8^{cd}	16.1^{f}	24.8^{c}	13.6ef	15.3^{de}	13.1^{e}	6.03^{c}
triticale/vetch	-	50.3^{abc}	27.0^{ef}	30.8^{c}	9.35^{f}	8.78^{e}	12.0^{e}	6.17^{c}
LSD (0.05)	-	**10.32**	**16.60**	**22.48**	**41.4**	**25.28**	**27.10**	**20.11**

abcde Means with no common superscript in columns, differed significantly (P<0.05)
LSD (0.05) compares within columns

The monthly growth rate (kg DM ha^{-1} day^{-1}) of different annual winter-growing pasture crops planted during April 2005 and April 2006 is shown in Table 7 and Table 8 respectively.

Table 7. The monthly growth rate (kg DM ha^{-1} day^{-1}) of different annual winter-growing pasture crops planted during April 2005.

Treatment	Apr	May	14 Jun	27 Jul	01 Sep	01 Oct	02 Nov
ryegrass	-	-	15.6^{d}	40.2^{ab}	62.3^{abc}	88.9^{ab}	73.4^{a}
oats	-	-	25.6^{ab}	35.0^{abc}	48.8^{cde}	76.1^{bcd}	43.7^{b}
triticale	-	-	22.6^{abc}	22.1^{c}	27.1^{f}	5.21^{e}	7.8^{c}
ryegrass/oats	-	-	25.7^{ab}	36.5^{ab}	62.1^{abc}	83.8^{abc}	75.1^{a}
ryegrass/triticale	-	-	22.2^{bcd}	34.8^{abc}	73.1^{a}	87.5^{ab}	80.8^{a}
ryegrass/serradella	-	-	17.7^{cd}	48.6^{a}	73.5^{a}	109.8^{a}	94.0^{a}
ryegrass/vetch	-	-	17.2^{cd}	39.1^{ab}	70.3^{ab}	90.3^{ab}	78.9^{a}
oats/triticale	-	-	29.1^{a}	32.4^{bc}	57.0^{abcd}	69.2^{bcd}	25.7^{bc}
oats/serradella	-	-	20.5^{bcd}	37.8^{ab}	53.4^{bcd}	51.7^{d}	12.8^{c}
oats/vetch	-	-	21.5^{bcd}	40.7^{ab}	54.1^{bcd}	56.2^{cd}	23.6^{bc}
triticale/serradella	-	-	24.8^{ab}	29.7^{bc}	31.7^{ef}	7.5^{e}	6.3^{c}
triticale/vetch	-	-	25.7^{ab}	40.1^{ab}	41.3^{def}	6.8^{e}	6.39^{c}
LSD (0.05)	-	-	**6.771**	**13.79**	**17.57**	**27.58**	**26.37**

abcde Means with no common superscript in columns, differed significantly (P<0.05)
LSD (0.05) compares within columns

The first grazing, following an April planting, occurred 61 days (14 June 2005) and 74 days (27 June 2006) after planting. The growth rate of the oats and oats/triticale mixture was highest (P>0.05) from planting to first grazing during both years. Pure ryegrass and mixtures of ryegrass with serradella or vetch, had similar (P>0.05) growth rates to crops with the lowest growth rate from planting until first grazing during both years. The growth rate of ryegrass was higher than (P<0.05), or similar to (P>0.05) that of any of the other species during the period from July 2005 and August 2006 until November. The growth rate of ryegrass was higher (P<0.05) than that of oats, triticale or mixtures of oats/triticale, oats/serradella, oats/vetch, triticale/serradella or triticale/vetch from September until November during both years (2005 and 2006).

Table 8. The monthly growth rate (kg DM ha^{-1} day^{-1}) of different annual winter-growing pasture crops planted during April 2006.

Treatment	Apr	May	27 Jun	7 Aug	11 Sep	11 Oct	14 Nov
ryegrass	-	-	30.5^{c}	68.9^{a}	65.8^{ab}	114.1^{a}	178.9^{a}
oats	-	-	44.8^{a}	57.9^{ab}	31.9^{de}	55.1^{cd}	75.2^{de}
triticale	-	-	42.1^{a}	64.5^{ab}	30.2^{de}	61.3^{bcd}	23.3^{f}
ryegrass/oats	-	-	42.3^{a}	58.0^{ab}	52.2^{bc}	142.4^{a}	172.7^{ab}
ryegrass/triticale	-	-	41.2^{ab}	61.6^{ab}	72.6^{a}	140.4^{a}	174.3^{ab}
ryegrass/serradella	-	-	29.8c	59.2^{ab}	44.9^{cd}	101.9^{ab}	110.6^{cd}
ryegrass/vetch	-	-	26.9^{c}	58.7^{ab}	69.3^{ab}	113.7^{a}	141.4^{bc}
oats/triticale	-	-	42.9^{a}	72.0^{a}	37.2^{cd}	67.7^{bc}	69.7^{e}
oats/serradella	-	-	33.4^{bc}	52.0^{b}	26.1^{de}	48.3^{cd}	47.2^{ef}
oats/vetch	-	-	39.3^{ab}	62.2^{ab}	37.1^{cd}	69.3^{bc}	62.6^{e}
triticale/serradella	-	-	41.9^{a}	48.6^{b}	14.4^{e}	21.1^{d}	13.5^{f}
triticale/vetch	-	-	29.3^{c}	64.5^{ab}	42.6^{cd}	46.6^{cd}	13.5^{f}
LSD (0.05)	-	-	**7.95**	**16.13**	**19.55**	**40.94**	**36.99**

^{abcde} Means with no common superscript in columns, differed significantly ($P<0.05$)
LSD (0.05) compares within columns

The monthly growth rate (kg DM ha^{-1} day^{-1}) of different annual winter-growing pastures crops planted during May 2005 and May 2006 is shown in Table 9 and Table 10 respectively.

Table 9. The monthly growth rate (kg DM ha^{-1} day^{-1}) of different annual winter-growing pasture crops planted during May 2005.

Treatment	Apr	Mei	Jun	05 Jul	6 Sep	10 Oct	25 Nov
ryegrass	-	-	-	36.4^{ab}	69.2^{abc}	100.5^{a}	86.1^{a}
oats	-	-	-	27.8^{b}	61.8^{abc}	83.3^{a}	32.1^{b}
triticale	-	-	-	44.0^{a}	58.8^{bcd}	37.8^{b}	10.8^{bc}
ryegrass/oats	-	-	-	35.8^{ab}	76.3^{a}	93.4^{a}	83.5^{a}
ryegrass/triticale	-	-	-	42.8^{a}	79.2^{a}	104.8^{a}	94.0^{a}
ryegrass/serradella	-	-	-	33.5^{ab}	66.0^{abc}	83.9^{a}	90.0^{a}
ryegrass/vetch	-	-	-	37.8^{ab}	71.3^{ab}	102.0^{a}	77.3^{a}
oats/triticale	-	-	-	34.0^{ab}	54.2^{bcd}	83.9^{a}	25.1^{bc}
oats/serradella	-	-	-	36.0^{ab}	67.7^{abc}	90.8^{a}	18.2^{bc}
oats/vetch	-	-	-	31.5^{ab}	52.2^{cd}	83.2^{a}	13.6^{bc}
triticale/serradella	-	-	-	40.1^{ab}	43.4^{d}	49.0^{b}	3.6^{c}
triticale/vetch	-	-	-	43.2^{a}	63.6^{abc}	41.5^{b}	4.6^{c}
LSD (0.05)	-	-	-	**13.69**	**17.44**	**24.00**	**22.45**

^{abcde} Means with no common superscript in columns, differed significantly ($P<0.05$)
LSD (0.05) compares within columns

The first grazing, following a May planting, occurred 51 days (July 2005) and 77 days (July 2006) after planting. The growth rate of ryegrass mixtures was higher ($P<0.05$), or similar ($P>0.05$), to the other species or mixtures during all months in both 2005 and 2006.

Table 10. The monthly growth rate (kg DM ha^{-1} day^{-1}) of different annual winter-growing pasture crops planted during May 2006.

Treatment	Apr	May	Jun	31 Jul	7 Sep	9 Oct	13 Nov
ryegrass	-	-	-	20.8^{bc}	57.4^{a}	139.8^{a}	163.4^{a}
oats	-	-	-	22.9^{abc}	26.4^{b}	61.3^{b}	68.8^{b}
triticale	-	-	-	26.8^{ab}	30.6^{b}	54.7^{b}	29.3^{cd}
ryegrass/oats	-	-	-	24.3^{abc}	57.6^{a}	121.9^{a}	148.7^{a}
ryegrass/triticale	-	-	-	29.3^{a}	65.2^{a}	135.8^{a}	157.6^{a}
ryegrass/serradella	-	-	-	23.1^{abc}	60.8^{a}	115.2^{a}	158.8^{a}
ryegrass/vetch	-	-	-	23.0^{abc}	51.1^{a}	115.1^{a}	154.5^{a}
oats/triticale	-	-	-	23.7^{abc}	21.6^{b}	62.3^{b}	64.0^{b}
oats/serradella	-	-	-	17.7^{c}	20.2^{b}	34.8^{b}	31.8^{cd}
oats/vetch	-	-	-	20.3^{bc}	24.1^{b}	48.0^{b}	51.1^{bc}
triticale/serradella	-	-	-	21.9^{abc}	16.6^{b}	39.1^{b}	22.7^{d}
triticale/vetch	-	-	-	22.0^{abc}	25.1^{b}	68.0^{b}	27.4^{cd}
LSD (0.05)	-	-	-	**8.133**	**15.76**	**33.28**	**26.47**

^{abcde} Means with no common superscript in columns, differed significantly (P<0.05)
LSD (0.05) compares within columns

The total annual dry matter production (kg DM ha-1) of different annual winter-producing pasture crops planted during February, March, April and May 2005 and 2006 is shown in Table 11 and 12 respectively.

Table 11. The total dry matter production (kg DM ha^{-1}) of different annual winter-growing pasture crops planted during February, March, April and May 2005.

Treatment	February	March	April	May
ryegrass	16198^{a}	12105^{efghij}	$9878^{klmnopq}$	$11902^{efghijk}$
oats	$11446^{efghijk}$	10966^{ghijkl}	$8396^{mnopqrs}$	$8462^{mnopqrs}$
triticale	6313^{stuvwx}	6186^{tuvwx}	3616^{xy}	7193^{rstuvw}
ryegrass/oats	14586^{abcd}	12600^{cdefgh}	$10189^{jklmnop}$	$11807^{efghijk}$
ryegrass/triticale	15040^{ab}	12438^{defgh}	10601^{hijklm}	13195^{bcdef}
ryegrass/serradella	14664^{abc}	12416^{defghi}	$12047^{efghijk}$	$11136^{fghijkl}$
ryegrass/vetch	13634^{bcde}	$11770^{efghijk}$	$10422^{hijklmn}$	$11821^{efghijk}$
oats/triticale	12929^{bcdefg}	$10221^{ijklmno}$	8004^{pqrstu}	$8372^{nopqrst}$
oats/serradella	$9925^{jklmnop}$	$8182^{opqrstu}$	6672^{stuvw}	$9040^{lmnopqr}$
oats/vetch	10831^{ghijkl}	$8465^{mnopqrs}$	7361^{rstuv}	7674^{qrstu}
triticale/serradella	5243^{vwxy}	6059^{uvwx}	4260^{xy}	6419^{stuvwx}
triticale/vetch	6776^{stuvw}	7110^{rstuvw}	5084^{wxy}	7232^{rstuvw}

^{abcde} Means with no common superscript in columns and rows, differed significantly (P<0.05)
LSD (0.05) = 2206 (compares over months and treatments)

Ryegrass planted during February had a higher (P<0.05) total DM production than any of the other species or species mixtures planted during March, April or May of 2005. Only ryegrass planted in mixtures with oats, triticale or serredalla during February achieved similar (P>0.05) total DM production to ryegrass planted in February. The highest total DM production for all species and species mixtures occurred with a February planting, except for triticale and triticale mixtures with serradella.

During 2006 the (P>0.05) highest total DM production was for the ryegrass/triticale mixture planted during March, with only ryegrass and the ryegrass/oats mixture achieving similar (P>0.05) total DM production.

Table 12. The total dry matter production (kg DM ha^{-1}) of different annual winter-growing pasture crops planted during February, March, April and May 2006.

Treatment	February	March	April	May
ryegrass	17726cdef	20048abc	16679fgh	13952ij
oats	12371ijkl	10199lmno	10750klmn	7111qrstu
triticale	7062rstu	6837rstuv	9193mnopqr	5973stuv
ryegrass/oats	19579bcd	20380ab	17229defg	13145ijk
ryegrass/triticale	19330bcde	22326a	18006bcdef	14567hi
ryegrass/serradella	17357defg	19399bcde	12842ijk	13312ij
ryegrass/vetch	17079defgh	16889efgh	14874ghi	12775ijk
oats/triticale	11531jklm	10687klmn	11570jklm	6850rstuv
oats/serradella	9676mnop	9060mnopqr	8369nopqrs	4340v
oats/vetch	10183lmno	9596mnopq	10726klmn	5781tuv
triticale/serradella	4929uv	5099uv	6433stuv	4344v
triticale/vetch	7173pqrstu	5713tuv	7979opqrst	5766tuv

abcde Means with no common superscript in columns and rows, differed significantly (P<0.05)
LSD (0.05) = 2519 (compares over months and treatments)

The total annual DM production of the 2006 trial indicated that mixtures of ryegrass/triticale, ryegrass/oats and ryegrass planted during March, produced more (P<0.05) total DM than any of the other species or mixtures planted during April or May. Ryegrass planted during February or March produced a similar (P>0.05) total annual DM production. Ryegrass/triticale planted during February had a higher (P<0.05) total annual DM production than ryegrass or any other species or mixture planted during February, April or May, but was similar (P>0.05) to the production of ryegrass/oats and ryegrass planted during February. Planting date did not affect (P>0.05) the total DM production of the triticale/serradella or triticale/vetch mixtures during 2005 or 2006.

The mean monthly and mean seasonal crude protein (CP) content (%) of different annual winter-producing pasture crops planted during February, March, April and May 2005 is shown in Tables 13, 14, 15 and 16 respectively.

Table 13. The mean monthly and mean seasonal crude protein (CP) content (%) of different annual winter-growing pasture crops planted during February 2005.

Treatment	31 Mrt	3 May	7 Jun	13 Jul	17 Aug	22 Sep	25 Oct	STD	mean
ryegrass	27.9	22.6	24.6	25.8	24.4	20.8	19.5	**2.90**	**23.0**
oats	23.7	20.7	27.2	28.0	22.9	24.5	17.0	**2.37**	**23.4**
triticale	21.1	21.2	23.0	21.5	23.3	16.7	na	**3.77**	**21.1**
ryegrass/oats	24.8	25.3	24.8	22.2	23.9	21.8	18.4	**2.44**	**22.7**
ryegrass/triticale	25.2	24.1	30.5	26.2	23.8	20.7	20.8	**3.37**	**24.4**
ryegrass/serradella	26.6	20.4	25.9	26.0	24.2	22.2	19.7	**2.82**	**23.1**
ryegrass/vetch	28.9	23.1	29.2	24.2	22.7	20.3	20.9	**3.57**	**23.4**
oats/triticale	24.0	21.5	26.6	23.3	23.6	22.5	17.2	**2.88**	**22.5**
oats/serradella	27.8	21.0	27.2	23.0	24.1	22.3	17.3	**3.62**	**22.5**
oats/vetch	28.3	20.4	26.4	26.9	24.0	23.9	16.5	**4.11**	**23.0**
triticale/serradella	23.8	17.9	22.7	20.8	19.6	15.6	na	**3.04**	**19.3**
triticale/vetch	26.8	19.0	25.2	24.6	27.4	18.9	20.7	**3.63**	**22.6**
STD	**2.36**	**2.08**	**2.29**	**2.27**	**1.74**	**2.68**	**1.73**		**1.29**

na = not available

Table 14. The mean monthly and mean seasonal crude protein (CP) content (%) of different annual winter-growing pasture crops planted during March 2005.

Treatment	Apr	4 May	8 Jun	14 Jul	23 Aug	26 Sep	31 Oct	STD	mean
ryegrass	-	29.7	28.8	27.1	22.9	23.2	18.7	**4.02**	**25.1**
oats	-	21.9	24.5	25.4	24.8	21.9	18.6	**2.57**	**22.9**
triticale	-	22.1	20.6	22.1	20.1	17.3	na	**1.97**	**20.4**
ryegrass/oats	-	23.1	27.3	29.9	26.7	24.0	21.7	**3.05**	**25.5**
ryegrass/triticale	-	26.7	24.3	29.4	27.2	24.6	21.6	**2.72**	**25.6**
ryegrass/serradella	-	29.9	28.1	27.5	26.8	26.0	22.5	**2.49**	**26.8**
ryegrass/vetch	-	30.6	25.8	23.8	24.0	24.3	22.0	**2.96**	**25.1**
oats/triticale	-	25.7	22.9	27.6	23.7	25.9	17.4	**3.58**	**23.9**
oats/serradella	-	26.8	26.0	27.4	24.5	21.6	16.1	**4.28**	**23.7**
oats/vetch	-	25.6	25.0	28.7	24.5	22.0	22.5	**2.41**	**24.7**
triticale/serradella	-	25.0	22.2	26.5	18.9	21.7	na	**2.97**	**22.9**
triticale/vetch	-	27.4	22.6	23.5	24.2	16.4	na	**4.02**	**22.8**
STD	-	**2.93**	**2.52**	**2.43**	**2.51**	**3.02**	**2.44**		**1.71**

na = not available

Table 15. The mean monthly and mean seasonal crude protein (CP) content (%) of different annual winter-growing pasture crops planted during April 2005.

Treatment	Apr	May	14 Jun	27 Jul	01 Sep	01 Oct	02 Nov	STD	mean
ryegrass	-	-	24.2	23.5	26.7	24.8	24.7	**1.19**	**24.8**
oats	-	-	25.1	25.2	27.2	24.5	16.6	**4.11**	**23.7**
triticale	-	-	26.2	23.2	22.4	20.2	17.6	**3.23**	**21.9**
ryegrass/oats	-	-	24.2	23.6	26.6	25.5	22.9	**1.49**	**24.6**
ryegrass/triticale	-	-	27.8	25.9	25.6	23.7	23.2	**1.85**	**25.2**
ryegrass/serradella	-	-	26.3	25.7	26.5	26.2	24.3	**0.89**	**25.8**
ryegrass/vetch	-	-	28.4	25.8	24.8	26.3	23.5	**1.82**	**25.8**
oats/triticale	-	-	25.4	26.1	22.3	23.5	18.1	**3.17**	**23.1**
oats/serradella	-	-	28.3	24.3	26.4	24.9	16.8	**4.38**	**24.1**
oats/vetch	-	-	29.4	25.6	26.1	22.9	18.6	**4.04**	**24.5**
triticale/serradella	-	-	26.9	21.9	23.9	20.3	na	**2.84**	**23.3**
triticale/vetch	-	-	25.8	23.2	24.4	22.7	21.0	**1.81**	**23.4**
STD	-	-	**1.69**	**1.39**	**1.68**	**2.02**	**3.17**		**1.17**

na = not available

The CP content was generally high (above 20%). The CP of the ryegrass and mixtures containing ryegrass was higher than 20% during the first five grazings, when planted during February, March and April. The inclusion of legumes (serradella and vetch) in ryegrass mixtures did not increase the CP content compared to pure ryegrass stands.

Table 16. The mean monthly and mean seasonal crude protein (CP) content (%) of different annual winter-growing pasture crops planted during May 2005.

Treatment	Apr	Mei	Jun	28 Jul	6 Sep	10 Oct	25 Nov	STD	mean
ryegrass	-	-	-	21.3	24.2	26.2	20.6	**2.60**	**23.1**
oats	-	-	-	21.8	21.0	16.7	14.8	**3.37**	**18.6**
triticale	-	-	-	22.7	22.4	17.7	15.1	**3.71**	**19.5**
ryegrass/oats	-	-	-	22.1	24.1	20.1	18.1	**2.58**	**21.1**
ryegrass/triticale	-	-	-	24.6	24.4	21.1	19.8	**2.40**	**22.5**
ryegrass/serradella	-	-	-	19.6	22.2	16.4	20.2	**2.41**	**19.6**
ryegrass/vetch	-	-	-	22.1	25.4	25.1	20.5	**2.38**	**23.3**
oats/triticale	-	-	-	20.0	22.6	17.0	14.1	**3.68**	**18.4**
oats/serradella	-	-	-	22.3	22.1	17.1	15.6	**3.43**	**19.3**
oats/vetch	-	-	-	24.1	25.1	21.6	15.4	**4.36**	**21.6**
triticale/serradella	-	-	-	18.0	21.8	17.2	na	**2.46**	**19.0**
triticale/vetch	-	-	-	19.8	23.7	19.3	17.0	**2.78**	**20.0**
STD	-	-	-	**1.91**	**1.41**	**3.32**	**2.54**		**1.76**

na = not available

The mean monthly and mean seasonal in vitro organic matter digestibility (IVOMD) (%) of different annual winter-growing pasture crops planted during February, March, April and May 2005 is shown in Tables 17, 18, 19 and 20 respectively.

Table 17. The mean monthly and mean seasonal *in vitro* organic matter digestibility (IVOMD) (%) of different annual winter growing pasture crops planted during February 2005.

Treatment	31 Mrt	3 May	7 Jun	13 Jul	17 Aug	22 Sep	25 Oct	STD	mean
ryegrass	80.1	77.1	71.2	80.1	75.8	69.8	68.6	**4.81**	**74.7**
oats	78.6	77.5	75.8	82.9	69.3	74.7	77.5	**4.14**	**76.6**
triticale	76.9	76.6	75.4	77.7	79.7	70.4	na	**3.14**	**76.1**
ryegrass/oats	76.9	80.8	72.0	77.5	n/a	67.4	70.6	**5.02**	**74.2**
ryegrass/triticale	78.5	74.2	80.6	76.7	84.0	68.6	65.9	**6.46**	**75.5**
ryegrass/serradella	80.4	74.5	76.5	66.0	79.9	72.5	69.2	**5.35**	**74.2**
ryegrass/vetch	78.2	74.2	77.9	84.1	78.7	68.1	72.6	**5.13**	**76.3**
oats/triticale	76.2	70.5	72.8	78.3	77.5	73.6	71.4	**3.04**	**74.3**
oats/serradella	80.9	69.9	77.8	76.7	78.1	73.2	73.3	**3.74**	**75.7**
oats/vetch	78.2	71.2	76.2	81.0	79.5	72.4	71.2	**4.09**	**75.7**
triticale/serradella	80.2	69.1	72.8	75.3	78.1	70.9	na	**4.27**	**74.4**
triticale/vetch	80.4	71.9	74.3	76.7	79.1	75.2	71.5	**3.39**	**75.6**
STD	**1.60**	**3.57**	**2.78**	**4.58**	**2.04**	**2.60**	**3.08**		**0.87**

na = not available

The IVOMD was high (70-86%) and tended to decrease from June to November. The inclusion of legumes did not increase the IVOMD of pastures.

Table 18. The mean monthly and mean seasonal *in vitro* organic matter digestibility (IVOMD) (%) of different annual winter-growing pasture crops planted during March 2005.

Treatment	Apr	4 May	8 Jun	14 Jul	23 Aug	26 Sep	31 Oct	STD	mean
ryegrass	-	78.3	78.0	84.0	82.8	74.3	73.5	**4.28**	**78.5**
oats	-	74.6	83.4	85.9	82.5	83.5	74.2	**5.00**	**80.7**
triticale	-	68.6	78.2	78.1	79.8	76.1	na	**4.43**	**76.1**
ryegrass/oats	-	75.0	85.1	85.3	83.8	80.5	73.8	**5.10**	**80.6**
ryegrass/triticale	-	71.9	78.9	85.3	83.2	80.9	76.2	**4.86**	**79.4**
ryegrass/serradella	-	77.0	82.2	83.8	82.0	80.1	76.7	**2.92**	**80.3**
ryegrass/vetch	-	78.6	83.9	82.8	85.9	79.9	77.1	**3.38**	**81.4**
oats/triticale	-	73.4	82.6	82.1	85.5	84.2	76.6	**4.71**	**80.7**
oats/serradella	-	77.9	83.6	85.8	86.2	83.0	76.8	**3.98**	**82.2**
oats/vetch	-	74.8	83.8	83.8	86.8	81.8	77.7	**4.98**	**81.4**
triticale/serradella	-	77.3	78.9	86.5	80.7	80.8	na	**4.43**	**80.8**
triticale/vetch	-	73.3	79.8	78.8	82.4	73.7	76.6	**3.48**	**77.4**
STD	-	**2.98**	**2.58**	**2.71**	**2.23**	**3.45**	**1.50**		**1.79**

na = not available

Table 19. The mean monthly and mean seasonal *in vitro* organic matter digestibility (IVOMD) (%) of different annual winter-growing pasture crops planted during April 2005.

Treatment	Apr	May	14 Jun	27 Jul	01 Sep	01 Oct	02 Nov	STD	mean
ryegrass	-	-	89.2	81.5	79.5	75.8	75.1	**5.67**	**80.2**
oats	-	-	87.7	81.3	83.0	79.8	73.5	**5.16**	**81.1**
triticale	-	-	85.5	83.9	75.5	75.4	71.5	**6.04**	**73.4**
ryegrass/oats	-	-	86.0	79.8	78.7	76.1	69.1	**6.13**	**77.9**
ryegrass/triticale	-	-	84.8	82.3	82.0	76.1	73.8	**4.63**	**79.7**
ryegrass/serradella	-	-	87.1	82.8	80.0	72.3	67.7	**7.88**	**78.0**
ryegrass/vetch	-	-	87.7	83.5	77.8	71.6	73.1	**6.80**	**78.7**
oats/triticale	-	-	82.3	81.9	79.6	80.1	75.1	**2.87**	**79.8**
oats/serradella	-	-	86.1	82.2	83.6	79.1	77.0	**3.61**	**81.6**
oats/vetch	-	-	84.0	81.9	76.9	81.3	78.4	**2.84**	**80.5**
triticale/serradella	-	-	80.4	78.1	79.3	76.1	75.2	**2.17**	**77.8**
triticale/vetch	-	-	82.7	77.5	80.7	70.2	74.3	**5.00**	**77.1**
STD	-	-	**2.57**	**1.98**	**2.39**	**3.52**	**3.04**		**2.22**

Table 20. The mean monthly and mean seasonal *in vitro* organic matter digestibility (IVOMD) (%) of different annual winter-growing pasture crops planted during May 2005.

Treatment	May	Jun	Jul	05 Jul	6 Sep	10 Oct	25 Nov	STD	mean
ryegrass	-	-	-	83.3	82.5	76.6	73.2	**4.83**	**78.9**
oats	-	-	-	86.8	83.2	83.8	73.1	**5.96**	**81.7**
triticale	-	-	-	79.7	76.2	76.0	75.3	**1.97**	**76.8**
ryegrass/oats	-	-	-	85.6	81.4	78.0	71.3	**6.04**	**79.1**
ryegrass/triticale	-	-	-	81.5	79.2	80.0	72.0	**4.23**	**78.2**
ryegrass/serradella	-	-	-	83.3	81.1	76.2	74.7	**4.05**	**78.9**
ryegrass/vetch	-	-	-	82.8	81.8	78.0	72.6	**4.62**	**78.8**
oats/triticale	-	-	-	83.1	83.3	82.5	74.3	**4.35**	**80.8**
oats/serradella	-	-	-	82.3	85.3	80.6	71.8	**5.80**	**80.0**
oats/vetch	-	-	-	83.6	83.4	79.8	74.9	**4.08**	**80.4**
triticale/serradella	-	-	-	82.5	79.0	76.3	na	**3.11**	**79.3**
triticale/vetch	-	-	-	79.0	76.1	79.8	71.6	**3.71**	**76.6**
STD	-	-	-	**2.16**	**2.89**	**2.56**	**1.44**		**1.50**

na = not available

Conclusion

Planting date influenced winter DM production. The earliest first grazing varied between 46-50 days if planted during February or March. February and March were the best planting dates to plant annual crops for winter (June, July and August) production. The high growth rate of oats or oats-triticale planted during February or March makes it suitable as a late autumn (May)- early winter (June) pasture crop. Annual ryegrass or annual ryegrass-oats mixtures planted during February or March, increased winter production. Annual ryegrass planted during February or March had a DM production rate during winter that was higher than, or similar to any of the other species evaluated. The mean CP content (>20%) and mean IVOMD (>70%) of the different annual growing pasture crops were high, making it suitable as a pasture crop for highly productive animals like dairy cows.

Comments

Results show that these crops have a higher winter DM production rate than most perennial grasses used as planted pastures for dairy cows (kikuyu; perennial ryegrass) in this area. However, if compared with the summer and autumn DM production ability of kikuyu and perennial ryegrass, the DM production potential of these annual winter growing crops is not high enough to prevent winter fodder shortages.

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13. The evaluation of perennial forage legumes

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Abstract

In South Africa, a large amount of cool-season perennial forage legume cultivars are available. From a production potential point of view, it is important that these cultivars are evaluated in terms of dry matter (DM) production as high quality forage for animal production. Forage legumes produce a higher quality pasture than pure grass stands and, is therefore sown in a mixture with grass. The aim of this study was to evaluate the production potential of 16 annual cool-season forage legume cultivars. This small plot trial was carried out on the Outeniqua Research Farm near George (Altitude 201m, 33º 58' 38" S, 22º 25' 16" E, rainfall 728 mm per year) in the Western Cape Province of South Africa. The study was executed under sprinkler irrigation on an Estcourt soil type. Tensiometer readings were used to determine irrigation scheduling. The trial was established on 20 May 2009. The experimental design was a complete randomised block design. Results are compared over seven cuttings. Strawberry clover (*Trifolium fragiferum*) Red clover (*T. pratense*), Birdsfoot trefoil (*Lotus corniculatus*), White clover (*T. repens*) and Caucasian clover (*T. ambiguum*) was used in this trial. KTA 202 (Caucasian clover) was planted later than the rest (due to unavailability of the seed) and was only sampled from the third cutting onwards. Suez and Amos had the highest mean DM production rate (kg DM ha^{-1} day^{-1}), although it did not differ significantly from that of Klondike, Rajah, Ladino, Vendelin and Haifa. KTA 202 had the highest mean DM content. Suez and Amos produced the highest total amount of DM (kg DM ha^{-1}), although it did not differ significantly from that of Klondike, Haifa, Ladino, Rajah and Vendelin. San Gabriel, KTA 202 and Palestine had the lowest total DM production.

Keywords: Perennial legumes, cultivars, dry matter production

Introduction

In South Africa a large amount of cool-season perennial forage legume cultivars are available. From a production potential point of view, it is important that these cultivars are being evaluated as high-quality forage for animal production (Wasserman, 1981). Legumes have the ability to fix nitrogen (N) in the soil, due to their relationship with rhizobium bacteria in the root nodules (Strijdom, *et al.*, 1980). This N provides in the needs of the plant and enriches the soil, thereby providing N for the grass plants in the sward (Pannar, 2007; Botha, 2008).

Perennial cool-season legumes provide forage from autumn to spring, except if winter temperatures are too low, impeding growth (Donaldson, 2001). Forage legumes produce a higher quality pasture than pure grass stands and is therefore sown in a mixture with grass (Bartholomew, 2005). The legume component contributes greatly to nutritional value, palatability, digestibility and intake of grass-legume pastures (Wasserman, 1981; Botha, 2008). The calcium and protein content of legumes are higher than most other forage crops, especially grasses (Donaldson, 2001).

Perennial legumes refer to legumes having a longer persistence, and can produce forage for several years (Bartholomew, 2005). The forage legumes included in this trial is strawberry clover (*Trifolium fragiferum*), red clover (*T. pratense*), birdsfoot trefoil (*Lotus corniculatus*), white clover (*T. repens*) and caucasian clover (*T. ambiguum*).

The aim of this study was to evaluate the production potential of 16 annual cool-season forage legume cultivars.

Materials and Methods

This small-plot trial was carried out on the Outeniqua Research Farm near George (Altitude 201m, 33º 58' 38" S, 22º 25' 16" E, rainfall 728 mm per year) in the Western Cape Province of South Africa. The study was executed under sprinkler irrigation on an Estcourt soil type. Irrigation scheduling was done according to tensiometer readings, commencing at –25 kPa and terminated at –10 kPa (Botha 2002). Fertiliser was applied to raise the soil nutrient levels to soil analysis recommendations. Phosphorous (P) and potassium (K) were applied before planting, at a rate of 36 kg ha^{-1} and 38 kg ha^{-1} respectively, to raise soil nutrient levels in accordance with the soil analysis report. Calsitic lime was applied to raise the soil pH to 5,5. Boron (B) and molybdenum (Mo) was applied to achieve the optimum levels of 0,6 mg kg^{-1} and 0,1 mg kg^{-1} in the soil respectively. The trial was planted on 20 May 2009. Lands were tilled with a harrow disk and kongskilde to create a seedbed and to mechanically eradicate weeds. Seed was broadcasted onto the soil and then plots were rolled with a land roller. A week before planting, seed was treated against insects with dimetoate and, a day before planting, inoculated with a specific rhizobium innoculant.

The trial consisted of 16 cultivars (treatments), each repeated three times, –a total of 48 plots. Plot size was 4 m x 6 m (24 m^2). Plots were sampled on a 28-day cycle, with the first sample date 1 September 2009. Three 0,5 m x 0,5 m quadrates were chosen randomly for sampling, and cut to a height of 50 mm. Approximately 500 g of the sample was placed in a brown paper bag and weighed wet and dry to determine DM content. Samples were dried in an oven at 60ºC for 72 hours to determine dry weight. Another 700 g of the sample was fractioned to determine the size of the legume component and thereby the DM production of the legume species. Species, common name, cultivar and seeding rate of each of the cultivars are shown in Table 1.

The experimental design was a complete randomised block design – all treatments were represented in the blocks. Treatment design consisted of 12 cultivars that were randomly allocated to 3 blocks. The data was analysed according to the described design. The data was continuous, therefore an analysis of variance (ANOVA) was performed using SAS version 9.1.3 (SAS, 1993). A Shapiro-Wilk test was performed to test for non-normality (Shapiro and Wilk, 1965). The residuals of the data was found to be normal – therefore the results from ANOVA were valid and reliable. Student's t-Least Significant Difference was calculated at the 5% confidence level to compare treatment means (Ott, 1998).

Results and discussion

Results were compared over seven cuttings. KTA 202 (Caucasian clover) was planted later than the rest (due to unavailability of the seed) and was only sampled from the third cutting onwards.

Table 2 shows the dry matter production rate (kg DM ha^{-1} day^{-1}) over seven cuttings as well as the mean dry matter production rate (kg DM ha^{-1} day^{-1}) of perennial winter-growing forage legume cultivars. Haifa had a higher ($P<0.05$) DM production rate than any of the other cultivars during the first cutting. During the second cutting, Haifa had the highest DM production rate, though it did not differ ($P>0.05$) significantly from that of Ladino, Klondike, Huia, Regal, Quiniquile, DP 85-3029 Pepsi and Suez. Haifa also had the highest DM production rate during the third cutting, although it did not differ significantly from that of Suez, Amos, Klondike, Vendelin and Ladino. Suez had the highest DM production rate during the fourth cutting, but it not significantly different from that of Klondike, Amos, Ladino, Rajah, Haifa, DP 85-3029 Pepsi and Vendelin. During the fifth cutting, Amos, Rajah, Suez and Vendelin had the highest DM production rate, though not significantly different from that of Ladino, Regal, Klondike, Haifa and DP 85-3029 Pepsi. Amos had the highest DM production rate during the sixth cutting, but not significantly different from that of Rajah, Vendelin, Klondike, Red Gold, Suez and Ladino. During the seventh cutting, Rajah had the highest DM production rate, although it did not differ significantly from that of Amos, Suez, Quiniquile and Vendelin. Suez and Amos had the highest mean DM production rate, although not significantly different from that of Klondike, Rajah, Ladino, Vendelin and Haifa.

Table 3 indicates the dry matter content (%) over seven cuttings and mean dry matter content (%) of perennial winter-growing forage legume cultivars. Quiniquile and Rajah had the highest DM content in the first cutting, but not significantly different from that of Suez, Vendelin and San Gabriel. During the second cutting, Rajah and Suez had the highest DM content, although similar to that of Amos, Red Gold, San Gabriel, Quiniquile, Vendelin, Palestine, Klondike and Rivendel. Palestine had the highest DM content during the third cutting, similar to that of San Gabriel, Rivendel and Vendelin. During the fourth cutting, Suez had the highest DM content, although it did not differ significantly from that of Palestine, KTA 202, Quiniquile, Regal and Rivendel. Quiniquile had the highest DM content for the fifth cutting, similar to that of Palestine, San Gabriel, Regal, Rivendel, KTA 202, Haifa, Huia, Rajah, Ladino and DP 85-3029. Regal had the highest DM content during the sixth cutting, although not significantly different from that of KTA 202. During the seventh cutting, KTA 202 had the highest DM content, although it did not differ significantly from that of Palestine. KTA 202 had the highest mean DM content.

Table 4 indicates the total dry matter production (kg DM ha^{-1}) of the perennial winter-growing forage legume cultivars over seven cuttings and in total. Haifa had a higher (P<0.05) DM production than any of the other cultivars during the first cutting. During the second cutting, Haifa also produced the highest amount of DM (P>0.05), but not significantly different from that of Ladino, Klondike, Huia, Regal, Quiniquile, DP 85-3029 Pepsi and Suez. Haifa again achieved the highest DM production during the third cutting, similar to that of Suez, Amos, Klondike, Vendelin and Ladino. During the fourth cutting, Suez produced the highest amount of DM, but it was not significantly different from that of Klondike, Amos, Ladino, Rajah, Haifa, DP 85-3029 Pepsi and Vendelin. During the fifth cutting, Amos, Rajah, Suez and Vendelin had the highest DM production, but not significantly different from that of Ladino, Regal, Klondike, Haifa and DP 85-3029 Pepsi. Amos had the highest DM production during the sixth cutting, although not significantly different from that of Rajah, Vendelin, Klondike, Red Gold, Suez and Ladino. During the seventh cutting, Rajah had the highest DM production rate, but not significantly different from that of Amos, Suez, Quiniquile and Vendelin. Suez and Amos produced the highest total amount of DM, although it did not differ significantly from that of Klondike, Haifa, Ladino, Rajah and Vendelin. San Gabriel, KTA 202 and Palestine had the lowest total DM production.

Conclusion

Klondike, Rajah, Ladino, Vendelin and Haifa had a similar mean DM production rate in comparison with Suez and Amos, that were the highest (P<0.05) producing cultivars. Haifa produced the highest or similar amount of DM per day than the highest producing cultivar for the first five cuttings. Palestine and KTA 202 had the lowest DM production rate.

The cultivar with the highest (P<0.05) DM content (%DM) was KTA 202. DM content varied within cultivars over cuttings.

The DM production (kg DM ha^{-1}) of cultivars over each cutting varied. Only Suez could produce the highest or similar amount of DM than the highest producing cultivar for six of the seven cuttings. In comparison with the highest producing cultivars, Suez and Amos, Klondike, Haifa, Ladino, Rajah and Vendelin, produced a similar total amount of DM. San Gabriel, KTA 202 and Palestine had the lowest total DM production.

Considering the results of this trial, Suez, Amos, Klondike, Haifa, Ladino, Rajah and Vendelin can be recommended for pasture production.

Acknowledgements

We would like to thank the plant production team at Outeniqua Research Farm, as well as Mardé Booyse for their help and support.

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Table 1. Different perennial legumes and cultivars, with prescribed seeding rates, used in the trial at Outeniqua Research Farm.

	Species	Common name	Cultivar	Seeding rate (kg ha^{-1})
1	*Trifolium fragiferum*	Strawberry clover	Palestine	6
2	*T. pratense*	Red clover	Amos	8
3	*T. pratense*	Red clover	Quiniquile	8
4	*T. pratense*	Red clover	Rajah	8
5	*T. pratense*	Red clover	Red Gold	8
6	*T. pratense*	Red clover	Suez	8
7	*T. pratense*	Red clover	Vendelin	8
8	*Lotus corniculatus*	Birdsfoot trefoil	San Gabriel	5
9	*T. repens*	White clover	DP 85-3029 Pepsi	8
10	*T. repens*	White clover	Haifa	8
11	*T. repens*	White clover	Huia	8
12	*T. repens*	White clover	Klondike	8
13	*T. repens*	White clover	Ladino	8
14	*T. repens*	White clover	Regal	8
15	*T. repens*	White clover	Rivendel	8
16	*T. ambiguum*	Caucasian clover	KTA 202	8

Table 2. The mean dry matter production rate (kg DM ha^{-1} day^{-1}) of perennial winter-growing forage legume cultivars planted on Outeniqua Research Farm.

Cultivar		Cut 1	Cut 2	Cut 3	Cut 4	Cut 5	Cut 6	Cut 7	Mean
1.	Palestine	1.3^{ef}	24.9^{bcdef}	18.7^{fg}	22.2^{ef}	22.1^{e}	6.1^{g}	4.6^{f}	14.3^{fg}
2.	Amos	1.5^{ef}	20.2^{def}	59.8^{abc}	68.0^{abc}	83.2^{a}	59.3^{a}	35.4^{ab}	46.8^{a}
3.	Quinequile	0.7^{f}	21.7^{abcd}	34.7^{ef}	44.7^{bcde}	54.5^{bc}	32.9^{bcdef}	32.5^{abc}	33.6^{cde}
4.	Rajah	1.3^{ef}	16.7^{efg}	40.7^{de}	59.9^{abc}	80.6^{a}	50.1^{ab}	41.6^{a}	41.8^{abc}
5.	Red Gold	2.0^{ef}	14.8^{fg}	39.7^{e}	43.7^{cde}	54.6^{bc}	38.7^{abcde}	22.2^{cd}	30.8^{de}
6.	Suez	1.8^{ef}	30.0^{abcdef}	63.1^{ab}	53.4^{a}	80.6^{a}	38.5^{abcde}	35.2^{ab}	47.0^{a}
7.	Vendelin	0.9^{f}	16.7^{efg}	52.1^{abcde}	54.9^{abcd}	80.5^{a}	46.1^{abc}	32.2^{abc}	40.5^{abc}
8.	San Gabriel	0.6^{f}	2.6^{g}	6.9^{g}	8.2^{f}	15.3^{e}	12.4^{fg}	23.9^{bcd}	10.0^{g}
9.	DP 85-3029	3.7^{cd}	32.7^{abcde}	44.6^{cde}	56.5^{abcd}	62.7^{abc}	30.8^{bcdef}	18.4^{de}	35.6^{bcd}
10.	Haifa	9.1^{a}	45.7^{a}	64.6^{a}	58.9^{abc}	62.8^{abc}	25.3^{cdefg}	16.0^{def}	40.4^{abc}
11.	Huia	3.7^{cd}	37.0^{abcd}	46.3^{bcde}	52.5^{bcd}	50.1^{cd}	23.3^{defg}	17.8^{de}	33.0^{cd}
12.	Klondike	6.1^{b}	38.2^{abc}	58.0^{abcd}	70.7^{ab}	62.9^{abc}	43.4^{abcd}	20.9^{cd}	42.9^{ab}
13.	Ladino	4.4^{c}	39.8^{ab}	49.8^{abcde}	65.0^{abc}	74.6^{ab}	37.6^{abcde}	14.5^{def}	40.8^{abc}
14.	Regal	3.5^{cd}	36.4^{abcd}	37.9^{e}	47.7^{bcde}	67.2^{abc}	26.2^{defg}	15.9^{def}	33.5^{bcd}
15.	Rivendel	2.4^{de}	21.2^{cdef}	34.9^{ef}	47.4^{bcde}	57.2^{bc}	30.8^{bcdef}	19.8^{d}	30.5^{de}
16.	KTA 202	-	-	-	31.2^{def}	29.4^{de}	18.7^{efg}	7.0^{ef}	21.6^{ef}
LSD (0.05)		1.5	17.1	18.0	26.9	22.0	21.7	11.7	20.1

^{abcde} Means with no common superscript, differ significantly (P<0.05)
LSD = Least significant difference

Table 3. The mean dry matter content (%DM) of perennial winter-growing forage legume cultivars planted on Outeniqua Research Farm.

Cultivar		Cut 1	Cut 2	Cut 3	Cut 4	Cut 5	Cut 6	Cut 7	Mean
1.	Palestine	13.5[bcde]	9.9[abc]	15.2[a]	13.7[ab]	17.4[ab]	22.1[bc]	15.2[ab]	15.3[b]
2.	Amos	13.2[cde]	10.4[ab]	12.5[ef]	9.9[cd]	13.7[bcd]	15.2[e]	12.5[d]	12.5[d]
3.	Quinequile	14.1[a]	10.2[ab]	13.5[bcde]	12.6[abcd]	18.0[a]	18.7[cde]	13.4[bcd]	14.8[bc]
4.	Rajah	15.8[a]	11.0[a]	13.8[bcd]	10.3[bcd]	14.4[abcd]	16.4[cde]	13.6[bcd]	13.6[bcd]
5.	Red Gold	13.5[bcde]	10.4[ab]	12.8[def]	10.8[bcd]	13.5[bcd]	18.4[cde]	14.0[bcd]	13.3[bcd]
6.	Suez	15.4[ab]	10.8[a]	13.2[cde]	13.2[a]	13.2[cd]	16.2[de]	12.8[cd]	13.9[bcd]
7.	Vendelin	14.8[abc]	10.2[ab]	14.1[abc]	10.8[bcd]	13.8[bcd]	16.5[cde]	13.7[bcd]	13.4[bcd]
8.	San Gabriel	14.0[abcd]	10.4[ab]	14.5[ab]	12.1[bcd]	17.4[abc]	21.3[bcd]	13.5[bcd]	14.7[bc]
9.	DP 85-3029	12.3[def]	9.0[bcd]	12.4[ef]	10.5[bcd]	13.9[abcd]	18.8[cde]	12.8[cd]	12.8[cd]
10.	Haifa	10.5[f]	8.4[cd]	11.6[f]	11.0[bcd]	15.8[abcd]	20.3[cde]	13.6[bcd]	13.0[cd]
11.	Huia	12.4[def]	9.0[bcd]	12.0[ef]	10.7[bcd]	15.3[abcd]	22.2[bc]	13.9[bcd]	13.6[bcd]
12.	Klondike	12.5[def]	9.5[abcd]	12.3[f]	9.3[d]	12.6[d]	17.7[cde]	13.0[bcd]	12.4[d]
13.	Ladino	13.1[cde]	7.9[d]	11.9[ef]	9.3[d]	14.2[abcd]	19.9[cde]	14.8[bc]	13.0[cd]
14.	Regal	12.5[ef]	9.1[bcd]	12.5[ef]	12.4[abcd]	16.9[abc]	28.1[a]	13.6[bcd]	14.9[bc]
15.	Rivendel	12.4[def]	9.4[abcd]	14.2[abc]	12.3[abcd]	16.4[abcd]	19.2[cde]	13.5[bcd]	13.9[bcd]
16.	KTA 202	-	-	-	13.2[abc]	16.4[abcd]	27.1[ab]	17.1[a]	18.5[a]
LSD (0.05)		2.2	2.9	1.2	3.5	4.2	5.9	2.3	2.1

[abcde] Means with no common superscript, differ significantly (P<0.05)
LSD = Least significant difference

Table 4. The total dry matter production (kg DM ha^{-1}) of perennial winter growing forage legume cultivars planted on Outeniqua Research Farm.

Cultivar		Cut 1	Cut 2	Cut 3	Cut 4	Cut 5	Cut 6	Cut 7	Total
1.	Palestine	135^{ef}	1022^{bcdef}	523^{fg}	621^{ef}	640^{e}	200^{g}	144^{f}	3285^{f}
2.	Amos	161^{ef}	829^{def}	1674^{abc}	1903^{abc}	2411^{a}	1957^{a}	1098^{ab}	10034^{a}
3.	Quinequile	74^{f}	888^{abcd}	973^{ef}	1252^{bcde}	1581^{bc}	1084^{bcdef}	1006^{abc}	7403^{de}
4.	Rajah	141^{ef}	687^{efg}	1139^{de}	1678^{abc}	2387^{a}	1653^{ab}	1289^{a}	8974^{abcd}
5.	Red Gold	212^{ef}	609^{fg}	1112^{e}	1223^{cde}	1583^{bc}	1277^{abcde}	687^{cd}	6702^{e}
6.	Suez	188^{ef}	1230^{abcdef}	1766^{ab}	1496^{a}	2336^{a}	1271^{abcde}	1091^{ab}	10117^{a}
7.	Vendelin	97^{f}	686^{efg}	1459^{abcde}	1537^{abcd}	2335^{a}	1521^{abc}	999^{abc}	8634^{abcde}
8.	San Gabriel	68^{f}	107^{g}	194^{g}	231^{f}	445^{e}	407^{fg}	739^{bcd}	2191^{f}
9.	DP 85-3029	390^{cd}	1339^{abcde}	1249^{cde}	1581^{abcd}	1819^{abc}	1016^{bcdef}	571^{de}	7964^{bcde}
10.	Haifa	955^{a}	1875^{a}	1809^{a}	1650^{abc}	1821^{abc}	834^{cdefg}	497^{def}	9441^{abc}
11.	Huia	392^{cd}	1519^{abcd}	1297^{bcde}	1469^{bcd}	1452^{cd}	767^{defg}	552^{de}	7447^{cde}
12.	Klondike	637^{b}	1567^{abc}	1625^{abcd}	1979^{ab}	1824^{abc}	1433^{abcd}	647^{cd}	9713^{ab}
13.	Ladino	464^{c}	1633^{ab}	1395^{abcde}	1819^{abc}	2162^{ab}	1241^{abcde}	451^{def}	9165^{abcd}
14.	Regal	369^{cd}	1492^{abcd}	1061^{e}	1335^{bcde}	1948^{abc}	863^{cdefg}	492^{def}	7559^{cde}
15.	Rivendel	256^{de}	869^{cdef}	977^{ef}	1329^{bcde}	1660^{bc}	1017^{bcdef}	613^{d}	6720^{e}
16.	KTA 202	-	-	-	874^{def}	853^{de}	618^{efg}	217^{ef}	2562^{f}
LSD (0.05)		153	703	504	754	638	716	361	2036

^{abcde} Means with no common superscript, differ significantly ($P<0.05$)
LSD = Least significant difference

14. The evaluation of annual forage legumes

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Abstract

In South Africa a large amount of cool-season annual forage legume cultivars are available. The evaluation of these cultivars is important from a production potential point of view, to determine the potential thereof as high-quality forage for animal production. Forage legumes produce a higher quality pasture than pure grass stands. Therefore it is sown in a mixture with grass. A small-plot trial was carried out on the Outeniqua Research Farm near George (Altitude 201m, 33º 58' 38" S, 22º 25' 16" E, rainfall 728 mm per year) in the Western Cape Province of South Africa. Sprinkler irrigation was used with irrigation scheduling done according to tensiometer readings. The trial of 12 cultivars (treatments) was planted on an Estcourt soil type on 20 May 2009. The forage legumes included in this trial is arrowleaf clover (*Trifolium vesiculosum*), balansa clover (*T. michelianum Savi.*), berseem clover (*T. alexandrinum L.*), Biserrula (*Biserrula pelecinus*), barrel medic (*Medicago trancatula*), burr clover (*M. polymorpha*), Sub clover (*T. subterraneun*), yellow serradella (*Ornithopus sativus*), Persian clover (*T. resupinatum*), pink serradella (*O. sativus*) and grazing vetch (*Vicia dasycarpa*). The experimental design was a complete randomised block design. Results are compared over four cuttings. Casbah (Biserrula), Paraggio (annual medic), Santiago (annual medic), Sharano (yellow Serradella), Emena (pink serradella) and Max (grazing vetch) could only succeed in producing DM for the first two cuttings. Calipso (berseem clover) had a higher production rate (kg DM ha^{-1} day^{-1}) than any other cultivar or a production rate similar to the highest producing cultivar over the mean and for each of the four cuttings. The cultivar with the highest mean DM content (% DM) was Campeda. Calipso produced a higher amount of DM content (kg DM ha^{-1}) higher than any other cultivar or similar to the highest producing cultivar in total and for each of the four cuttings.

Keywords: Annual legumes, cultivars, dry matter production

Introduction

A large amount of cool-season annual forage legume cultivars are available in South Africa. From a production potential point of view, it is important that these cultivars are being evaluated as high-quality forage for animal production (Wasserman, 1981). Furthermore, legumes have the ability, in their relationship with rhizobium bacteria in the root nodules, to fix nitrogen (N) in the soil (Strijdom, *et al.*, 1980). This N provides in the needs of the plant and enriches the soil, thereby providing N for the grass plants in the sward (Pannar, 2007; Botha, 2008).

Annual cool-season legumes provide forage from autumn to spring, except if winter temperatures are too low, impeding growth (Donaldson, 2001). The legume component contributes greatly to nutritional value, palatability, digestibility and intake of grass-legume pastures (Wasserman, 1981; Botha, 2008). The calcium and protein content of legumes are higher than most other forage crops, especially grasses (Donaldson, 2001). Forage legumes produce a higher quality pasture than pure grass stands and is therefore sown in a mixture with grass (Bartholomew, 2005).

Annual legumes refer to plants having a lifespan of one year (Bartholomew, 2005). The forage legumes included in this trial are arrowleaf clover (*Trifolium vesiculosum*), balansa clover (*T. michelianum Savi.*), berseem clover (*T. alexandrinum L.*), biserrula (*Biserrula pelecinus*), barrel medic (*Medicago trancatula*), burr clover (*M. polymorpha*), sub clover (*T. subterraneun*), yellow serradella (*Ornithopus sativus*), Persian clover (*T. resupinatum*), pink serradella (*O. sativus*) and grazing vetch (*Vicia dasycarpa*).

The aim of this study was to evaluate the production potential of 12 annual cool-season forage legume cultivars.

Materials and Methods

This small-plot trial was carried out on the Outeniqua Research Farm near George (Altitude 201m, 33º 58' 38" S, 22º 25' 16" E, rainfall 728 mm per year) in the Western Cape Province of South Africa. The study was executed under sprinkler irrigation on an Estcourt soil type. Irrigation scheduling was done according to tensiometer readings, commencing at –25 kPa and terminated at –10 kPa (Botha 2002). Fertiliser was applied to raise the soil nutrient levels to soil analysis recommendations. Phosphorous (P) and potassium (K) was applied before planting at a rate of 36 kg ha^{-1} and 38 kg ha^{-1} respectively, to raise soil nutrient levels in accordance with the soil analysis report. Calsitic lime was applied to raise the soil pH to 5,5. Boron (B) and molybdenum (Mo) was applied to achieve the optimum levels of 0,6 mg kg^{-1} and 0,1 mg kg^{-1} in the soil respectively. The trial was planted on 20 May 2009. Lands were tilled with a harrow disk and kongskilde to create a seedbed and to mechanically eradicate weeds. Seed was broadcasted onto the soil and then plots were rolled with a land roller. A week before planting, seed was treated against insects with dimetoate and, a day before planting, inoculated with a specific rhizobium innoculant.

The trial consisted of 12 cultivars (treatments), each repeated three times, – 36 plots in total. Plot size was 2 m x 6 m (12 m^2). Plots were sampled on a 28-day cycle, with the first sample date 1 September 2009. Three 0.5 m x 0.5 m quadrates were chosen randomly for sampling and cut to a height of 50 mm. Approximately 500 g of the sample was placed in a brown paper bag and weighed wet and dry to determine DM content. Samples were dried in an oven at 60ºC for 72 hours to determine dry weight. Another 700 g of the sample was fractioned to determine the size of the legume component and thereby the DM production of the legume species. Species, common name, cultivar and seeding rate of each of the cultivars are shown in Table 1.

The experimental design was a complete randomised block design – all treatments were represented in the blocks. Treatment design consisted of 12 cultivars that were randomly allocated to 3 blocks. The data was analysed according to the described design. The data was continuous, therefore an analysis of variance (ANOVA) was performed using SAS version 9.1.3 (SAS, 1993). A Shapiro-Wilk test was performed to test for non-normality (Shapiro and Wilk, 1965). The residuals of the data were found to be normal – therefore the results from ANOVA were valid and reliable. Student's t-Least Significant Difference was calculated at the 5% confidence level to compare treatment means (Ott, 1998).

Results and discussion

Results were compared over four cuttings. Casbah (Biserrula), Paraggio, Santiago, Sharano (yellow Serradella), Emena and Max (grazing Vetch) could only succeed in producing DM for the first two cuttings.

Table 2 shows the dry matter production rate (kg DM ha^{-1} day^{-1}) over four cuttings as well as the mean dry matter production rate (kg DM ha^{-1} day^{-1}) of annual winter-growing forage legume cultivars. Calipso had the highest DM production rate during the third and fourth cutting. During the second cutting, Woogenellup had a similar DM production rate to the highest producing cultivar, Calipso. Santiago had the highest DM production rate during the first cutting, though it did not differ significantly from that of Calipso, Paraggio and Emena. As a result, Calipso had the highest mean DM production rate, whereas Casbah had the lowest mean DM production rate. Calipso had the highest ($P<0.05$,) or similar ($P>0.05$) production rate to that of the highest producing cultivar for each of the four cuttings. These results suggest that Calipso had a higher production rate than any other cultivar or a production rate similar to the highest producing cultivar over the mean and for each of the four cuttings.

Table 3 indicates the dry matter content (%) over four cuttings and mean dry matter content (%) of annual winter-growing forage legume cultivars. During the first cut, the DM content of Casbah and Campeda did not differ ($P>0.05$) from that of Woogenellup, but was higher ($P<0.05$) than any of the other cultivars. Paraggio had the highest DM content during the second cutting. During the third cutting, Paradana and Campeda had a higher DM content than any of the other cultivars. The highest producer during the fourth cutting was Campeda, although the DM content of Woogenellup did not differ significantly from it. The cultivar with the highest mean DM content was Campeda.

Table 4 indicates the total dry matter production (kg DM ha^{-1}) of the annual winter-growing forage legume cultivars over four cuttings and in total. Calipso (Berseem clover) had the highest total dry matter production during the third and fourth cutting. During the second cutting Calipso also produced the highest amount of dry matter, but it did not differ significantly from Woogenellup (Subterranean clover). The Santiago (Burr clover), produced the highest amount of DM during the first cutting, but it did not differ significantly from Calipso, Paraggio (Barrel medic) and Emena (pink Serradella). This resulted in Calipso producing the highest ($P<0.05$) total amount of DM (kg DM ha^{-1}). Calipso produced the highest ($P<0.05$) or similar ($P>0.05$) amount of DM content as the highest producing cultivar for each of the four cuttings. It appears that Calipso produced a higher amount of DM content than any other cultivar or similar to the highest producing cultivar in total, and for each of the four cuttings. Casbah had the lowest total DM production. Paradana, Campeda and Woogenellup produced, over four cuttings, similar amounts of DM than Emena and Max over two cuttings.

Conclusion

Casbah, Paraggio, Santiago, Sharano, Emena and Max could only succeed in producing DM for the first two cuttings.

Calipso had the highest mean DM production rate (kg DM ha^{-1} day^{-1}) and Casbah the lowest. Calipso had a higher production rate than any other cultivar or a production rate similar to the highest producing cultivar over the mean and for each of the four cuttings.

The cultivar with the highest mean DM content was Campeda. The DM content within the cultivars varied over cuttings.

The results indicate that Calipso produced higher DM content than any other cultivar or similar to the highest producing cultivar in total, and for each of the four cuttings. Casbah had the lowest total DM production. Calipso should therefore be recommended for pasture production.

Acknowledgements

We would like to thank the plant production team at Outeniqua Research Farm, as well as Mardé Booyse for their help and support.

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Table 1. Different annual legumes and cultivars, with prescribed seeding rates, used in the trial at Outeniqua Research Farm.

Species		Common name	Cultivar	Seeding rate (kg ha^{-1})
1	*Trifolium vesiculosum*	Arrowleaf clover	Zulu	20
2	*T. michelianum* Savi.	Balansa clover	Paradana	4
3	*T. alexandrinum* L.	Berseem clover	Calipso	15
4	*Biserrula pelecinus*	Biserrula	Casbah	35
5	*Medicago trancatula*	Barrel medcic	Paraggio	15
6	*M. polymorpha*	Burr clover	Santiago	15
7	*T. subterraneun*	Sub clover	Campeda	15
8	*Ornithopus compressus*	Yellow serradella	Sharano	25
9	*T. subterraneun*	Sub clover	Woogenellup	15
10	*T. resupinatum*	Persian clover	Lazer	10
11	*O. sativus*	Pink serradella	Emena	35
12	*Vicia dasycarpa*	Grazing vetch	Max	25

Table 2. The mean dry matter production rate (kg DM ha^{-1} day^{-1}) of annual winter-growing forage legume cultivars evaluated at Outeniqua Research Farm.

Treatment		Cut 1	Cut 2	Cut 3	Cut 4	Mean
1.	Zulu	28.2^{bcde}	55.4^{b}	21.9^{b}	29.6^{bc}	33.8^{bcd}
2.	Paradana	19.0^{e}	41.4^{bc}	19.5^{b}	3.8^{c}	20.9^{e}
3.	Calipso	35.5^{abcd}	73.8^{a}	113.6^{a}	83.1^{a}	76.5^{a}
4.	Casbah	4.5^{f}	8.0^{e}	.	.	6.2^{f}
5.	Paraggio	38.7^{abc}	31.9^{cd}	.	.	35.3^{bcd}
6.	Santiago	49.6^{a}	34.3^{cd}	.	.	42.0^{bc}
7.	Campeda	22.0^{de}	46.2^{bc}	31.0^{b}	0.7^{c}	25.0^{de}
8.	Sharano	26.1^{cde}	32.3^{cd}	.	.	29.2^{de}
9.	Woogenellup	22.0^{de}	56.1^{ab}	25.5^{b}	0.5^{c}	26.0^{de}
10.	Lazer	22.6^{de}	19.1^{de}	38.4^{b}	44.2^{b}	31.1^{cde}
11.	Emena	40.4^{ab}	47.1^{bc}	.	.	43.8^{b}
12.	Max	34.7^{bcd}	54.3^{b}	.	.	44.5^{b}
LSD (0.05)		14.2	18.1	28.1	32.0	11.1

^{abcde} Means with no common superscript, differ significantly ($P<0.05$)
LSD = Least significant difference

Table 3. The mean dry matter content (%DM) of annual winter-growing forage legume cultivars evaluated at Outeniqua Research Farm.

Treatment		Cut 1	Cut 2	Cut 3	Cut 4	Mean
1.	Zulu	10.8^{cd}	10.5^{de}	14.9^{b}	17.0^{b}	13.3^{bc}
2.	Paradana	9.7^{de}	9.1^{d}	17.7^{a}	17.0^{b}	13.3^{bc}
3.	Calipso	8.8^{e}	8.4^{f}	11.7^{c}	14.3^{b}	10.8^{cd}
4.	Casbah	13.4^{a}	12.8^{bc}	.	.	13.1^{bc}
5.	Paraggio	11.3^{bc}	15.8^{a}	.	.	13.5^{bc}
6.	Santiago	10.3^{cde}	14.0^{b}	.	.	12.2^{cd}
7.	Campeda	13.1^{a}	11.6^{cd}	17.9^{a}	35.6^{a}	19.6^{a}
8.	Sharano	9.9^{cde}	10.4^{de}	.	.	10.1^{cd}
9.	Woogenellup	12.6^{ab}	10.3^{de}	15.3^{b}	24.9^{ab}	15.8^{b}
10.	Lazer	9.8^{cde}	8.6^{f}	10.7^{c}	13.5^{b}	10.7^{cd}
11.	Emena	10.3^{cde}	8.6^{f}	.	.	9.4^{d}
12.	Max	9.9^{cde}	10.9^{d}	.	.	10.4^{cd}
LSD (0.05)		1.5	1.5	2.1	17.1	3.4

^{abcde} Means with no common superscript, differ significantly ($P<0.05$)
LSD = Least significant difference

Table 4. The total dry matter production (kg DM ha^{-1}) of annual winter-growing forage legume cultivars evaluated at Outeniqua Research Farm.

Treatment		Cut 1	Cut 2	Cut 3	Cut 4	Total
1.	Zulu	790^{bcde}	2272^{b}	833^{b}	978^{bc}	4874^{b}
2.	Paradana	533^{e}	1698^{bc}	740^{b}	124^{c}	3094^{defg}
3.	Calipso	994^{abcd}	3028^{a}	4315^{a}	2741^{a}	11078^{a}
4.	Casbah	125^{f}	326^{e}	.	.	451^{h}
5.	Paraggio	1085^{abc}	1306^{cd}	.	.	2391^{fg}
6.	Santiago	1389^{a}	1407^{cd}	.	.	2796^{efg}
7.	Campeda	616^{de}	1893^{bc}	1176^{b}	22^{c}	3707^{cde}
8.	Sharano	730^{cde}	1325^{cd}	.	.	2055^{g}
9.	Woogenellup	617^{de}	2299^{ab}	969^{b}	17^{c}	3902^{bcd}
10.	Lazer	632^{de}	783^{de}	1458^{b}	1458^{b}	4332^{bc}
11.	Emena	1131^{ab}	1933^{bc}	.	.	3064^{defg}
12.	Max	972^{bcd}	2225^{b}	.	.	3197^{def}
LSD (0.05)		398	742	1069	1057	1062

^{abcde} Means with no common superscript, differ significantly ($P<0.05$)
LSD = Least significant difference

15. Kikuyu over-sown with different ryegrass species or clover: recent research

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Introduction

Kikuyu comprises the greater part of irrigated summer and autumn pasturage for milk production in the southern Cape of South Africa. Well managed kikuyu has a high dry matter (DM) yield, which supports high stocking rates and milk production per hectare (Reeves, 1997). Compared to temperate pasture species, the forage quality of kikuyu is low and consequently, milk production per cow is also low (Marais, 2001). The main nutritional limitation is a low digestible energy content and low digestibility of structural carbohydrates (Marais 2001). Due to a lack of readily digestible, non-structural carbohydrates, and high structural carbohydrate content, energy is the major limiting factor for milk production (Marais, 2001). Kikuyu contains oxalic acid, which binds calcium (Ca), rendering it largely unavailable to the grazing animal (Marais, 1998, 2001). Kikuyu is also deficient in sodium (Na) (Miles *et al.* 1995; Marais,1998, 2001) and prone to Ca:phosphate (P) and potassium (K):Ca + magnesium (Mg) imbalances (Miles *et al.*, 1995).

The nutritive quality of kikuyu is determined by its unique morphology, physiology and chemical composition, which could change, depending on the growth stage and environmental conditions during growth (Marais, 2001). Due to the fact that kikuyu produces stem material for the duration of the growing season, its nutritive value is influenced by the stage of re-growth. When fertilised with high levels of nitrogen (N), it accumulates NO_3 – which may have a negative impact on digestion and animal performance (Reeves, 1997; Marais, 2001). Reeves (1997) found that modest applications of N (50 kg N ha^{-1} per dressing) provide enough protein to uphold DM production and increase protein concentration, to meet the needs of a lactating cow. Subsequently, high levels of N will increase nitrate concentration – which may reduce rumen microbial activity and disrupt rumen function (Reeves, 1997). Concentrate supplements are used to obtain satisfactory performance from animals fed on kikuyu (Marais, 2001). However, these supplements are expensive and increase the cost of milk production.

Other strategies, such as over-sowing kikuyu with grasses or legumes for improving animal production, were hampered by difficulties regarding establishment (Pottinger *et al.*, 1993) and persistency of species (Marais, 2001). The strategic incorporation of legumes and other grasses into a kikuyu pasture, if successful, could increase the seasonal dry matter (DM) production and quality of the pasture, with a reduction in N fertiliser needs.

Botha *et al.* (2008a, 2008b) and Van der Colf *et al.* (2009) reported on studies where kikuyu was over-sown with different ryegrass species and/or clover. The aim of these studies was to determine the persistence and the seasonal dry matter yield, botanical composition, nutritional value, grazing capacity, milk production and milk composition of irrigated kikuyu over-sown with ryegrass and/or clovers. Although these studies were conducted in different years – Study 1 from 1999 until 2002 (Botha *et al.* 2008a, 2008b) and Study 2 from 2007 until 2009 (Van der Colf *et al.*, 2009) – and thus statistically not comparable, they were carried out on the same site, using the same camps. Similar methods were used to measure pasture production and milk production – the same techniques and laboratories were also used to determine the nutritional composition of the pasture and milk composition. Because this information is important to assist local dairy farmers in decision-making, relevant data is shown in adjacent tables, without comparing in a direct way. Scientific papers on these studies can be consulted for in-depth information.

Materials and Methods

Both Study 1 and Study 2 were carried out on the Outeniqua Research Farm near George in the Western Cape Province of South Africa. The area has a temperate climate, with mean minimum and maximum air temperatures varying between 7–15°C and 18–25°C respectively. The trials were carried out on nine hectares of kikuyu pasture under sprinkler irrigation, on an Estcourt soil type (Soil Classification Workgroup, 1991).

The treatments of each study consisted of three pasture systems. The selection of the systems was based on a request from commercial dairy farmers to evaluate existing pasture systems in terms of production potential and nutritional value. The main systems used in commercial dairy farming were perennial or annual ryegrass over-sown annually into kikuyu. In Trial 1 perennial white and red clover was over-sown into kikuyu. The rationale in evaluating a legume against a grass is in the nutritional value of the species, and cost-saving on nitrogen fertiliser on legume pastures. Different methods are needed to over-sow ryegrass or clovers into an existing kikuyu pasture. The intensive cultivation method used to plant clover into kikuyu and the subsequent negative effect on kikuyu growth make it important to evaluate the system as a perennial pasture with optimum seasonal production, kikuyu rectification and 30% clover content as objectives within the system.

Table 1 shows the pasture species and cultivars used in the trials. Table 2 shows the different treatments, botanical composition of the treatments, seeding rate and over-sowing methods used in the trials. The Kikuyu/clover pasture was established using a rotavator (Botha *et al.*, 2008). The kikuyu was grazed to 50 mm, mulched to ground level and rotavated afterwards to a depth of 100 mm, then rolled once with a Cambridge land roller. The seed was broadcast by hand, rolled again and irrigated. The kikuyu/ Westerwolds ryegrass was established using a mulcher (Botha *et al.*, 2008). The kikuyu was grazed down to 50mm and annual ryegrass seed broadcast over the remaining kikuyu pasture. The kikuyu pasture was then mulched to ground level without the blades touching the soil. The mixture of mulched plant material and seed was then rolled once with a Cambridge land roller and irrigated. The kikuyu-perennial and kikuyu-Italian ryegrass were established using an Aitcheson planter. The kikuyu was grazed to 50 mm, mulched to ground level, planted with the planter and rolled once with a Cambridge roller (Van der Colf *et al.*, 2009).

Irrigation was scheduled by means of tensiometers. Irrigation commenced at a tensiometer reading of -25 Kpa and terminated at a reading of -10 Kpa. Fertiliser was applied to raise the soil phosphorus level to 35 mg kg^{-1} (citric acid), potash level to 80 mg kg^{-1} (citric acid) and the pH (KCL) to 5.5. No nitrogen was applied to the KC (kikuyu-clover)$^{1st\ year}$, KC$^{2nd\ year}$ and KRC (kikuyu-ryegrass-clover) pastures. The K (kikuyu) and KR (kikuyu-ryegrass) pastures systems were fertilised at a rate of 560 kg N ha^{-1} in ten applications of 56 kg N ha^{-1}. Dry matter production was estimated by the Ellinbank rising plate meter (RPM) mass (Fulkerson, 1997; Stockdale, 1984). The RPM was calibrated by developing a linear regression between meter reading and herbage DM. A different regression was developed for the various treatments for each season of every year. Pasture height was estimated daily by taking RPM readings before and after grazing (Botha *et al.*, 2008; Van der Colf *et al.*, 2009).

Jersey cows strip-grazed pasture treatments in a 28-day grazing cycle. Cows were fed two kg of dairy concentrate (composition: 11.5 MJ ME, 12% crude protein (CP), 13% NDF, 1.2% calcium (Ca), 0.4% phosphorus (P)) during each milking, and were milked twice daily (4 kg dairy concentrate per cow per day). The number of cows per paddock was adjusted daily to ensure a forage availability of 10 kg DM cow^{-1} day^{-1}.

Results and discussion

The data shown focus on aspects important for farmers in their decision-making regarding fodder-flow-and management.

Growth rate

The mean monthly growth rate (kg DM ha month) of kikuyu over-sown with clover, Westerwolds, Italian or perennial ryegrass, is shown in Figure 1. The growth rate of different species varied over months. Kikuyu-ryegrass, fertilised with nitrogen fertiliser, had a dry matter production rate similar to that of kikuyu-clover from August to December, but higher from January to April. As the kikuyu content of the kikuyu-clover pastures increased and the clover content decreased, the seasonal growth rate changed from a higher spring/summer growth rate in the first year to a higher summer/autumn growth rate in the second year. The growth of kikuyu-clover during winter was low compared to the spring, summer and autumn growth.

Kikuyu-ryegrass has a higher growth rate than kikuyu-clover during spring, summer and autumn (Botha *et al.*, 2008a). The mean monthly growth rate (kg DM ha^{-1} day^{-1}) of kikuyu over-sown with clover (1st year of growth, 2nd year of growth), Italian, Westerwolds or perennial ryegrass, is shown in Table 3. The growth rate of kikuyu-clover was low during winter and varied between 56 and 60 kg DM ha^{-1} day^{-1} during August and January.

The low growth rate of the Westerwolds ryegrass treatment during November resulted in an increase in the kikuyu component during spring, summer and autumn. The opposite occurred in the Italian ryegrass and perennial ryegrass treatments where the growth rate during November was high, resulting in a lower kikuyu component (Van der Colf *et al.*, 2009).

Botanical composition

Table 4 shows the mean seasonal kikuyu, ryegrass and clover content (%) of kikuyu over-sown with different ryegrass varieties and white and red clovers, over a period of two years. The ryegrass-kikuyu ratio of the pasture has an important influence on the seasonal DM production and quality of the pasture. The clover content of the kikuyu-clover remained at levels higher than 30% for more than two years. The grass content of the kikuyu-Westerwold ryegrass pasture varied from ryegrass-dominant in winter and spring to kikuyu-dominant in autumn (Botha *et al.*, 2008a).

The ryegrass component remained high in the perennial ryegrass treatment from spring to autumn relative to the Italian and Westerwolds ryegrass treatments. The kikuyu component increased from spring to autumn in the Westerwolds ryegrass treatment and from summer to autumn in the Italian ryegrass treatment. The Westerwolds ryegrass treatment appears to favour the growth of the kikuyu component, especially during summer, whereas the perennial ryegrass treatment seems to favour the growth of the ryegrass component (Van der Colf *et al.*, 2009).

Dry matter production

The total seasonal dry matter (kg DM ha-1 season-1) and total annual dry matter (kg DM ha^{-1} $year^{-1}$) production of the two trials, where kikuyu was over-sown with ryegrass or clover over two years, are shown in Table 5. The lowest annual total DM yield was produced by kikuyu-clover during the first year of growth (Botha *et al.*, 2008a).

Metabolisable energy (ME)

Table 6 shows the mean seasonal metabolisable energy (ME) (MJ/kg DM) of the two trials. The seasonal ME content of the grass pastures, or pastures where the grass component increased to the detriment of the clover content, had a lower ME content than the clover-dominant pasture. Kikuyu-clover was the only pasture that could provide sufficient energy for higher-producing dairy cows. The ME content of the kikuyu-clover pasture decreased seasonally as the grass content increased. The ME content of the kikuyu-ryegrass pasture was high during spring but decreased during summer and autumn when kikuyu became more dominant. The low ME content of kikuyu is, according to Reeves and Fulkerson (1995,) the first limiting factor for milk production from kikuyu. The ME content of Westerwolds ryegrass and perennial ryegrass during summer and autumn as well as Italian ryegrass during autumn was below 10 MJ kg^{-1}. Such low ME values could limit milk production. The forage quality of all treatments tended to decline from winter to summer in terms of CP and ME. This could possibly be attributed to the increase in the kikuyu component from winter to summer and the high growth rates of kikuyu during summer (Van der Colf *et al.*, 2009).

Crude protein (CP)

The mean seasonal crude protein (CP) content (%) of the two trials is shown in Table 7. The CP content in all the pastures was in excess of what is needed by dairy cows (NRC, 1989) for optimum milk production.

Neutral detergent fibre (NDF) content

Table 8 shows the mean seasonal neutral detergent fibre (NDF) content (%) of kikuyu in the two trials. The grass pastures had the highest NDF content (%) while pastures with high clover content had the lowest NDF content. The botanical composition of pasture affected its NDF content – the transforming of the kikuyu-ryegrass pasture from ryegrass-dominant in spring to kikuyu-dominant in summer, and only kikuyu in autumn, led to a seasonal increase in NDF. The NDF content of kikuyu-ryegrass pasture was higher than 60% during summer and autumn. With this high fibre content of the pasture, a low digestibility can be expected (Butterworth, 1967). The kikuyu-clover pastures had a NDF content of lower than 50% during most of its production period. This would have a positive effect on the DM intake and digestibility of the pasture (Botha *et al.*, 2008a).

Grazing capacity

The mean seasonal grazing capacity (cows ha^{-1} $season^{-1}$) of the two trials is presented in Table 9. The seasonal grazing capacity of the pastures was high, compared to similar pastures (Rethman, 1975; Dugmore, 1998). Kikuyu-ryegrass fertilised with nitrogen, had a higher summer and autumn growth rate (Botha *et al.*, 2008a) and therefore a higher grazing capacity than kikuyu-clover pastures not receiving nitrogen applications. The grazing capacity of the kikuyu-clover pasture was the highest during the spring and summer, decreased during autumn and reached its lowest capacity during winter. The autumn grazing capacity of kikuyu-clover pasture was higher during the second year of growth, because of increased kikuyu growth (Botha *et al.*, 2008a). The seasonal variation in grazing capacity of the kikuyu-ryegrass pastures was less than that of the clover-based pasture (Botha *et al.*, 2008b). Van der Colf *et al.* (2009) found that the grazing capacities follow a similar trend to the growth rates of the species, with the lowest grazing capacities occurring during the winter months of June and July.

The annual grazing capacity of the grass-dominant pasture was higher than that of the clover pasture (Botha *et al.*, 2008b). Kikuyu over-sown with ryegrass increased the annual grazing capacity of kikuyu (Botha *et al.*, 2003). This finding is supported by Van Heerden (1986) who found that pure grass pasture, or pasture with a high grass component, has a higher grazing capacity than pure clover or pastures with high clover content. The annual grazing capacity of kikuyu-clover was lower than kikuyu-ryegrass – however, taking into account that no nitrogen was applied on the kikuyu-clover pastures while kikuyu-ryegrass received 600 kg N ha^{-1}, the grazing capacity of the clover based pastures was still high.

Milk production and milk composition

The mean milk production per cow (kg milk cow day), 4% fat-corrected milk per cow (kg FCM cow day), butter-fat percentage and protein percentage from the two trials, where kikuyu were over-sown with ryegrass or clover over two years, are presented in Table 10. Milk production per cow from kikuyu-clover was higher than from kikuyu-ryegrass pasture during summer and autumn in Year 1 of production (Botha *et al.*, 2008b). Cows produced more milk per day from kikuyu-ryegrass during the second season of growth than from kikuyu-ryegrass pasture during the autumn. This may be a result of the lower fibre and higher ME content of clover pasture during autumn (Botha *et al.*, 2008a). Botha *et al.* (2008a) also found that the milk production from kikuyu over-sown with high quality fodder crops resembling ryegrass or clover could be higher than that from a pure kikuyu pasture. The low milk production of the kikuyu, kikuyu-ryegrass and kikuyu-clover pastures were the result of annual ryegrass dying during early summer, resulting in pure kikuyu stands, and the increase of the kikuyu component during the second year in the clover-based pastures (Botha *et al.*, 2008a).

The differences in milk-fat content between pastures during the corresponding seasons were small. This finding is comparable to that of Caradus *et al.* (1996, who found a similar milk-fat content of 5.26% and 5.29% on ryegrass and white clover pasture respectively. Harris *et al.* (1997) supported this finding and reported that the milk-fat content of milk produced from ryegrass-clover pasture with a 20%, 50% and 80% clover content, did not differ significantly, and contained a milk-fat content of 5.88%, 5.73% and 5.65% respectively.

There was no indication that the clover content of the pastures influenced the seasonal protein content of milk. Botha *et al.* (2008b) found that the protein content of all the treatments over a period of three years varied between 3.41% and 3.73%. This is similar to the protein assessment of 3.64% calculated as norm by the Agricultural Research Council for Jerseys (ARC, 2002). According to Muller (2002), registered Jersey cows in South Africa, annually produce 4944 kg milk with a protein content of 3.6%.

Table 11 shows the total annual milk production (kg milk ha^{-1}), 4% fat-corrected milk (kg FCM ha), milk solids (kg milk solids ha^{-1}), and average grazing capacity (cows ha^{-1} $season^{-1}$) of the two trials. The total annual milk production (kg ha^{-1}) from the different pastures was high. In similar studies, annual milk production from kikuyu varied between 12 820 kg ha^{-1} for Jersey cows (Cross, 1979; Dugmore, 1998) and 15 000 kg ha^{-1} for Friesland cows (Olney & Albertsen, 1984), which is lower than the milk production obtained in the Outeniqua studies. Small differences were found between the total annual milk production from grass- and clover pastures during matching years. During the first year the total annual milk production between treatments were similar. The reasons for this is that the grass and clover pastures reached either a high grazing capacity (cows ha^{-1}) or a high milk production per cow, which resulted in a small variation in milk production per hectare between pastures.

Discussion

Study 1

The incorporation of annual ryegrass or perennial clover into kikuyu pasture changed the seasonal fodder availability and increased the spring dry matter production of kikuyu (Botha *et al.*, 2008b). The over-sowing of kikuyu with annual ryegrass during May had no effect on the dry matter production of kikuyu during the summer and autumn (Botha *et al.*, 2008a). Kikuyu-ryegrass fertilised with nitrogen fertiliser had a higher dry matter production rate than kikuyu-clover during the both years of growth. The ryegrass-kikuyu ratio of the pasture has an important influence on the seasonal DM production and quality of the pasture. The clover content of the kikuyu-clover persisted at levels higher than 30% for more than two years.

The over-sowing of kikuyu with clover resulted in lower NDF values and higher CP and ME values. The ME value of kikuyu-clover pasture was high during spring. The lower ME content of kikuyu-ryegrass pastures during summer and autumn will be a limiting factor for milk production from kikuyu. The lowest CP content in kikuyu-ryegrass pasture was found during summer and autumn. The CP content of the concentrate supplement fed to cows should be increased during summer and autumn when cows graze kikuyu-dominant pasture.

Both the kikuyu-ryegrass and kikuyu-clover systems were persistent under good management conditions. The differences between the systems were the higher seasonal DM production and lower nutritional value of the kikuyu-ryegrass system, compared the kikuyu-clover system. These factors will not only have an influence on the seasonal grazing capacity of the system but also on the production potential of the individual grazing animal. Subsequently these factors will also affect the animal production per hectare.

The choice of system will be influenced by a number of factors. Factors in favour of the kikuyu-ryegrass system are the high seasonal DM production potential, the easy execution and management, and it also requires fewer and less expensive implements. It is a no-till system executed only when kikuyu is dormant and, because of that, has no influence on the summer and autumn production potential of kikuyu pasture. However, the lower nutritional value and dependence of nitrogen fertiliser could negatively influence the preference of the kikuyu-grass system.

The high nutritional value and independency of nitrogen fertiliser are in favour of the kikuyu-clover system. Negative factors include the lower seasonal DM production, the need to cultivate the soil with an expensive implement not popular in seedbed preparation (rotavator), the set back of the kikuyu production potential during the first year because of the intensive cultivation method, the overshadowing effect of the clover on the kikuyu that delays kikuyu growth, and the competition for soil nutrients between the clovers and kikuyu during the active growth period of kikuyu. The cost of nitrogen fertiliser as well as the milk price will determine the preferred system.

The high grazing capacity (cows ha^{-1}) and milk production per cow (kg cow^{-1} ha^{-1}) resulted in a high milk production per ha. The clover content of the pasture did not influence the milk protein or milk-fat content. Milk production per cow was the highest on pasture with high clover content and the grazing capacity of pasture increased as the grass component increased. Kikuyu-ryegrass pasture obtained a similar or a higher seasonal grazing capacity than kikuyu-clover pasture. Kikuyu-ryegrass pasture, compared to that of kikuyu-clover pasture, provided more even seasonal fodder availability, resulting in less variation in grazing capacity and milk production.

Study 2

Van der Colf *et al.* (2009) noted that the growth rate of different species varied over months. The low growth rate of the Westerwolds ryegrass treatment during November resulted in an increase in the kikuyu component during spring, summer and autumn. The opposite occurred in the Italian and perennial ryegrass treatments, where the growth rate during November was high – resulting in a lower kikuyu component. Although perennial ryegrass did not produce significantly more milk than Westerwolds and Italian per cow during either year, it had a higher grazing capacity over the ten-month lactation period (Van der Colf *et al.*, 2009). Perennial ryegrass showed higher growth rates during the winter and spring of Year 2, due to the carry-over effect of plants from Year 1 that survived into Year 2. Forage quality tended to decline for all pasture treatments from winter to summer as the kikuyu component present in pasture increased. Perennial ryegrass had higher milk production values per hectare than Westerwolds and Italian ryegrass during both years.

Conclusion

Milk production per ha was similar for clover over-sowed into kikuyu compared to kikuyu-ryegrass pasture. Kikuyu-clover reduced input cost.

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Table 1. The pasture species and cultivars used in the trials.

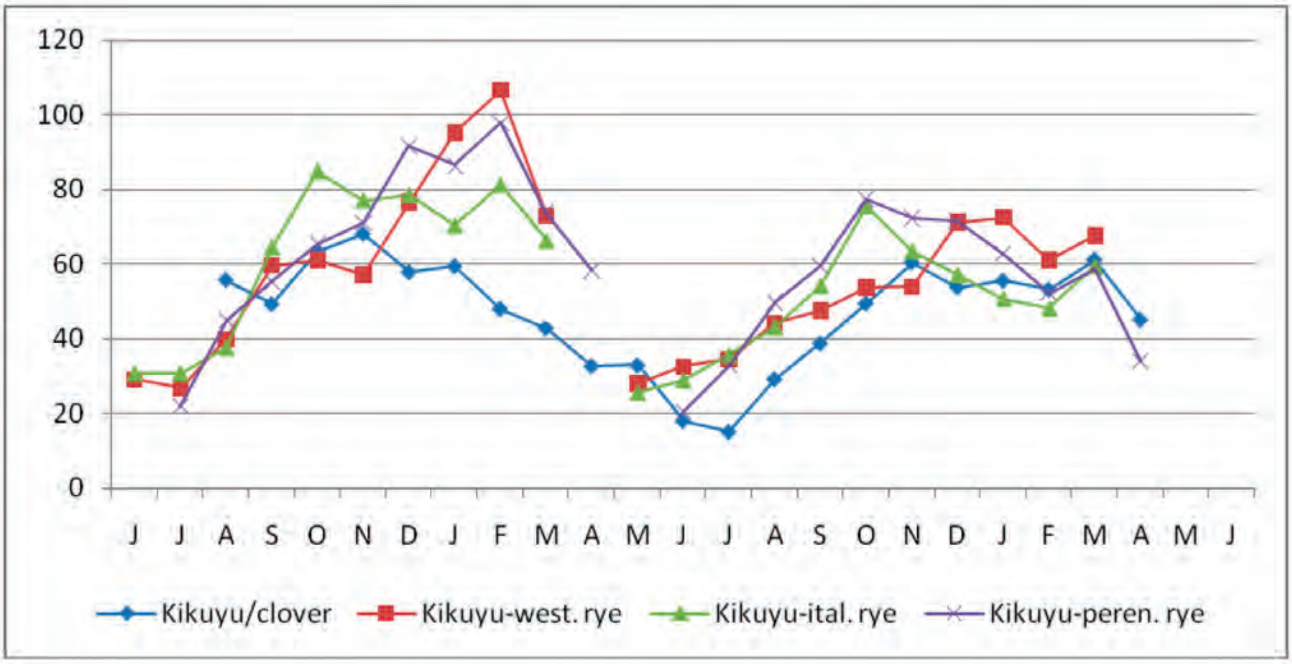
Pasture species	Cultivars
Kikuyu	Local strain (Southern Cape, South Africa)
(*Pennisetum clandestinum*)	
Annual ryegrass	
(*Lolium multiflorum* var. *westerwoldicum*)	Energa
Study 1:	Jivet
Study 2:	
Annual ryegrass	
(*Lolium multiflorum* var. *italicum*)	Jeanne
Study 2:	
Perennial ryegrass	Bronsyn
(*Lolium perenne*)	
Study 2:	
White clover	Mixture of Haifa and Waverley
(*Trifolium repens*)	
Study 1:	
	Mixture of Kenland and Cherokee
Red clover (*Trifolium pratense*)	
Study 1:	

Table 2. The different treatments, botanical composition of the treatments, seeding rate and over-sowing methods used in both studies.

Treatment	Species	Seeding rate kg ha^{-1}	Over-sowing methods
Kikuyu clover	Kikuyu white clover red clover	Existing stand 5 6	Grazed to 50 mm Mulcher Rotavator Cambridge roller Broadcast seed Cambridge roller
Kikuyu-West. rye	Kikuyu annual ryegrass	Existing stand 25	Grazed to 50 mm Broadcast seed Mulcher Cambridge roller
Kikuyu-Italian ryegrass	Kikuyu- Italian ryegrass	Existing stand 25	Grazed to 50 mm Mulcher Aicheson Planter Cambridge roller
Kikuyu-perennial ryegrass	Kikuyu Perennial ryegrass	Existing stand 20	Grazed to 50 mm Mulcher Aicheson Planter Cambridge roller

Botha *et al.*, 2008a; Van der Colf *et al.*, 2009

Figure 1. The mean monthly growth rate (kg DM ha-1 month-1) of kikuyu over-sown with clover, Westerwolds, Italian or perennial ryegrass.



Botha *et al.*, 2008a; Van der Colf *et al.*, 2009

Table 3. The mean monthly growth rate (kg DM ha^{-1} day^{-1}) of kikuyu over-sown with clover (1st year of growth). Clover (2nd year of growth), Italian, westerwolds or perennial ryegrass.

Months	Kik/west. rye	Kik/clover 1st year growth	Kik/clover 2nd year growth	Kik/west. rye	Kik/ital. rye	Kik/peren. rye
	Study 1			**Study 2**		
Jun	-	18	29	32	30	20
Jul	-	15	39	31	34	26
Aug	54	56	50	42	41	48
Sep	51	50	61	54	60	58
Oct	61	64	54	58	80	71
Nov	73	68	56	56	70	72
Dec	64	58	53	74	68	82
Jan	74	60	61	84	61	75
Feb	84	48	45	84	65	75
Mar	84	43	(over sow)	71	63	67
Apr	58	33	(over sow)	0 (over sow)	0 (over sow)	46
May	-	33	(over sow)	28	26	0 (over sow)

Botha *et al.* 2008a; Van der Colf *et al.*, 2009

Table 4. The mean seasonal kikuyu, ryegrass and clover content (%) of kikuyu over-sown with different ryegrass varieties, white and red clovers over a period of two years.

Study 1		**Winter**	**Spring**	**Summer**	**Autumn**
Kik/west. rye	kikuyu	na	na	na	na
	ryegrass				
Kik/clover 1st year growth	kikuyu	na	9	14	30
	clover		83	84	69
Kik/clover 2nd year growth	kikuyu	31	26	45	56
	clover	66	68	51	42
Study 2		Winter	Spring	Summer	Autumn
Kik/west. rye	kikuyu	18	12	64	87
	ryegrass	73	66	12	1
	other	9	22	25	12
Kik/ital. rye	kikuyu	11	3	45	95
	ryegrass	80	93	40	2
	other	9	3	15	3
Kik/peren. rye	kikuyu	3	2	26	51
	ryegrass	77	79	59	33
	other	19	20	15	16

Botha *et al.*, 2008a ; Van der Colf *et al.*, 2009

Table 5. The total seasonal dry matter (kg DM ha^{-1} $season^{-1}$) and total annual dry matter (kg DM ha^{-1} $year^{-1}$) production of kikuyu over-sown with ryegrass or clover over a period of two years.

Study 1	**Winter**	**Spring**	**Summer**	**Autumn**	**Total**
Kik/west. rye	na	4879	5904	6183	16966
Kik/clover 1st year growth	na	4902	5006	3395	13303
Kik/clover 2nd year growth	1787	3440	4875	4468	14570
Study 2	Winter	Spring	Summer	Autumn	Total
Kik/west. rye	3190	4461	6465	2473	16461
Kik/ital. rye	3188	5527	5273	2252	16123
Kik/peren. rye	2679	5364	6212	2894	17143

Botha *et al.*, 2008a ; Van der Colf *et al.*, 2009

Table 6. The mean seasonal metabolisable energy (ME) (MJ/kg DM) of kikuyu over-sown with ryegrass or clover over two years.

Study 1	**Winter**	**Spring**	**Summer**	**Autumn**
Kik/west. rye	na	11.5	9.53	8.0
Kik/clover 1st year growth	na	11.3	10.9	10.6
Kik/clover 2nd year growth	11.6	11.1	9.9	8.4
Study 2	Winter	Spring	Summer	Autumn
Kik/west. rye	12.2	11.2	9.7	9.5
Kik/ital. rye	11.9	11.4	10.4	9.9
Kik/peren. rye	12.5	11.4	9.7	9.2

Botha *et al.*, 2008a ; Van der Colf *et al.*, 2009

Table 7. The mean seasonal crude protein (CP) content (%) of kikuyu over-sown with ryegrass or clover over two years.

Study 1	**Winter**	**Spring**	**Summer**	**Autumn**
Kik/west. rye	na	21	20	21
Kik/clover 1st year growth	na	28	27	26
Kik/clover 2nd year growth	30	26	20	18
Study 2	Winter	Spring	Summer	Autumn
Kik/west. rye	31	27	19	22
Kik/ital. rye	30	26	20	22
Kik/peren. rye	27	23	19	21

Botha *et al.*, 2008a ; Van der Colf *et al.*, 2009

Table 8. The mean seasonal neutral detergent fibre (NDF) content (%) of kikuyu kikuyu over-sown with ryegrass or clover over two years.

Study 1	**Winter**	**Spring**	**Summer**	**Autumn**
Kik/west rye	na	48.1	62.7	67.7
Kik/clover 1st year growth	na	36.4	39.8	45.9
Kik/clover 2nd year growth	36.5	40.8	54.2	64.4
Study 2	Winter	Spring	Summer	Autumn
Kik/west. rye	38	42.4	60.8	59.4
Kik/ital. rye	38.6	41.2	54.6	57.9
Kik/peren. rye	39.4	45.3	56.7	58.1

Botha *et al.*, 2008a ; Van der Colf *et al.*, 2009

Table 9. The mean seasonal grazing capacity (cows ha^{-1} $season^{-1}$) of kikuyu over-sown with ryegrass or clover over two years.

Study 1	**Winter**	**Spring**	**Summer**	**Autumn**
Kik/west rye	na	6.7	7.8	9.5
Kik/clover 1st year growth	na	6.7	7.0	5.2
Kik/clover 2nd year growth	3.2	4.3	5.9	6.6
Study 2	Winter	Spring	Summer	Autumn
Kik/west. rye	3.9	5.5	8.2	4.3
Kik/ital. rye	4.1	6.9	6.6	3.9
Kik/peren. rye	3.4	7.0	7.9	4.5

Botha *et al.*, 2008a ; Van der Colf *et al.*, 2009

Table 10. The mean milk production per cow (kg milk cow^{-1} day^{-1}), 4% fat-corrected milk per cow (kg FCM cow^{-1} day^{-1}), butter fat percentage and protein percentage of kikuyu over-sown with ryegrass or clover over two years.

Study 1	**Kg milk cow²**	**Kg FCM cow²**	**Fat %**	**Protein**
Kik/west rye	15.9	17	4.5	3.5
Kik/clover 1st year growth	16.6	17.8	4.5	3.5
Kik/clover 2nd year growth	17.0	17.5	4.2	3.6
Study 2				
Kik/west. rye	16.7	18.5	4.85	3.68
Kik/ital. rye	16.8	18.5	4.72	3.70
Kik/peren. rye	16.2	17.3	4.52	3.59

Botha *et al.*, 2008a ; Van der Colf *et al.*, 2009

Table 11. The total annual milk production (kg milk ha^{-1}), 4% fat-corrected milk (kg FCM ha^{-1}), milk solids (kg milk solids ha^{-1}) and average grazing capacity (cows ha^{-1} season^{-1}) of kikuyu over-sown with ryegrass or clover over two years.

Study 1	**Kg milk ha**	**Kg FCM ha**	**Kg milk solids**	**Cows ha**
Kik/west rye	30489	32627	2434	7.94
Kik/clover 1st year growth	30277	32932	2452	5.53
Kik/clover 2nd year growth	23455	24103	1816	5.57
Study 2				
Kik/west. rye	28397	32055	2412	5.99
Kik/ital. rye	29260	32322	2437	5.87
Kik/peren. rye	31837	34177	2548	5.86

Botha *et al.*, 2008a ; Van der Colf *et al.*, 2009

16. The effect of over-sowing kikuyu with Italian, Westerwolds or perennial ryegrass on pasture yield and milk production

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Introduction

Kikuyu (*Pennisetum clandestinum*) is a C_4 pasture species that is well adapted to the main milk-producing areas of the Western Cape Province of South Africa. Kikuyu is highly productive during summer and autumn, but winter and spring dry matter (DM) production is low. Forage quality of kikuyu pasture is low and consequently milk production per cow compared to temperate grass (C_3) species is low (Marais, 2001). The strategic incorporation of temperate grasses like Westerwolds ryegrass (*Lolium multiflorum* var. *westerwoldicum*), Italian ryegrass (*L. Multiflorum* var. *italicum*) and perennial ryegrass (*L. perenne*) into kikuyu pasture, can increase the seasonal DM production and quality of the pasture (Botha *et al.*, 2008a, 2008b). Dairy farmers have to make decisions on the species (annual or perennial) and variety (Italian or Westerwolds) of ryegrass, as well as the system, to over-sow these ryegrasses into kikuyu. These decisions have a major impact on the profitability of dairy farming. At present, no applicable scientific data, comparing different systems with annual or perennial ryegrass grazed by dairy cows is available to assist farmers in decision-making. Farmers requested an in-depth evaluation of the over-sowing systems using annual and perennial ryegrass as the correct pasture system. The aim of this study was to quantify the dry matter yield, growth rate, grazing capacity and milk production potential of kikuyu over-sown with Westerwolds ryegrass (WR), Italian ryegrass (IR) or perennial ryegrass (PR).

Materials and Methods

Project layout and treatments

The study was carried out over two years on the Outeniqua Research Farm near George in the Western Cape Province of South Africa. Nine hectares of an Estcourt soil type (Soil Classification Workgroup, 1991) under irrigated kikuyu pasture was divided into eight blocks. Each block was divided into three experimental paddocks. Each of the three pasture treatments was allocated randomly to an experimental paddock within a block, and each paddock divided into two grazing strips.

Jersey cows strip-grazed each strip for two days, and each paddock for four days. Cows were on the trial area for a total of 32 days, but while one block was being grazed, the other seven blocks were being rested, resulting in a 28-day grazing cycle.

Irrigation was scheduled by means of tensiometers – irrigation commenced at a tensiometer reading of -25 Kpa and terminated at a reading of -10 Kpa (Botha, 2002). Westerwolds ryegrass was over-sown into kikuyu at 25 kg ha^{-1} during March, using a mulcher (1.6 m Nobili with 24 blades) – Italian ryegrass was planted into mulched kikuyu using an Aitchison seeder at 25 kg ha^{-1} during the same time. Perennial ryegrass was planted into mulched kikuyu using an Aitchison seeder during April, at 20 kg ha^{-1}. Fertiliser was applied to raise the soil phosphorus level to 35 mg kg^{-1}, potash level to 80 mg kg^{-1} and the pH (KCl) to 5.5. The treatments were top-dressed monthly with nitrogen at 55 kg N ha^{-1}. The number of animals per paddock was adjusted daily using a put-and-take system based on DM availability.

Table 1 shows the treatments, cultivars, seeding densities, abbreviations and over-sowing methods used in the trial. Winter is defined as the months of June, July and August; spring as September, October and November; summer as December, January and February; and autumn as March, April and May.

Pasture measurements

Dry matter production, growth rate, botanical composition and forage quality of all pasture treatments were determined. Dry matter production was estimated using the difference between pre- and post-grazing mass, estimated with the Ellinbank rising plate meter (RPM) (Stockdale, 1984; Fulkerson, 1997). The RPM was calibrated by developing a linear regression that relates the height of the pasture measured by the RPM to herbage DM mass. Calibration of the RPM was undertaken at 10-day intervals – before and after grazing at a height of 30 mm. During each calibration, a total of 18 samples of 0,098 m^2 were cut per treatment – six samples each at a low, medium and high pasture height. Plant material was dried for 72 hours at 60ºC and then weighed to determine the DM yield per cutting. The calibration equation $y = mx + b$ was used for predicting pasture mass, where y = yield (kg DM ha^{-1}), m = factor, x = RPM height and b=constant. A cumulative regression equation was used throughout the study to estimate DM production of pastures. Dry matter production was determined by taking 100 discmeter readings per grazing strip before grazing.

For methods regarding the determination of botanical composition, refer to the article 'Methods to determine botanical composition of cultivated pastures' by Vermeulen *et al.* (2008).

Animal measurements

Forty-five jersey cows were blocked – using calving date, 4% fat-corrected, 305-day milk production for the previous lactation, and lactation number. Cows within blocks were allocated randomly to treatments, with 15 trial cows per treatment. Cows were on the trial for the duration of a complete lactation (305 days), with a new group of cows allocated during Year 2 of the trial. Milk production was measured on the Italian and Westerwolds treatments from June to March and on the perennial treatment from July to April. Cows were weighed and condition scored at calving, and monthly thereafter, after the morning milking. Cows were milked twice daily at 07:30 and 14:00 with a 20 point swing-over milk machine (Dairymaster). The automated machine allowed milk yield to be measured on a daily basis. Milk samples were taken on a monthly basis to determine milk composition (fat, protein, lactose and MUN). The milk samples were analysed with a MilkoScan FT 6 000 analyser according to the International IDF standard 141B (IDF 1996). Cows received 2 kg of concentrate during each milking (4 kg day^{-1}), in addition to the 9 kg pasture day^{-1}.

Results and discussion

Monthly growth rate (kg DM ha^{-1} day^{-1})

The average monthly growth rates (kg DM ha^{-1} day^{-1}) is given in Table 2 (Year 1) and Table 3 (Year 2). During both years the lowest ($P<0.05$) growth rates occurred during the winter months of June and July. The highest ($P<0.05$) overall growth rate during Year 1 was achieved by the WR treatment during February, with the PR treatment during February and the WR treatment during January reaching similar ($P>0.05$) growth rates. During Year 2, the highest ($P<0.05$) overall growth rate occurred during October for PR, with the growth rates of WR during December and January and PR during November and December being similar ($P>0.05$). During both Year 1 and 2, WR had a significantly lower ($P<0.05$) growth rate than IR during November, as well as during October of Year 2. The IR treatment had lower growth rates ($P<0.05$) than the WR and PR treatments during January and February of Year 1 and December and January of Year 2. There were no differences ($P>0.05$) in growth rates between treatments within the months June, July, August, September, December and March during Year 1. During Year 2 the growth rates between treatments was similar ($P>0.05$) during July and August. Growth rates varied over and within months for all investigated species.

Botanical composition (%)

The botanical composition for the different treatments during Year 2 is given in Table 6. The ryegrass component remained high in the PR treatment from spring to autumn relative to the IR and WR treatments. The kikuyu component increased from spring to autumn in the WR treatment and from summer to autumn in the IR treatment. The WR treatment appears to favour the growth of the kikuyu component, especially during summer, whereas the PR treatment seems to favour the growth of the ryegrass component.

Forage Quality (% CP, ME, NDF, Ca:P)

The seasonal crude protein percentage (%CP) of kikuyu over-sown with Italian, Westerwolds or perennial ryegrass is given in Table 7. CP content for all treatments decreased from winter to summer, falling below the recommended level of 20% during summer for all treatments. During autumn the CP levels increased again above the recommended level of 20% for all treatments.

The seasonal neutral detergent fibre (%NDF) of all treatments during Year 1 is given in Table 8. The NDF content of all treatments increased from winter to summer, but decreased slightly during autumn.

The seasonal metabolisable energy (ME) content (MJ kg^{-1} DM) for Year 1 is given in Table 9. The ME content of all pasture treatments decreased from winter to autumn. The ME content of WR and PR during summer and autumn as well as IR during autumn fell below 10 MJ kg^{-1}. Such low ME values could limit milk production. The forage quality of all treatments tended to decline from winter to summer in terms of CP and ME. This could possibly be attributed to the increase in the kikuyu component from winter to summer and the very high growth rates of kikuyu during summer. The Ca:P ratio was unfavourable throughout the trial period ranging from 1,08 to 0,87:1.

Forage quality for all three treatments decreased from winter to summer.

Monthly mean grazing capacity (cows ha^{-1})

The mean monthly grazing capacities are presented in Table 11 (Year 1) and Table 12 (Year 2). The grazing capacities followed a similar trend to the growth rates, with the lowest grazing capacities occurring during the winter months of June and July in both years. The highest (P<0.05) grazing capacity during Year 1 occurred during February for WR, with similar (P>0.05) values obtained from WR in January and PR in February. During Year 2, WR had the highest (P<0.05) grazing capacities during both December and January, with similar (P>0.05) values reached by PR during October, December and January. WR had significantly lower (P<0.05) grazing capacities than PR and IR during November of Year 1, and during October and November in Year 2. PR and WR had higher (P<0.05) grazing capacities than IR during January and February of Year 1 and December and January during Year 2. The WR treatment had a higher (P<0.05) grazing capacity than both IR and PR during March of Year 2. Grazing capacities were similar (P>0.05) for all treatments during June, July, September and March of Year 1 and during June and August of Year 2.

Milk production

The milk production (kg milk ha^{-1}), fat-corrected milk production (kg FCM ha^{-1}) and milk solids (kg MS ha^{-1}) per hectare are given in Table 14. The PR treatment produced more milk ha^{-1} than both IR and WR during Year 1, with no differences (P>0.05) in the kg FMC ha^{-1} or kg MS ha^{-1} between treatments. During Year 2, PR produced more (P<0.05) milk, FCM and MS ha^{-1} than WR and IR.

Average 305-day milk production per cow (kg milk cow^{-1}), 305-day 4% fat-corrected milk production per cow (kg FCM cow^{-1}), butter fat percentage and protein percentage of kikuyu over-sown with Italian, Westerwolds and perennial ryegrass, is given in Table 13. The 305-day milk production and FCM production per cow was similar (P>0.05) for all treatments in Year 1. The IR treatment had the highest (P<0.05) protein percentage in Year 1, but there were no significant differences in milk composition during Year 2. The PR treatment had a lower (P<0.05) production per cow than IR and WR during Year 2. Although PR gave lower production values per cow in Year 2, it gave higher production values per hectare during the same period, due to the higher average grazing capacity during the ten months when milk production was measured.

Conclusion

The growth rate of different species varied over months. The low growth rate of the Westerwolds ryegrass treatment (WR) during November resulted in an increase in the kikuyu component during spring, summer and autumn. The opposite occurred in the Italian (IR) and perennial ryegrass (PR) treatments, where the growth rate during November was high, resulting in a lower kikuyu component during summer. The PR treatment showed higher growth rates during the winter and spring of Year 2, due to the carry-over effect of plants from Year 1 that survived into Year 2. All treatments showed similar (P>0.05) levels of annual dry matter production (kg DM ha^{-1}) during Year 1, but PR had a higher (P<0.05) annual dry matter production rate than both IR and WR during Year 2. Forage quality tended to decline for all pasture treatments from winter to summer as the kikuyu component present in pasture increased. PR had higher milk production values per hectare than WR and IR during Year 1 and 2. Although PR did not produce significantly (P>0.05) more milk than WR and IR per cow during Year 1 or 2, it had a higher (P<0.05) grazing capacity over the ten month lactation period.

MESSAGE TO THE FARMER

Kikuyu over-sown with perennial ryegrass obtained the highest pasture and milk production per hectare.

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Table 1. Treatments, cultivars, seeding densities, abbreviations and over-sowing methods used in the trial.

Treatment	Scientific Name	Cultivars	Seeding Density	Abbrev.	Over-sowing method
Perennial ryegrass	*Lolium perenne*	Bronsyn	20 kg ha^{-1}	PR	1. Graze to 50 mm 2. Mulch 3. Seeder 4. Land roller
Italian ryegrass	*Lolium multiflorum* var. *italicum*	Jeanne	25 kg ha^{-1}	IR	• Graze to 50 mm • Mulch • Seeder • Land roller
Westerworlds ryegrass	*Lolium multiflorum* var. *westerworldicum*	Jivet	25 kg ha^{-1}	WR	1. Graze to 50mm 2. Broadcast seed 3. Mulcher 4. Land roller

Table 2. The mean monthly growth rate (kg DM ha^{-1} day^{-1}) of kikuyu over-sown with Italian (IR), westerwolds (WR) or perennial ryegrass (PR) for Year 1.

Year 1	IR	WR	PR
June	31^{pqr}	30^{pqr}	0
July	31^{pqr}	27^{qrs}	18^{s}
August	38^{op}	40^{opq}	45no
September	65^{jklm}	60^{lm}	55^{mn}
October	85^{cdef}	61^{klm}	65^{ijklm}
November	77^{efgh}	57^{m}	71^{ghijkl}
December	79^{efg}	76^{efghi}	91^{bcd}
January	70^{ghijkl}	95^{abc}	86^{bcde}
February	81^{defg}	106^{a}	98^{ab}
March	66^{hijklm}	73^{ghijk}	74^{fghij}
April	0	0	58^{m}
May	26^{rs}	28^{qrs}	0
LSD (0.05)		11.73	

Means with no same superscript, differ significantly (P<0.05).
LSD(0.05) compares over month and treatment.

Table 3. The mean monthly growth rate (kg DM ha^{-1} day^{-1}) of kikuyu over-sown with Italian (IR), westerwolds (WR) or perennial (PR) ryegrass for Year 2.

Year 2	IR	WR	PR
June	29^{l}	33^{l}	20^{m}
July	36^{kl}	34^{l}	33^{l}
August	43^{jk}	44^{ij}	50^{ghij}
September	54^{efgh}	47^{hij}	60^{cdef}
October	75^{ab}	54^{efgh}	77^{a}
November	63^{cd}	55^{efgh}	72^{ab}
December	57^{defg}	72^{ab}	72^{ab}
January	51^{ghij}	72^{ab}	63^{cd}
February	48^{hij}	61^{cde}	52^{fghi}
March	60^{cdef}	68^{bc}	59^{def}
April	0	0	34^{l}
LSD (0.05)		8.09	

Means with no same superscript, differ significantly ($P<0.05$).
LSD(0.05) compares over month and treatment.

Table 4. The total seasonal dry matter production (kg DM ha^{-1} $season^{-1}$) of kikuyu over-sown with Westerwolds (WR), Italian (IR) or perennial ryegrass (PR) for Year 1.

Year 1	IR	WR	PR
Winter	3512^{d}	3422^{d}	2084^{e}
Spring	6073^{b}	4774^{c}	5117^{c}
Summer	6161^{b}	7412^{a}	7380^{a}
Autumn	3022^{d}	3272^{d}	3502^{d}
LSD(0.05)=780			
Year 2	**IR**	**WR**	**PR**
Winter	2864^{de}	2958^{de}	3273^{d}
Spring	4980^{ab}	4149^{c}	5610^{a}
Summer	4385^{bc}	5516^{a}	5044^{ab}
Autumn	1428^{g}	1621^{fg}	2275^{ef}
LSD(0.05)=687			

Means with no same superscript, differ significantly ($P<0.05$).
LSD(0.05) compares over season and treatment within a year.

Table 5. The total annual dry matter production (kg DM ha^{-1} $year^{-1}$) of kikuyu over-sown with Italian (IR), westerwolds (WR) or perennial (PR) ryegrass.

Year	IR	WR	PR	LSD
1	18767[a]	18880[a]	18083[a]	819
2	13479[b]	14040[b]	16202[a]	713

Means with no same superscript, differ significantly (P<0.05).
LSD (0.05) compares over treatments within a year.

Table 6. Seasonal botanical composition (%DM) of kikuyu over-sown with Italian (IR), Westerwolds (WR) or perennial (PR) ryegrass for Year 2.

	IR	WR	PR
Winter			
Kikuyu	11	18	3
Ryegrass	80	73	77
Other	9	9	19
Spring			
Kikuyu	4	11	2
Ryegrass	93	67	78
Other	3	22	21
Summer			
Kikuyu	45	64	26
Ryegrass	40	12	59
Other	15	25	15
Autumn			
Kikuyu	95	87	51
Ryegrass	2	1	33
Other	3	12	16

Table 7. Crude protein content (% DM) of kikuyu over-sown with Italian (IR), Westerwolds (WR) or perennial (PR) ryegrass for Year 1.

	IR	WR	PR
Winter	30.45	32.25	25.80
Spring	22.73	22.50	22.00
Summer	19.67	19.13	17.87
Autumn	22.30	23.00	23.05

Table 8. Neutral detergent fibre (% DM) of kikuyu over-sown with Italian (IR), Westerwolds (WR) or perennial (PR) ryegrass for Year 1.

	IR	WR	PR
Winter	37.9	37.4	40.8
Spring	45.9	48.9	48.7
Summer	56.8	62.1	59.0
Autumn	57.9	58.6	57.4

Table 9. Metabolisable energy (MJ kg^{-1} DM) of kikuyu over-sown with Italian (IR), Westerwolds (WR) or perennial (PR) ryegrass for Year 1.

	IR	WR	PR
Winter	12.0	12.0	12.0
Spring	10.9	10.6	11.1
Summer	10.0	9.4	9.2
Autumn	9.9	9.7	9.2

Table 10. Calcium: Phosphorous ratio of kikuyu over-sown with Italian (IR), Westerwolds (WR) or perennial (PR) ryegrass.

	IR	WR	PR
Winter	0.87:1	0.88:1	1.01:1
Spring	1.03:1	1.06:1	1.03:1
Summer	0.91:1	0.95:1	0.96:1
Autumn	0.97:1	0.92:1	1.08:1

Table 11. Monthly grazing capacity (cows ha^{-1} $month^{-1}$) of the kikuyu over-sown with Italian (IR), Westerwolds (WR) or perennial (PR) ryegrass for Year 1.

Year 1	IR	WR	PR
June	6.10^{ghijk}	5.71^{hijkl}	0
July	3.10^{op}	2.65^{p}	3.16^{op}
August	3.88^{no}	4.07^{mno}	4.50^{lmn}
September	6.29^{ghij}	5.64^{hijkl}	5.42^{ijkl}
October	8.17^{cd}	6.42^{fghij}	6.75^{efgh}
November	7.48^{def}	5.53^{ijkl}	7.05^{defg}
December	7.77^{cde}	7.49^{def}	8.93^{bc}
January	7.02^{defg}	9.45^{ab}	8.71^{bc}
February	7.90^{cde}	10.29^{a}	9.51^{ab}
March	6.54^{fghi}	7.78^{defg}	7.39^{def}
April	0	0	6.04^{ghijk}
May	5.06^{klmn}	5.21^{jklm}	0
LSD(0.05)		1.22	

Means with no same superscript, differ significantly (P<0.05).
LSD (0.05) compares over treatments within a year.

Table 12. Monthly grazing capacity (cows ha^{-1} month^{-1}) of the kikuyu over-sown with Italian (IR), Westerwolds (WR) or perennial (PR) ryegrass for Year 2.

Year 2	IR	WR	PR
June	3.22^{po}	3.20^{po}	3.96^{lmno}
July	3.79^{mno}	3.46^{npo}	2.88^{p}
August	4.37^{klm}	4.40^{jklm}	4.92^{hijk}
September	5.21^{ghij}	4.64^{ijkl}	5.86^{efg}
October	7.41^{ab}	5.28^{ghi}	7.62^{a}
November	6.55^{cde}	5.64^{fgh}	7.46^{ab}
December	5.99^{defg}	7.65^{a}	7.52^{ab}
January	5.66^{fgh}	7.83^{a}	6.74^{bcd}
February	5.36^{ghi}	6.46^{cdef}	5.89^{efg}
March	6.36^{cdef}	7.18^{abc}	6.32^{def}
April	0	0	4.22^{klmn}
LSD(0.05)		0.83	

Means with no common superscript, differ significantly (P<0.05).
LSD (0.05) compares over treatments and months.

Table 13. Average 305 day milk production per cow (kg milk cow^{-1}), 305 day 4% fat-corrected milk production per cow (kg FCM cow^{-1}), butter fat percentage and protein percentage of kikuyu over-sown with Italian (IR), Westerwolds (WR) or perennial (PR)ryegrass.

	Kg milk cow^{-1}	Kg FCM cow^{-1}	Fat %	Protein %
Year 1				
IR	4829^{a}	5504^{a}	4.94^{a}	3.84^{a}
WR	5025^{a}	5728^{a}	4.94^{a}	3.74^{ab}
PR	4944^{a}	5396^{a}	4.63^{a}	3.64^{b}
LSD(0.05)	352	403	0.38	0.17
Year 2				
IR	5410^{a}	5773^{a}	4.50^{a}	3.55^{a}
WR	5131^{ab}	5696^{a}	4.75^{a}	3.61^{a}
PR	4916^{b}	5186^{b}	4.40^{a}	3.53^{a}
LSD(0.05)	380	346	0.39	0.15

Means with no common superscript, differ significantly (P<0.05).
LSD (0.05) compares over treatments and months.

Table 14. Total annual milk production (kg milk/ha), 4 % fat-corrected milk (kg FCM/ha), milk solids (kg milk solids/ha) and average grazing capacity (cows/ha) of kikuyu over-sown with Italian (IR), Westerwolds (WR) or perennial (PR) ryegrass.

	Kg milk/ha	Kg FCM/ha	Kg milk solids/ha	Cows/ha
Year 1				
IR	30446^{b}	34556^{a}	2627^{a}	6.44^{b}
WR	29761^{b}	34057^{a}	2566^{a}	6.49^{b}
PR	32288^{a}	35268^{a}	2639^{a}	6.93^{a}
LSD(0.05)	1540	1699	128	0.27
Year 2				
IR	28073^{b}	30087^{b}	2246^{b}	5.34^{b}
WR	27032^{b}	30052^{b}	2258^{b}	5.52^{b}
PR	31385^{a}	33086^{a}	2457^{a}	5.96^{a}
LSD(0.05)	1253	1462	107	0.35

Means with no common superscript, differ significantly ($P<0.05$).
LSD (0.05) compares over treatments within years.

17. Factors affecting the persistence and production potential of kikuyu (*Pennisetum clandestinum*) over-sown with different ryegrass and clover species in the southern Cape of South Africa

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Introduction

Kikuyu (*Pennisetum clandestinum*) is a productive pasture species that is well adapted to the main milk-producing areas of the southern Cape region in South Africa. The main challenges experienced with kikuyu (a sub-tropical C_4 grass) are the seasonality of production and its relatively low nutrient quality (Marais, 2001). In this region kikuyu is highly productive during summer and autumn, but has a low production potential in winter and spring. Compared to temperate grass (C_3) species, the forage quality of kikuyu is low. Consequently, milk production per cow grazing on kikuyu pastures is lower than for cows grazing on temperate grass pastures (Marais, 2001). Cows grazing kikuyu-based pasture must therefore be supplemented with concentrate feeds to increase milk yields. However, nutrient supplementation is costly and also requires a high level of management to implement successfully.

A major problem experienced in the mild climate of the southern Cape was the invasion of high-cost, irrigated ryegrass-clover pastures by kikuyu. Research during the 1980s, focusing on the prevention of kikuyu invading irrigated perennial ryegrass-clover pasture, was unsuccessful. The vigorous growth and ability of kikuyu to propagate through seed and rhizomes, made it impossible to find a cost-effective way to keep kikuyu out of the irrigated pastures. During the 1990s, research focused on the possibility of using kikuyu as a summer and autumn pasture, and as a pasture-base during winter and spring, by over-sowing it with high quality ryegrass and/or clover species.

The problem was that kikuyu is a very strong competitor for soil nutrients, water and sunlight – the most important components needed for growth by plants. A lack of understanding of the ability of kikuyu to compete for these components was the main reason why the initial attempts to over-sow kikuyu with clovers and temperate grass species were unsuccessful (costly, unpredictable and not sustainable). Ongoing research has shown that kikuyu growth and its ability to compete, is suppressed if it is managed in such a way that it is not allowed to over-shadow companion plants in the pasture or to accumulate growth reserves in its stems.

Kikuyu uses some of the growth reserves that accumulate during autumn to over-winter – it also uses most (70–75%) of the root reserves that accumulate during autumn, for the development of new leaves and roots in the following spring. During late spring and summer, kikuyu needs a large quantity of sunlight on its growing points to form new leaves for growth. The above-ground growth of kikuyu consists of about 80% leaves during spring – at this time new stolons and rhizomes are formed. If water and nutrients are available, the plant will grow very aggressively and invade other crops in summer and autumn. During the summer and autumn, as the plant stores its reserves, more space for storage is required, thus stimulating rhizome and stolon development. Leaf to stem ratio therefore decreases from 60% in summer to 25% in late autumn (Whyte *et al.*, 1968; Jagger, 1999). Forage quality of kikuyu declines as leaf:stem ratio decreases.

Jagger (1999) and Weinmann (1940), however, suggested that it is possible to decrease the competitive dominance of kikuyu during spring, by preventing it from building up root reserves during autumn. These findings helped researchers at Outeniqua Research Farm to find ways to strategically decrease the aggressive growth of kikuyu during spring. Research focused on preventing kikuyu from storing reserves in autumn – through the removal of large amounts of stem material during autumn, prior to over-sowing the pasture with temperate grass species and clovers, and preventing sunlight from reaching the growing points of the plant during spring.

The basis of this research was to graze kikuyu as short as possible during early autumn and then using a mulcher to mulch all above-ground plant material – the kikuyu stems and leaves. This way a large amount of the kikuyu's reserve-carrying stem material is destroyed – the mulched material also creates an excellent growth medium for winter- and spring-growing grasses. The mulch layer together with grasses further prevent sunlight from reaching the growing points of the kikuyu plant during spring – thus limiting the forming of new leaves, rhizomes and stolons. With this management, maximum sunlight will only reach the growing points of kikuyu when the over-sown ryegrass completes its growth cycle (towards the end of spring). The sunlight then stimulates leaf growth and a new kikuyu growing season. The start of this season depends on the ryegrass species or variety selected to over-sow kikuyu. Perennial and Italian ryegrass, with their ability to grow during spring and summer, will overshadow kikuyu longer than the annual Westerwolds ryegrass varieties, which have a shorter growing season.

Research at Outeniqua Research Farm has shown that the strategic incorporation of different temperate C^3 grass species and clovers into kikuyu can increase the seasonal dry matter (DM) production and quality of kikuyu pasture. However, the persistence and production potential of these pasture species planted into kikuyu, and the response of kikuyu to the over-sowing practices, depend on the management of a number of important decision-making factors – these include soil fertility, soil moisture content, temperature, overshadowing, choice of species and varieties, grazing management and planting methods.

Soil

Optimum pasture production depends upon correct management of soil fertility. The persistence of ryegrass and legumes in a kikuyu pasture depends upon the physical aspects of the soil, soil fertility and the availability of water to the plant. Deeper, well-drained soils would normally be allocated to deep-rooted legume plants e.g. lucerne, whereas kikuyu, ryegrass and clover pastures are well-suited for shallow soils, provided adequate moisture is available.

Soil profile map

Before any choice can be made regarding the selection of pasture species, a map showing the different soil types, based on an evaluation of soil profiles, is required – soils with the same features can then be divided into different camps or management areas. This will enable allocation of different pasture species with specific physical soil requirements such as texture, depth, drainage etc., to different soil types. This concept of bringing the plant to the soil is introduced to ensure optimum plant production on different soil types.

Annual soil sampling

Annual soil sampling is required to obtain and monitor soil nutrient levels. Soil analysis will indicate whether or not additional nutrients are needed to raise soil nutrient status to the required levels, or simply to apply nutrients to ensure maintenance of current levels. Once the maintenance rates have been established, soil sampling should be undertaken every second year. The main advantage of soil analysis will be achieved by repeated testing over a number of years. A picture of trends in soil fertility status of the farm, on a per-camp basis, would then be recorded, which could be used to monitor progress in achieving or maintaining nutrient levels. This picture of trends is an extremely important tool for the management of soil fertility in each pasture on the farm.

The importance of correct sampling procedures cannot be over-emphasised. Miles (2003) stated that a poor soil sample is worse than none at all because the results can be misleading. The correct sampling depth for a pasture that requires seedbed preparation (e.g. cultivating the soil before planting lucerne) is 150 mm. For maintenance fertiliser or in no-till systems, similar to kikuyu or grass-clover over-sown with ryegrass using the planter or mulcher method, a 100 mm sample depth is recommended.

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[1] This machine is similar to a rotavator with the difference that it pulverises all plant material down to the soil surface without disturbing the soil (type: 1.6 m Nobili with 32 blades).

Important notes

- sample the same time every year on perennial pasture,
- the sample must represent one soil type,
- avoid unusual areas,
- take separate samples on weak areas,
- take 20–40 cores in zigzag pattern – mix thoroughly – take standard sample,
- record results over time.

Soil fertility

Kikuyu pastures are fertilised to raise soil fertility to the levels required for optimum growth and to maintain those fertility levels by replacing nutrients lost through grazing and leaching. Kikuyu is sensitive for deficiency in carbon (C), nitrogen (N), magnesium (Mg), phosphorus (P), potassium (K), sulphur (S), iron (Fe), copper (Cu) and manganese (Mn) and less sensitive for calcium (Ca), boron (B), molybdenum (Mo) and zinc (Zn).

Recommended soil fertility levels for a mixed kikuyu-ryegrass pasture are:

Organic carbon (C)	>2%
pH (KCl)	5.0-5.5
P (citric acid)	> 30 mg/kg,
K	80-100 mg/kg,
Ca	>400
Mg	>70 (Ca:Mg = 4:1)
S	>11 mg/kg,
Cu	>1.0 mg/kg,
Zn	>1.0 mg/kg
Mn	0-15 mg/kg

A pH above 5.0 (KCl) is important for optimum production and it is recommended that lime is top-dressed annually at an application rate of between 500 and 1000 kg/ha. Annual soil samples at a depth of 10 cm during February and corrections during March are necessary to prevent nutrient shortages during winter and spring. Kikuyu-ryegrass pastures should be fertilised with 20 kg of P/ha during September, regardless of the P status of the soil (Hardy, 2002).

Carbon (C) content (%)

The organic carbon content of the soil is an indication of the soil organic matter content. Soil organic matter is essential for humus development in the soil – an important plant nutrient which improves soil productivity. Soils without organic matter and humus could be considered dead – no soil organisms will survive, resulting in soil not being suitable for plant growth. Soil carbon content higher than 2% is needed for optimum DM production and persistence of different ryegrass species over-sown into kikuyu.

Managing high fertilisation costs

The following factors could help to manage the high fertilisation costs of kikuyu-ryegrass pastures:

- Take annual soil samples and keep a record of results.
- The strategic applications of nitrogen (N) during the active growth period of grasses are important. High levels of N applied at the wrong time in an attempt to create out-of-season pasture are uneconomical.
- Fertilise N at recommended amounts according to pasture species and expected yield.
- The amount of N should be applied in conjunction with pH, macro- and micro element status of soil. Under optimum soil fertility conditions, 50 kg N/ha/month is recommended for optimum DM production.
- Urea as an N fertiliser is ineffective if applied on wet grass pastures in windy conditions.
- Within 10–14 days after nitrogen is applied onto pasture, the N level in plants is high and the dry matter content of the plant material is low. From that point onwards plants will use the nitrogen for growth and the DM content and grazing capacity of the pasture will increase. Therefore, the timing of grazing on a newly fertilised pasture is a critical management decision. The influence of this on milk per hectare will positively influence fertilisation costs.

- Irrigation scheduling is essential. Maintaining the soil moisture content is a critical management requirement for optimum plant production. Without irrigation scheduling, valuable soil nutrients like N, K and Mn will be leached from the soil and shortages could occur, resulting in lower DM production.
- Management should focus on the protection and improvement of soil organic material.
- Soil mineral imbalances should be monitored - they will negatively influence plant growth and reduce the positive influence of nitrogen on growth:
    1. High K levels in the soil will decrease uptake of sodium (Na), Mg and Ca by the plant.
    2. Too much S influences the availability of Cu and molybdenum (Mo).
    3. A soil S content of 7–8 mg/kg is necessary to maximise the response of pastures to high levels of N fertiliser.

Soil moisture content

Low soil moisture levels, combined with high temperatures (>30°C), will reduce ryegrass growth. Maintaining moisture content of soils is a critical management requirement for optimum production and botanical composition of grass-clover pastures. Clover growth is reduced as soils dry out and high temperatures prevail. Soil moisture management depends on rooting depth of the pasture species, the growth rate of the plants, soil type and the availability of water. A useful tool available to the farmer for scheduling irrigation is the tensiometer. This instrument, if placed at the correct depth and correctly maintained, will provide a good indication of moisture availability to the plants. For example, on the Estcourt soil types of the George area, a tensiometer depth of 150 mm and a maximum reading of -25 kPa are recommended for kikuyu-ryegrass pastures. The shallow rooted ryegrasses need an irrigation system that can provide 10-15 mm of water on a frequent basis (2–3 times a week).

Temperature

Temperature has a significant effect on the growth of kikuyu and ryegrass pasture. The DM production of kikuyu is the highest at a maximum air temperature of 21°C and minimum air temperature of 9°C (Andrewes & Jagger, 1999). The active growth period of kikuyu is during summer and autumn. The production rate of kikuyu is also higher than that of ryegrass at high temperatures with high moisture content. The DM production of kikuyu will decrease by 11 kg/ha/day for each 1°C that the soil temperature falls below 18°C at a depth of 50 mm.

Ryegrass has an optimum air temperature of 18°C for growth. This is one reason why ryegrass can successfully be planted into kikuyu pastures during autumn and be dominant during winter and spring. The kikuyu component will increase as the soil temperature rises above 18°C and kikuyu will be dominant during summer and autumn. Ryegrass will react to N fertilisation at temperatures as low as 5°C. This ability of ryegrass to react to nitrogen at low temperatures will stimulate higher grass production during winter.

Overshadowing

Light is needed to trigger the growing points of parent clover stolons and ryegrass tillers to produce new daughter stolons and tillers. Shading reduces the production of daughter tillers and stolons – this means fewer growing points, resulting in lower clover and ryegrass production. Under-grazing is the main cause for the overshadowing of pasture. To prevent under-grazing, it is important to implement the correct management practices as discussed under the heading Grazing Management.

Choice of pasture species and varieties

The selection of pasture species and varieties is based on the physical and morphological characteristics of the soil, soil fertility (availability of macro- and micro- elements and organic material content), availability of water, climate (atmospheric pressure, rainfall, temperature, wind, humidity) and fodder programme requirements. Species best adapted to these conditions in a specific area will be selected by farmers for over-sowing into kikuyu pasture. The aim of over-sowing is to increase and maintain the seasonal and monthly DM production, production rate (kg DM/ha/day) and animal production. It is important that the varieties selected must have the ability to produce adequate, high-quality, palatable fodder during the periods when the production and/or quality of kikuyu cannot provide in the needs of high-producing dairy cattle.

Furthermore, the species selected for over-sowing must have the ability to compete within a strategic management system with the vigorous growth of kikuyu. According to the fodder-flow programme, the aim could be to over-shadow kikuyu during spring and/or early summer.

Perennial ryegrass (*Lolium perenne*), annual ryegrass (*L. multiflorum*) varieties italicum and westerworldicum, white clover (*Trifolium repens*) and red clovers (*T. pratense*) species have been evaluated at Outeniqua Research Farm.

Perennial ryegrass

The persistence of perennial ryegrass depends on environmental and management factors. Although it persists in cooler countries for up to ten years, it seldom persists for longer than four years in South Africa. Research at Outeniqua has shown that the total DM production of perennial ryegrass decreases annually. For this reason perennial ryegrass is over-sown annually during April/May into kikuyu. This gives perennial ryegrasses the ability to overshadow kikuyu during winter and spring and thus competing with kikuyu during summer and autumn.

Annual ryegrass

Annual ryegrass consists of *L. multiflorum* var. *westerwoldicum* and *L. multiflorum* var. *italicum*, commonly named Westerwolds and Italian ryegrass respectively. Although Westerwolds and Italian ryegrass are closely related, there are some very important differences.

Italian ryegrass

Italian ryegrass has a vernalisation gene that delays flowering. This vernalisation gene is switched off by a combination of low (winter) temperatures and/or short days followed by increasing day-length (spring), resulting in the initiation of flowering (Nash & Ammann, 2006). Italian ryegrass also has the ability to produce new daughter tillers after flowering (Fairy,1997; Wallacy & Yan, 1998; Nash & Ammann, 2006). The degree to which the variety is able to produce daughter tillers will influence the persistence of the variety in spring and summer (Nash & Ammann 2006). Italian ryegrass is therefore not a true annual. Persistence will depend on the cold of winter, if planted before the winter, and day length if planted late winter or early spring. Strategically, this variety can also be used to seasonally compete and overshadow kikuyu during the growth period of kikuyu.

Westerwolds ryegrass

Westerwolds ryegrass is a true annual. When planted in autumn Westerwolds ryegrass tends to flower earlier than Italian ryegrasses – they also do not produce as many daughter tillers after flowering and consequently, the plants die and the pasture does not persist after flowering (Nash & Ammann 2006). Therefore, as a true annual, the fact that it has a strong seedling which quickly become a vigorous fast-growing grass plant with the only aim to go into seed within 5-6 months, Westerwolds ryegrass can be planted during late summer (February) or early autumn (March) into kikuyu for winter (June, July and August) pasture. Because it can be planted during autumn, it also plays a vital role in the strategic over-sowing of kikuyu. It is the only annual ryegrass that fits into the strategy where the removal of the stem material of kikuyu is part of the plan to deplete kikuyu of its growth reserves. As this can be done while the kikuyu is still growing, Westerwolds ryegrass has the ability to establish fast, overshadowing kikuyu and preventing it from creating new leaves and supplementing its root reserves.

Westerwolds and Italian ryegrass cultivars are commonly recommended for their total herbage production. As Goodenough *et al.* (1987) argued, high levels of herbage production has some merit, but attention should rather be given to how these varieties match the fodder-flow requirements in a given enterprise. Westerwolds ryegrass cultivars have a greater yield performance than the Italian ryegrass cultivars during the colder winter months, but the Italian ryegrass cultivars generally out-yield the Westerwolds ryegrass cultivars during mid-spring. Goodenough *et al.* (1987) also found that spring-planted Westerwolds ryegrass cultivars flowered and died within five months of planting, thus limiting the productive life of the pasture. In comparison, spring-planted Italian ryegrass cultivars do not flower, tend to form daughter tillers, do not die during summer and, consequently, provide high quality pasture during the following autumn months.

Different ryegrass species are usually planted into kikuyu during autumn in an attempt to provide animals with adequate fodder of high quality during winter and spring months when the production of Kikuyu is low. The aim is to:

- increase the yield of the areas under kikuyu during periods when kikuyu is dormant,
- increase the quality of the kikuyu-based pasture
- and enhance the palatability of kikuyu-based pasture.

When different ryegrass species are planted into Kikuyu pastures, inter-species competition can be expected. The characteristics of different ryegrass species will determine their persistence during spring or whether they will eventually set seed and die off, resulting in kikuyu dominating the pasture.

Van der Colf *et al.* (2008) found that the greatest effects of inter-species competition occur during autumn, when ryegrass is over-sown into Kikuyu for winter fodder production – also during spring, when kikuyu starts to recover from winter dormancy. The rate at which the kikuyu-ryegrass pastures change from ryegrass dominance to kikuyu dominance during spring, varies between different ryegrass types. The Westerwolds ryegrass is usually the first to show a decrease in abundance and production during spring. Westerwolds ryegrass presents less competition to the emerging kikuyu, especially in terms of sunlight during spring – this allows kikuyu to establish well, with high dry matter production during summer.

In contrast, Italian ryegrass continues to dominate pastures well into spring, often displaying higher dry matter production rates during this period than Westerwolds ryegrass-kikuyu pastures. As a result, the summer production of kikuyu is impacted negatively by the overshadowing effect of the dense spring Italian ryegrass stand.

Perennial ryegrass is intermediate in terms of the competitive effect that it has on summer production of kikuyu. Although perennial ryegrass plants may still be found in kikuyu pastures, even at the end of summer, summer production of such pastures was found to be higher than the Italian ryegrass-kikuyu pastures. It is possible that the differences in growth form of the annual and perennial ryegrass types play a role.

Kikuyu could have a similar effect on the successful establishment of ryegrass during autumn. This may be attributed to the 'strength' of the kikuyu component during autumn when planting commences. The Westerwolds ryegrass-kikuyu pastures seemed to have a stronger and more vigorous kikuyu basis than both Italian and perennial ryegrass-kikuyu pastures. The end result was that emerging Westerwolds ryegrass seedlings had to compete with kikuyu for sunlight, water and nutrients to a greater degree than Italian or perennial ryegrass seedlings.

The understanding of how Italian, Westerwolds and perennial ryegrass interact with kikuyu, has a significant effect on the production potential, botanical composition and persistence of these pastures.

The DM production potential, milk production and economy of kikuyu over-sown with perennial, Westerwolds or Italian ryegrass is discussed in this publication (Van der Colf *et al.*, 2008).

Kikuyu over-sown with clover

Without a legume component, kikuyu pasture is dependent on the application of nitrogen, thus increasing the input cost. The inclusion of a legume component, could potentially reduce the N fertilisation requirements and increase the quality of the forage produced by the pasture. A study at Outeniqua Research Farm showed that the rotavator method was preferable in establishing perennial white and red clovers into kikuyu, rather than the mulcher method. The rotavator method produced a clover content of the kikuyu-clover pasture ranging from 15–60%, compared to the mulcher method that produced a clover content ranging from 5.2–20.7% (Botha, 2003).

Although it is not difficult to establish clovers into kikuyu, a number of factors render the over-sowing of clover into Kikuyu unpopular with farmers. The high cost of establishing clovers into kikuyu, using expensive implements in preparing a seedbed, maintaining high intensity of grazing, and strategic nitrogen applications are but a few.

Overshadowing is the main reason why clover is not persistent in a kikuyu-clover pasture. Where clover is shaded, the production of daughter stolons is reduced, due to the lack of sunlight, which is essential for the production of the stolons – the more stolons, the more growing points, and the more growing points, the more leaf production and growth (Curtis & O'Brien, 1994). Overshadowing because of under-grazing is the main reason why the 30–40% clover fraction needed in a kikuyu-clover pasture to have a positive effect on nitrogen fixation and the quality of the pasture, cannot be maintained.

The inability of farmers to manage kikuyu in such a way that it is always grazed short enough for clovers to persist, starts annually during spring. The growth rate of winter-growing ryegrass pastures increases during spring, usually resulting in the production of more fodder than can be effectively grazed by the dairy herd. A similar problem occurs during autumn when the growth rate of kikuyu is high but the palatability is low. Animals will then find it difficult to graze the pasture down to the recommended height of 5–10 cm. The result is under-grazed kikuyu, with insufficient sunlight penetrating the canopy which overshadows the clover component – this reduces the ability of clovers to produce stolons and therefore to persist in the kikuyu-clover pasture. The declining of the clover component reduces organic N availability to the pasture. Since only strategic nitrogen applications during winter are recommended to sustain clover in kikuyu-clover pasture, the outcome is a decrease in DM production and carrying capacity. Farmers are then forced to apply nitrogen on a regular basis to boost the growth rate of the ryegrass component of the pasture. The result is a diminishing clover component.

Grazing management

A good grazing management system is based on the optimum production (kg DM/ha) of adequate high-quality, palatable dry matter and the highest possible animal intake (kg DM/cow/day). A well-planned fodder-flow programme and utilisation management system of kikuyu-ryegrass is thus essential in a successful grazing management system. It requires that kikuyu is over-sown with ryegrass according to a specific plan, that grazing only takes place when adequate high-quality, palatable pasture is available, and that the intensity (how short) and frequency (grazing intervals) of utilisation is accurately executed. To obtain these goals, the pasture should be grazed at a point where the kikuyu and ryegrass are mature before they are grazed. Kikuyu and ryegrass should be grazed at the 4,5 and 3 leaf stages respectively. This could vary between 3 and 6 weeks, depending on factors like temperature, light intensity, day length and availability of water, which influence leaf appearance. If ryegrass pasture is allowed to get older, the third ryegrass leaf will die, resulting not only in pasture waste, but also in unpalatable roughage and in overshadowing of the growth points of the ryegrass. This will prevent the development of new daughter tillers. Not only will the life of the pasture be shortened, but the ryegrass component in a kikuyu-ryegrass pasture will also decline.

Correct grazing intervals and grazing intensity are the only management practices that will ensure optimum utilization of kikuyu-grass pasture. However, the intensity of grazing and grazing intervals should not be measured in time or in pasture height, but by the DM availability and the residual DM of a pasture (kg DM/ha). To achieve this goal, pasture allocation is one of the most important management factors, to prevent over- or under- grazing. The allocation of inadequate or excessive pasture will result in pasture waste or a loss in milk production.

On Outeniqua Research Farm, the quantity of available ryegrass from July to August is measured with the following regression equation: pasture available higher than 30 mm (kg DM/ha) = 76,5 x RPM (Rising Plate Meter) height -521. The pasture DM intake of Jersey cows weighing 400 kg and fed 6 kg supplement per day is estimated at 8 kg DM per day. If the pasture height before grazing is 20-25 units on the RPM, 999-1379 kg DM is available per hectare. Pasture allocation of 10 kg DM per cow per day will ensure that cows take in 8 kg DM. This means that 1000 kg or one ha will be allocated to 100 cows per day at a RPM height of 20. The aim is to graze pasture down to 50 mm or a RPM height of 10. Always evaluate the system and never graze pasture lower than a height of 10 on the RPM. Such a system will ensure proper pasture utilisation. It will also ensure that pasture rotation will vary with seasons.

The accuracy of regression for pasture measurement is affected by the botanical composition, grazing interval and grazing intensity, which differs between farms. Post-grazing height is the only measurement that can indicate whether pasture is being over- or under- utilised. Research done on the Outeniqua

Research farm showed that a post-grazing height of 50 mm, or 10 on the RPM, is an indicator of pasture that has been optimally utilised. Producers could follow this guideline to determine whether pasture has been grazed too short (an indicator that too little pasture was allocated to animals) or whether too much pasture remained after grazing (which indicates that too much pasture was allocated).

Pasture intake is reduced by the feeding of concentrates. In a study done at Outeniqua Research Farm, Jersey cows grazed mainly on ryegrass-clover, were fed 0, 2.4, 4.8, or 7.2 kg of concentrate per day over two lactations, and produced 12.8, 15.2, 15.8 and 17 kg of fat-corrected milk per day respectively. The feeding of each additional kg of concentrate resulted in production of 1.0, 0.71 and 0.58 kg fat-corrected milk (FCM). The poor response to concentrate feeding can be attributed to substitution of pasture by concentrates. The substitution rate (SR) can be calculated as follows: SR = 0.093 X kg of concentrate fed per cow/day. Feeding of high levels of concentrates will result in reduced pasture intake, higher feed cost and under-utilisation of pasture (Meeske, 2006).

Methods of planting different species into kikuyu

Research at Outeniqua Research Farm showed that different methods are required to plant different pasture species into kikuyu. Three methods were proven to be effective:

Perennial or Italian ryegrass pasture

Perennial and Italian ryegrass species are successfully planted into kikuyu using the mulcher-planter method. The kikuyu pasture is grazed to 50 mm, mulched to ground level and afterwards planted with an Aitcheson planter. The seedbed is then rolled once with a Cambridge land roller and irrigated. March/April is recommended for planting Italian and April/May for perennial ryegrass.

Westerwolds ryegrass

Although Westerwolds can also be planted with a planter, it can be established using a mulcher (1.6 m Nobili with 32 blades). This is cost-effective and the only really effective method of planting ryegrass pasture into kikuyu. The kikuyu is grazed down to 50 mm and the ryegrass seed broadcast over the remaining kikuyu pasture. The kikuyu pasture is then mulched to ground level without the blades touching the soil. The mixture of mulched plant material and seed are then rolled once with a Cambridge land roller and irrigated.

Clover or a mixture of ryegrass-clover

The only effective way to establish clover or perennial ryegrass-clover pasture into kikuyu is to cultivate the kikuyu pasture using a rotavator (1.55 m Celli with 36 blades). The kikuyu pasture is grazed to 50 mm, mulched to ground level and afterwards rotavated to a depth of 100 mm. The seedbed is then rolled once with a Cambridge land roller, the seed is broadcast by hand, rolled again and irrigated. It is recommended that clovers or mixtures of ryegrass-clover are planted during April/May when the soil temperature at a depth of 10 cm is 18 ^{0}C and the kikuyu is dormant. From a strategic point of view, it is a good option to plant clovers or mixtures of ryegrass-clover into kikuyu pasture that has been over-sown the previous two years during February or March with Westerwolds or Italian ryegrasses. The negative effect of mulching the kikuyu during the previous two autumns, regarding the storing of root reserves and overshadowing during autumn and summer, decreases the ability of kikuyu to compete with the perennial clovers or mixtures of ryegrass-clover during the first year of growth.

Notes

- The seeds of perennial ryegrass, perennial clovers and Italian ryegrass need to make contact with the soil for the seedling to establish well. The seedlings also don't have the ability to compete with actively growing kikuyu. The planting method or time of planting must be chosen in a way to benefit the over-sown crops, hamper the growth of kikuyu or selected at a time when kikuyu is dormant.
- Clovers need a well-prepared seedbed. In a study evaluating mulcher and rotavator methods to plant white and red clover into kikuyu, the rotavator method was found a better method to establish perennial white and red clover. With the rotavator method, the clover content of a kikuyu-clover pasture was higher than the clover content established by the mulcher method, for a period of two years after establishing the pastures.
- It is recommended that a kikuyu pasture be grazed, or the leaf and stem (stolons) material be

removed to a height of 50-100 mm before being mulched, regardless of the planting method or species being planted. An excess of mulched material will cause a nitrogen negative period, in which it will be difficult for the Westerwold ryegrass seedlings to germinate and grow fast enough for the roots to reach the soil. It will also cause clotting of the planter's coulters, affecting planting depth and the overshadowing of emerging seedlings.

Table 1 (below) shows the botanical composition, seeding rate and over-sowing methods of different pasture species, varieties and cultivars evaluated in kikuyu over-sown system trials at Outeniqua Research Farm.

Table 1. Botanical composition, seeding rate and over-sowing methods of different pasture species, varieties and cultivars evaluated in kikuyu over-sown system trials at Outeniqua Research Farm.

Botanical compositions of pasture treatments	Seeding rate kg ha^{-1}	Over-sowing methods
Kikuyu	Existing stand	Pure Kikuyu pasture
Kikuyu	Existing stand	
Westerwold ryegrass	25	Grazed to 50 mm
		Broadcast seed
		Mulcher
		Cambridge roller
Kikuyu	Existing stand	Grazed to 50 mm
Italian ryegrass	25	Mulcher
		Aicheson planter
		Cambridge roller
Kikuyu	Existing stand	Grazed to 50 mm
Perennial ryegrass	25	Mulcher
		Aicheson planter
		Cambridge roller
Kikuyu	Existing stand	Grazed to 50 mm
white clover cv. Haifa	2.5	Mulcher
White clover cv. Waverley	2.5	Rotavator
Red clover cv. Kenland	3	Cambridge roller
Red clover cv. Cherokee	3	Broadcast seed
		Cambridge roller
Kikuyu	Existing stand	Grazed to 50 mm
Perennial ryegrass cv. Yatsyn	5	Mulcher
Perennial ryegrass cv. Dobson	5	Rotavator
White clover cv. Haifa	2	Cambridge roller
White clover cv. Waverley	2	Broadcast seed
Red clover cv. Kenland	2	Cambridge roller
Red clover cv. Cherokee	2	

Conclusion

A number of factors are important for ryegrass or clover growth and persistence in a mixed kikuyu-ryegrass or kikuyu-ryegrass-clover pasture. It is important that all the factors discussed above are addressed, in order to achieve optimum DM production, quality and palatability. The goal should be to seasonally increase the ryegrass content using different ryegrass species, without reducing annual pasture dry matter yield. Higher ryegrass content will improve milk yields for the same levels of dry matter available in the pasture. The pasture production, the amount of pasture used by our animals and the actual cost in relation to our production cost will be the only guidelines that will tell us if we can produce our milk competitively on an international market.

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18. High fibre concentrates for Jersey cows grazing kikuyu pasture

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Introduction

Profitability of milk production on pasture-based systems is under pressure, due to high input costs and low milk prices. Dairy concentrates can contribute up to 66% of total feed costs in a pasture grazing system (Meeske *et al.*, 2006). These increased costs necessitated more efficient pasture management practices in recent years (Dillon, 2006; McEvoy *et al.*, 2009). Increasing the proportion of grazed forages in the diet has become a key objective for producers, seeing as grazed forages are currently the cheapest nutrient source for dairy cows (Clark & Kanneganti, 1998; McEvoy *et al.*, 2009). A previous study by Lingnau *et al.*, (2010) showed that the partial replacement of maize with high fibre by-products in the concentrate fed to Jersey cows grazing ryegrass pasture during spring, sustained milk yield and increased milk fat content. kikuyu pasture, however, has a higher fibre content than ryegrass and may require a higher ruminal pH for optimal ruminal fibre digestion. This higher ruminal pH could be achieved by increasing the fibre content in the dairy concentrate by replacing maize with high-fibre by-products. With energy being the first limiting nutrient on kikuyu pasture, supplementation is essential and usually consists mostly of maize, due its high energy content. High-fibre by-products are available at a lower cost than maize and, by partially replacing maize with these by-products, the price of the concentrate can be reduced, therefore lowering input costs.

The aim of this trial is to determine what the effect of increasing the fibre content of a dairy concentrate will be on the milk production and milk composition of Jersey cows grazing kikuyu pasture.

Materials and Methods

The trial took place at the Outeniqua Research Farm in the Western Cape Province of South Africa, from 28 January to 5 April 2013. Fifty-one high-producing Jersey cows were selected and blocked according to milk yield, days in milk (DIM) and lactation number. They were then randomly allocated to three treatments of low, medium and high fibre, allowing 17 cows per treatment. All cows were milked twice a day, at 05:30 and 14:00, and received 6 kg (as is) of concentrate, split over two milkings. After each milking all the cows returned to fresh kikuyu pasture which was allocated at approximately 10 kg DM/cow above a stubble height of 30 mm. Cows grazed as one group and received fresh water *ad lib* at all times. Pasture strips were measured pre- and post-grazing with a rising plate meter (RPM) to estimate pasture yield and intake, as well as to ensure that the pasture was grazed down to a stubble height of 50 to 60 mm. Body weight (BW) and body condition score (BCS; scale 1-5) were measured after morning milking over 2 consecutive days at the start and end of the trial period.

The ingredients and nutritional composition of the three different concentrates are represented in Table 1.

Table 1. Composition of the three concentrates used for experimental treatments fed to Jersey cows grazing kikuyu pasture during summer.

Ingredient[1] (%)	Concentrates		
	Low fibre	Medium fibre	High fibre
Maize	78.5	50.8	22.7
Hominy chop	0	17.5	35
Wheat bran	0	9	18
Gluten 20	0	6	12
Soybean oilcake	13.1	8.8	4.5
Molasses	4	4	4
Feed lime	1.8	1.9	2.2
MCP	0.8	0.3	0
Salt	1	1	1
MgO	0.3	0.2	0.1
Premix[2]	0.5	0.5	0.5
Nutrient[3] (% of DM or as stated)			
DM	86.8	86.4	86.2
CP	12.3	12.3	12.3
ME (MJ/kg DM)	11.5	11.2	10.9
NDF	7.65	13.4	19.1
Fat	3.21	4.07	4.92
Calcium	0.86	0.84	0.91
Phosphorus	0.40	0.40	0.45
Magnesium	0.33	0.32	0.32

[1] MCP – mono-calcium phosphate; MgO – magnesium oxide

[2] Premix – 6x10^6 IU Vitamin A; 1x10^6 IU Vitamin D3; 8x10^3 IU Vitamin E; 4 g/kg copper; 10 g/kg manganese; 20 g/kg zinc; 340 mg/kg iodine; 200 mg/kg cobalt; 60 mg/kg selenium

[3] DM – Dry Matter; CP – Crude Protein; ME – Metabolisable Energy; NDF – Neutral Detergent Fibre.

Each cow's milk yield was recorded daily in the milking parlour. A composite milk sample (16 ml morning and 8 ml afternoon) was taken from each cow fortnightly during the collection period and was sent away for analysis. Feed samples were taken three days per week and pooled fortnightly. Pasture samples were taken each week for the duration of the trial.

Results and discussion

The nutrient composition of the concentrates and pasture given in Table 2 is a representation of the actual nutrient composition of samples taken during the trial period.

Table 2. Mean and standard deviation of the nutrient composition of each of the three treatments (n = 4) fed to jersey cows at 6 kg (as is)/day and *ad lib* kikuyu pasture (n = 8).

Nutrient[1]	**Treatment**			**Pasture**
(% of DM or as stated)	**Low fibre**	**Medium fibre**	**High fibre**	
DM	97.2 ± 0.2	97.3 ± 0.2	97.5 ± 0.4	91.3 ± 1.1
Ash	6.62 ± 0.08	6.74 ± 0.2	6.91 ± 0.2	9.55 ± 0.9
OM	93.4 ± 0.08	93.3 ± 0.2	93.1 ± 0.2	90.5 ± 0.9
CP	14.0 ± 0.2	14.4 ±0.2	14.5 ± 0.1	20.1 ± 2.2
EE	2.52 ± 0.5	3.97 ± 0.2	5.16 ± 0.1	2.92 ± 0.6
NDF	9.43 ± 0.4	15.4 ± 0.2	22.6 ± 0.3	57.1 ± 4.4
NDIN	-	-	-	2.57 ± 0.3
ADF	2.84 ± 0.1	4.63 ± 0.04	6.76 ± 0.2	26.9 ± 1.6
ADIN	-	-	-	1.35 ± 0.4
IVDMD	97.2 ± 0.6	93.6 ± 1.1	87.1 ± 0.9	69.1 ± 7.6
Starch	49.0 ± 2.1	41.3 ± 3.7	31.9 ± 0.09	-
GE (MJ/kg DM)	17.7 ± 0.08	17.8 ± 0.3	18.3 ± 0.2	18.5 ± 0.1
ME (MJ/kg DM)	14.4 ± 0.05	14.0 ± 0.3	13.4 ± 0.2	10.4 ± 1.1
Calcium	1.25 ± 0.05	1.25 ± 0.06	1.21 ± 0.06	0.53 ± 0.05
Phosphorus	0.59 ± 0.01	0.62 ± 0.01	0.67 ± 0.02	0.50 ± 0.05
Ca:P ratio	2.10 ± 0.06	2.00 ± 0.08	1.79 ± 0.07	1.06 ± 0.14
Potassium	0.89 ± 0.02	0.99 ± 0.01	1.14 ± 0.05	3.42 ± 0.61

[1] DM – Dry Matter; OM – Organic Matter; CP – Crude Protein; EE – Ether Extract; NDF – Neutral Detergent Fibre; NDIN – Neutral Detergent Insoluble Nitrogen; ADF – Acid Detergent Fibre; ADIN – Acid Detergent Insoluble Nitrogen; IVDMD – *In Vitro* Dry Matter Digestibility; GE – Gross Energy; ME – Metabolisable Energy; Ca:P – Calcium To Phosphorus Ratio

The CP content in Table 2 shows a lower protein content for the low-fibre concentrate, although the concentrates were formulated on an iso-nitrogenous basis as shown in Table 1. The concentrates are described as low, medium and high fibre concentrates, based on the decreasing starch, *IV*DMD and ME content, and the increasing NDF and ADF content, in order of low<high-fibre concentrate.

Results of the milk yield and milk composition are represented in Table 3. The milk yield, milk fat content and 4% fat corrected milk (FCM) did not differ between cows receiving the different concentrate treatments (P > 0.05). Milk yield was maintained even though the metabolisable energy level was lower in the medium- and high-fibre concentrates. A higher milk fat content is a result of the increased acetate and butyrate production from the increased NDF content in the diet (McDonald *et al.*, 2002; Bargo *et al.*, 2003; Lingnau, 2011).

The milk protein content was lowest for cows supplemented with the high-fibre concentrate and highest for cows supplemented with the low-fibre concentrate (P<0.05). Milk lactose content was the lowest for cows receiving the high-fibre concentrate compared to cows receiving the medium- and low-fibre concentrate treatments (P<0.05). The low milk protein and lactose content in the high-fibre concentrate treatment can be explained by the lower energy content, as energy is a precursor for lactose, fat and protein (Mertens, 1985; Varga *et al.*, 1998). The somatic cell count (SCC) did differ between treatments (P<0.05) – this is not related to the treatments but rather to the individual animals. Changes in BW and BCS are shown in Table 3. Changes in BW and BCS did not differ between the treatments (P>0.05), however, over all, cows gained weight as well as condition over the duration of the study.

Table 3. Mean milk yield, milk composition and BW and BCS change of Jersey cows (n = 17) grazing kikuyu pasture and fed 6 kg (as is) of low-, medium- and high-fibre concentrates during summer.

Parameter[1]	Treatment			SEM[2]	P-value
	Low fibre	Medium fibre	High fibre		
Milk yield (kg/cow/day)	18.8	18.9	18.3	0.35	0.35
Milk fat (%)	4.18	4.14	4.27	0.09	0.62
4% FCM (kg/cow/day)	19.2	19.2	18.9	0.41	0.84
Milk protein (%)	3.66[a]	3.53[a,b]	3.45[b]	0.05	0.01
Milk lactose (%)	4.73[a]	4.73[a]	4.49[b]	0.05	<.001
MUN (mg/dl)	10.2	10.3	9.26	0.33	0.11
SCC (x 1000/ml)	141[a]	145[a]	230[b]	28.6	0.06
BW start (kg)	387	383	386	4.83	0.88
BW end (kg)	400	395	394	5.11	0.63
BW change (kg)	+13.0	+11.4	+8.12	2.47	0.37
BCS start (scale 1 - 5)	2.06	2.06	2.03	0.03	0.77
BCS end (scale 1 - 5)	2.41	2.40	2.32	0.05	0.38
BCS change (scale 1 - 5)	+0.35	+0.34	+0.29	0.04	0.50

[1] FCM – Fat Corrected Milk; MUN – Milk Urea Nitrogen; SCC – Somatic Cell Count;
BW – Body Weight; BCS – Body Condition Score

[2] SEM – Standard Error of the Mean

[a, b] Means in the same row with different superscripts differ ($P < 0.05$)

Economic evaluation

A comparison of the daily margin over feed cost and the daily profit increase is represented in Table 4.

Table 4. Daily margin over feed cost as calculated by milk price according to milk composition, feed cost and pasture cost for the low-, medium- and high-fibre treatments.

Parameter[1]	Treatment		
	Low fibre	Medium fibre	High fibre
Milk yield (kg/cow/day)	18.8	18.9	18.3
Milk fat (%)	4.18	4.14	4.27
Milk protein (%)	3.66	3.53	3.45
Milk price (R/l)	3.99	4.04	4.16
Milk income (R/cow/day)	75.01	76.36	76.13
Total feed cost (R/cow/day)	35.46	33.18	30.96
Concentrate price (R/ton)	3910	3530	3160
Feed price (R/cow/day)	23.46	21.18	18.96
Pasture cost (10 kg X R1.20 in R/cow/day)	12.00	12.00	12.00
Margin over feed cost (R/cow/day)	39.55	43.18	45.17
Increase in profit (R/cow/day)	0	3.62	5.62

[1] R – South African Rand

The feed cost per ton as in January 2013 was obtained from NOVA feeds. The economical evaluation from this study illustrated that the high-fibre treatment resulted in the highest margin over feed cost per cow per day. The high-fibre treatment had a higher milk price per litre and a lower feed price per cow per day, which can explain the higher margin over feed cost. The high-fibre treatment has the highest increase in profit per cow per day compared to the low-fibre treatment. With an average herd size of 300 cows, supplementing the high-fibre treatment could result in a monthly profit increase of R51 386 compared to the low-fibre treatment and R18 226 compared to the medium-fibre treatment.

Conclusion

Milk production was maintained when cows were fed a high-fibre concentrate – however, milk protein and lactose was compromised. Overall cow health was maintained as can be seen from the increase in BCS. By partially substituting maize with high-fibre by-products, milk yield can be sustained at a lower cost.

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19. The use of buffers in the concentrate supplement for Jersey cows grazing ryegrass pasture in spring

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Introduction

Dairy farmers are under financial pressure due to increased input costs– it is therefore important to optimise feeding of cows. Producing milk from pasture is a method to limit input costs as pasture is the cheapest source of nutrients for animals (Clark *et al.*, 1998). The rumen environment however, may not be optimal when cows graze high quality ryegrass during spring. The rumen pH of cows may decrease below 5.8 for three to six hours of the day, which could indicate sub-acute rumen acidosis. Feeding supplemental concentrate to grazing cows could increase energy intake, milk production and possibly profits, but could decrease the ruminal pH even further. This could reduce intake, impair ruminal fibre digestion and depress milk yield. A lowered ruminal pH is also known to reduce the percentage of milk fat (Staples & Lough, 1989). The inclusion of buffers in dairy concentrates fed to cows grazing high-quality pasture, could stabilise the ruminal pH and improve the ruminal environment. This could improve ruminal fibre digestion, that could increase milk yield and milk fat content, and ultimately lead to higher profits.

The aim of this study was to determine the effect of feeding buffers in the concentrate fed to Jersey cows grazing annual ryegrass during spring – on milk production, milk composition, body weight, and condition score.

Materials and Methods

A study was conducted at the Outeniqua Research Farm near George (Altitude 201 m, 33° 58’ 38” S, 22° 25’ 16” E) in the Western Cape Province of South Africa. The area has a temperate climate. The trial was conducted from September to November 2012, resulting in a 64 d data collecting period. Cows grazed a paddock consisting of 8,55 ha of permanently irrigated kikuyu (*Pennisetum clandestinum*) pasture, over-sown in March 2012 with annual ryegrass (*Lolium multiflorum* var. *italicum*). The annual ryegrass was the dominant species during the experimental period. The paddock was divided into thirty nine strips, 150 by 15 m. The pasture was fertilised with 42 kg N (LAN, limestone ammonia nitrate) per ha after each grazing. Pasture height was measured before and after each grazing by using the rising plate meter (RPM) to estimate pasture yield and allocate pasture.

Fifty four high-producing Jersey cows were blocked according to milk production (MP), days in milk (DIM), and lactation number. The cows were randomly allocated to one of three treatments –dairy concentrate with no buffer (control), concentrate with 2% sodium bicarbonate, or concentrate with 1% acid buf. Cows were fed 6 kg DM concentrate per day split over two milking periods, resulting in an intake of 60 g/cow/day and 120 g/cow/day of acid buf and sodium bicarbonate, respectively. Concentrate composition is shown in Table 1. Pasture was allocated to supply ca. 10 kg DM/cow/day and clean water was available *ad lib* at all times. Milk production was recorded daily and milk samples were taken every two weeks. A representative milk sample was taken in the morning and in the afternoon, and pooled before sent for analysis. A total of four milk samples of each cow were taken over the experimental period. The data collection period only started after an adaptation period of 14 days. Body weight (BW) and body condition score (BCS) were determined at the beginning and the end of the trial period.

Table 1. The ingredient and mean nutrient composition of each of the three treatment concentrates (n = 4) fed to Jersey cows grazing annual ryegrass pasture during spring.

Ingredient (%)	**Treatment concentrates**		
	Control	**Acid Buf**	**Sodium Bicarbonate**
Maize	62	62	62
Hominy chop	15	15	15
Wheat bran	11.4	11.2	8.9
Soybean oilcake	4	4	4.5
Molasses	4	4	4
Feed lime	2.2	1.5	2.2
Salt	1	1	1
Sodium bicarbonate	0	0	2
Acid Buf	0	1	0
MgO	0.3	0.2	0.3
Premix[1]	0.1	0.1	0.1
Nutrient Composition[2] **(% or as stated)**			
DM	86.4	86.4	86.7
Protein	9.82	9.79	9.69
Ash	5.61	4.83	7.46
NDF	11.8	11.7	11.0
Ca	0.90	0.95	0.90
P	0.32	0.32	0.30
Mg	0.36	0.35	0.35
K	0.49	0.49	0.48
Na	0.41	0.42	0.95
ME (MJ/kg)	11.3	11.3	11.1

[1] Premix supplied by Feedtek.
[2] DM – Dry Matter; NDF – Neutral Detergent Fibre; Ca – Calcium; P – Phosphorus; Mg – Magnesium; K – Potassium; Na – Sodium; ME – Metabolisable Energy.

Results and discussion

Milk production parameters are presented in Table 2. Milk production and milk fat content did not differ (P>0.05) between cows on the three different treatments. The 4% fat corrected milk (FCM) production (P=0.08), tended to be higher for cows on the Acid Buf treatment, compared to cows on the control treatment. The milk protein content (P=0.09), tended to be higher for cows on the sodium bicarbonate treatment compared to cows on the control treatment. Milk lactose content of cows supplemented with the Acid Buf or sodium bicarbonate treatment concentrate was higher than for cows supplemented with the control treatment concentrate (P<0.05). The milk urea nitrogen (MUN) levels indicated that protein was not limiting in the diets of cows on any of the treatments. Erdman (1988) summarised the effect of buffer addition on milk parameters. It was found that on high-forage diets, milk fat increased by 0,3–0,6% when buffer was added, which is in line with the response found in the current study. The effect of buffer addition on milk production was not pronounced, as was the milk protein content and FCM (Erdman, 1988). In a previous study done by Rearte *et al.* (1984), grazing dairy cows were fed supplemental concentrate with added sodium bicarbonate at 1,9% inclusion rate, or without added buffer inclusion. Concentrate level was determined according to 4% FCM. In this study no difference was found in milk production, milk fat or milk protein content between cows on the added buffer and no added buffer treatments. This is consistent with the results found by Miller *et al.*

(1965), in a study on dairy cows grazing pasture and supplemented with 7–8 kg of concentrate, with or without buffer. Literature regarding this topic is variable and limited. The effect of buffer inclusion in the concentrate fed to cows grazing high-quality ryegrass is however expected to be more pronounced when higher levels of concentrate are fed.

Table 2. Mean milk parameters and body weight and body condition change of Jersey cows (n =18) fed 6 kg concentrate per day, which included either 0% buffer, 1% Acid Buf or 2% sodium bicarbonate inclusion, respectively, grazing annual ryegrass pasture during spring.

Parameter[1]	**Treatments**			**SEM**	**P-value**
	Control	**Acid Buf**	**Sodium Bicarbonate**		
Milk production (kg/d)	20.2	20.5	20.3	0.34	0.82
Milk fat (%)	4.24	4.51	4.50	0.12	0.20
4% FCM (kg/d)	20.84[c]	21.89[d]	21.80[cd]	0.35	0.08
Milk protein (%)	3.41[c]	3.50[cd]	3.56[d]	0.05	0.09
Milk lactose (%)	4.49[a]	4.76[b]	4.76[b]	0.03	<0.01
SCC (x1000)	107	146	132	24.5	0.52
MUN (mg/dl)	10.5[a]	9.6[b]	9.7[ab]	0.28	0.05
BW before (kg)	371	378	373	8.04	0.83
BW after (kg)	393	403	396	7.76	0.64
BW change (kg)	+21.9	+25.3	+23.2	2.33	0.58
BCS before (kg)	2.04	2.13	2.11	0.04	0.33
BCS after (kg)	2.19	2.25	2.17	0.06	0.60
BCS change (kg)	+0.15	+0.12	+0.06	0.06	0.44

[1] FCM – Fat Corrected Milk; SCC – Somatic Cell Count; MUN – Milk Urea Nitrogen; BW – Body Weight; BCS – Body Condition Score

[a,b] Means in the same row with different superscript differ in significance (P<0.05)

[c,d] Means in the same row with different superscript tend to differ (P<0.10)

The changes in BW and BCS as affected by the respective diets are recorded in Table 2. Cows on all treatments gained BW and body condition and different concentrate treatments had no effect. A possible reason for increase in BW as well as BCS could be due to increased pasture intake. This is facilitated by accurate pasture allocation and improved pasture availability as well as a higher level of concentrate feeding.

Economic evaluation

The economic implication of buffer addition is shown in Table 3. The cost of milk fat and milk protein was taken as R36.50 and R62.05 per kg, respectively. This may vary depending on the specific milk buyer and supply and demand in the market place. The prices for Acid Buf and sodium bicarbonate were provided by a feeding company as R8.00 and R4.60 per kg, respectively.

Table 3. Economic implications of buffer addition (1% Acid Buff or 2% sodium bicarbonate) in concentrates fed to cows at 6 kg (DM)/day grazing annual ryegrass pasture during spring.

Parameter[1]	Treatments		
	Control	Acid Buf	Sodium Bicarbonate
Milk fat production (kg/cow/d)	0.8565	0.9246	0.9135
Milk protein production (kg/cow/d)	0.6888	0.7175	0.7227
Income - milk fat (R/cow/d)	R 31.26	R 33.75	R 33.34
Income – milk protein (R/cow/d)	R 42.74	R 44.52	R 44.84
Total income R/cow/d)	R 74.00	R 78.27	R 78.19
Additional income vs. control (R/cow/d)	-	R 4.27	R 4.19
Cost of buffer (R/cow/d)	-	R 0.48	R 0.55
Additional profit (R/cow/d)	-	R 3.79	R 3.64
Return on investment in buffer (R/R)	-	8.90	7.62

[1]R – South African Rand

The return on investment of R8.90 and R7.62 for Acid Buf and sodium bicarbonate supplementation, respectively, for each rand spend on buffer was high. Increasing profit by R4.27 and R4.19 per cow per day will result in a substantial increase in monthly profit of R34 110.00 and R32 760.00 per month in a dairy herd of 300 cows in milk for the Acid Buf and sodium bicarbonate treatments, respectively. Farmers should always critically evaluate the effect of any supplement on their farm and monitor if milk production and/or milk composition change justifies the additional cost of the additive. Our study showed that the addition of buffers could be very cost-effective.

Conclusion

Adding buffers to concentrates fed to Jersey cows grazing ryegrass pasture in spring, tended to increase fat corrected milk production, milk protein content and increased milk lactose content. The return on investment when adding buffers was high and therefore, inclusion of buffers in the concentrate supplement for dairy cows grazing high-quality pasture should be considered.

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20. The effect of lucerne (*Medicago sativa*) hay quality on the milk production of Jersey cows

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Introduction

Forage quality is a major challenge for lucerne growers. The demand for high quality lucerne has grown significantly in recent years because the milk-production potential of cows has increased drastically since the 1970s. High-producing cows have a restricted rumen capacity and need forages with high digestibility, a good palatability, high intake potential, and high protein levels. Lucerne hay is a typical high quality forage, and therefore demand for it has increased (Orloff & Putnam, 2007).

Scholtz *et al.* (2009c) evaluated different parameters which had been used to assess lucerne-hay quality, and found large differences in the accuracy of their predictions – which were evaluated by looking at milk yield. They found that in dairy diets, the acid-detergent fibre (ADF) content of lucerne hay, was the best parameter to predict milk yield of dairy cattle. By including ADF, ash and lignin, in a multiple linear equation, the accuracy of milk prediction improved remarkably. He concluded that protein parameters are a poor indicator of milk yield, and thus the protein content of lucerne hay is not a very reliable indicator of the quality of lucerne hay (Scholtz *et al.*, 2003c).

The aim of this study was to determine the effect of lucerne-hay quality – as determined by the model developed by Scholtz *et al.* (2003c) – on the milk production of Jersey cows which had been fed a lucerne-based, total mixed ration, as well as the influence of quality on rumen parameters.

Materials and Methods

The trial was conducted from July to September 2012 at the Outeniqua Research Farm near George, in the Western Cape Province, South Africa. The three treatments consisted of total mixed rations (TMR) containing three different grades of lucerne hay. The treatments were:

Prime treatment: 53% prime lucerne hay, 7% wheat straw, and 40% concentrate.

Grade 1 treatment: 53% grade 1 lucerne hay, 7% wheat straw, and 40% concentrate.

Grade 2 treatment: 53% grade 2 lucerne hay, 7% wheat straw, and 40% concentrate.

The lucerne hay was graded according to the New Lucerne Quality Index (NLQI; Scholtz *et al.*, 2009c). The ingredients of the concentrates are shown in Table 1.

Table 1: Composition of concentrates mixed with prime, grade 1 and grade 2 lucerne hay-based, total mixed rations fed to Jersey cows.

Ingredients (% of DM)	Prime lucerne concentrate	Grade 1 lucerne concentrate	Grade 2 lucerne concentrate
Maize	43.2	43.2	42.45
Hominy chop	45.0	45.0	45.0
Wheat bran	10.0	10.0	10.0
Urea	0	0	0.75
Salt	1.00	1.00	1.00
MgO	0.30	0.30	0.30
Premix	0.50	0.50	0.50

The nutrient composition of the three grades of lucerne – as analysed by Near Infrared Spectroscopy (NIR) – is indicated in Table 2.

Table 2: Nutrient composition, as well as indexes of lucerne hay, as measured by the NIR instrument.

Nutrients (% of DM)	Prime lucerne	Grade 1 lucerne	Grade 2 lucerne
Moisture	10.05	11.17	6.96
Lignin	4.86	6.69	8.31
Ash	8.89	11.7	6.22
ADF	24.8	32.7	37.9
Protein	26.7	22.9	19.9
NDF	29.1	40.8	49.3
NLQI	115	103	98.5

ADF – Acid detergent fibre.
NDF – Neutral detergent fibre.
NLQI – New Lucerne Quality Index.

Fifty seven Jersey cows were used in the production study. and three rumen-fistulated Jersey cows in the rumen study. The average milk production, lactation number, and days in milk of cows in each group at the onset of the trial, are given in Table 3.

Table 3: Average milk production, lactation number, and days in milk at the onset of the trial, in each of the treatment groups

Item	Prime	Grade 1	Grade 2
Milk production (kg/cow/day)	17.4 ± 2.51	18.0 ± 1.92	17.7 ± 1.57
Lactation nr	4.00 ± 1.97	5.42 ± 2.63	5.21 ± 2.76
DIM	113 ± 66.1	109 ± 65.0	113 ± 68.8

IThe cows were blocked according to milk production of the previous month, days in milk, and lactation number. Cows within blocks were then randomly allocated to one of the three treatments. The 19 cows allocated to each treatment were then further divided into 4 groups of 5 each – with the cannulated cow used for the rumen study filling the last space of the group with only four animals. Twelve feeding camps were used in the study, with 4 camps allocated to each treatment. This allowed collection of intake data. The cows were fed lucerne-based total mixed rations, once a day, at 09:00.

Dry-matter intake and milk production were measured daily, and milk samples were taken every two weeks in order to determine milk composition. The rumen pH of the fistulated cows was measured over two days, an in sacco digestibility trial was done, and rumen fluid samples were taken from each of the cows in the rumen study.

Results and Discussion

Shown in Table 4 are: average dry-matter intake (DMI), feed-conversion ratio (FCR) of milk production and FCR of 4% fat-corrected milk (FCM) production, average milk yield measured during the measurement period of the trial and the milk composition obtained from milk samples taken during the trial, and body weight (BW) and body-condition score (BCS) of the animals in each treatment taken at the beginning and end of the trial, as well as the change.

Table 4 : Dry-matter intake, milk production, feed-conversion ratio, milk composition, body weight, and body-condition score of Jersey cows fed prime, grade 1, and grade 2 lucerne total mixed rations.

Item	Treatment			SEM*	P value
	Prime	Grade 1	Grade 2		
DMI (kg/day)	16.67	18.51	17.31	0.58	0.15
Milk production (kg/day)	19.98^{a}	19.95^{a}	17.71^{b}	0.68	0.04
FCM(kg/day)	20.30^{a}	19.93^{ab}	18.40 ^{b}	0.63	0.09
FCR (kg Milk/Kg DMI)	1.19	1.08	1.02	0.05	0.54
FCR (kg 4% FCM/kg DMI)	1.22	1.08	1.06	0.04	0.48
Milk fat (%)	3.99	4.00	4.12	0.11	0.66
Milk protein (%)	3.69^{a}	3.52^{b}	3.53^{b}	0.05	0.04
Milk Lactose (%)	4.76	4.72	4.64	0.04	0.14
SCC x 1000	207	196	2936	44.3	0.25
MUN (mg/dl)	15.85^{a}	13.45^{b}	13.47^{b}	0.42	0.0002
BW beginning (kg)	386.95	399.74	381.21	9.23	0.36
BW end (kg)	403.86	420.84	407.32	10.03	0.46
BW change (kg)	+17.72^{c}	+21.11^{cd}	+26.11^{d}	2.64	0.09
BCS beginning	2.11	2.04	2.08	0.03	0.38
BCS end	2.41	2.29	2.28	0.07	0.32
BCS change	+0.31	+0.25	+0.20	0.05	0.31

*SEM: Standard Error of Mean, FCM: 4% fat-corrected milk, FCR: Feed Conversion Ration,
SCC: Somatic Cell Count, BW: Body weight, BCS: Body Condition Score Scale 1-5.
$^{a, b}$ Means in the same row with different superscripts differ (P<0.05).
^{c,d} Means in the same row with different superscripts differ (P<0.10).

DMI did not differ significantly (P>0.05) between treatments. The FCR for milk production – as well as for 4% FCM – were also not significantly different between treatments.

The milk production differed between treatments (P<0.05). The milk production of cows on the prime and grade 1 lucerne treatment was significantly higher than that of cows on the grade 2 lucerne treatment. The fat-corrected milk yield did not differ significantly between prime and grade 1 lucerne treatments (P>0.05), but cows on the prime lucerne treatment tended to have a higher milk production than cows on the grade 2 lucerne treatment. Milk fat, milk lactose, and somatic cell count did not differ between treatments. Milk protein and milk urea nitrogen levels, were significantly higher (P<0.05) on the prime lucerne treatment – compared to the grade 1 and grade 2 lucerne treatments.

The body weight and body condition score of the animals at the start and end of trial, as well as the change in body condition, did not differ between treatments. The increase in body weight also did not differ significantly between treatments, but the increase in body weight tended (P=0.09) to be lower in the prime treatment, than in the grade 2 treatment.

When the NDF content of a diet increases, the time spent chewing will increase (Beauchemin, 1991) and dry-matter intake will therefore decrease. The milk production then decreases as a result of the decreased intake, as well as the low energy density of the diet (Mertens, 1997). In this study, the high amount of NDF in the grade 2 lucerne did not decrease intake significantly – but the milk production was lower probably due to the lower energy density. Nelson and Satter (1990) also observed a decrease in milk production as the lucerne used as roughage in rations for dairy cows increased in maturity, and thus also increased in NDF.

Conclusion

Cows on the prime lucerne-hay based TMR did not produce significantly more milk than those on the grade 1 lucerne-hay based TMR. The prime and grade 1 lucerne-hay treatment did, however, result in a higher milk production than the grade 2 lucerne-hay treatment. The prime lucerne-hay treatment presented challenges in terms of effective fibre in the total diet.

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21. Palm-kernel expeller as a supplement for dairy cows grazing kikuyu/ryegrass pasture

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Introduction

The number of milk producers in South Africa decreased by 36% from January 2007 to January 2012 (Coetzee, 2012). The Western Cape has the highest number of milk producers and producer-distributors, as well as the second highest number of milk buyers – compared to the other South African provinces (Coetzee, 2012). The decrease in milk producers places great pressure on prevailing milk producers to satisfy the ever increasing demand for milk and milk products. Low milk prices and increased input costs, amplify the financial pressure experienced by today's dairy farmer – with not even mentioning the need to lower their carbon footprint.

Improving the efficiency of production and reducing the cost of concentrate supplements for dairy cows, are becoming increasingly important for the dairy farmer. Dairy concentrates contribute up to 66% of the total feed cost in pasture-grazing systems, according to Meeske *et al.* (2006). High maize and oilcake prices have a substantial impact on milk production costs. Maize grain can constitute up to 70 to 80% of a conventional dairy concentrate, and soybean oilcake can constitute up to 8 to 12% of the concentrate (Meeske *et al.*, 2009), and both of these feed sources are expensive. When the maize price is high, replacing maize with lower cost high-fibre byproducts, becomes an economically viable option.

In a study previously carried out at the Outeniqua Research Farm, it was shown that maize – in the concentrate supplement of dairy cows – can be replaced by high-fibre byproducts such as hominy chop, gluten 20, and bran, without causing a reduction in milk production and it actually increased milk-fat content (Lingnau *et al.*, 2010). Input cost can be markedly reduced by replacing a starch-based concentrate with a fibre-based concentrate (Muller *et al.*, 2001). A fibre-based concentrate also results in an increase in pasture intake and total dry-matter intake (Meijs, 1986; Sayers, 1999), and can sustain or even increase milk production and milk-fat percentages for dairy cows grazing ryegrass pasture (Meijs, 1986; Sayers, 1999; Delahoy *et al.*, 2003).

Palm-kernel expeller (PKE) is a low cost, high fibre residue or byproduct of the palm-kernel oil-extraction process of the African Palm Seed (Abdullah & Hutagalung, 1988; Carvalho *et al.*, 2006; Chanjula *et al.*, 2011). The African Palm seed is produced mainly from tropical parts of South-East Asia, South America, and Africa. The neutral detergent fibre (NDF) content of PKE is high (69%), and is therefore regarded as a high fibre byproduct. The crude protein content of PKE is 17% – which is higher than that of maize grain (7%). Most of the energy of PKE comes from the oil and NDF content. As PKE is very low in starch and sugars, it lowers the risk of developing acidosis and other rumen health disorders (Varga *et al.*, 1998). Palm-kernel expeller is invaluable in supplying protein to ruminants, and most of the common minerals are within acceptable ranges (Alimon, 2004). According to Zahari and Alimon (2003), PKE is used as a source of energy and fibre for dairy cows at inclusion levels of 30–50%, however, Carvalho *et al.* (2006) state that PKE is generally included in small amounts (<10%) in dairy concentrates – due to its low palatability. Palm-kernel expeller is mainly used as a pasture extender in Australia and New Zealand, when pasture growth rate is low.

The aim of this study was to determine the effect of partially replacing maize with PKE in concentrates for dairy cows – on milk production, milk composition, live weight, and body condition score of cows grazing ryegrass pasture during spring.

Materials and Methods

The study was conducted at the Outeniqua Research Farm, near George in the Western Cape Province of South Africa. The altitude, latitude, and longitude are: 204 m above sea-level, 33° 58' 38" S, 22° 25' 16" E, respectively. The George area has a temperate climate. The long-term mean rainfall in the area – over a period of 45 years, since 1967 – is 731.45 mm p.a. (ARC, 2011). The study took place from 12 August 2011 to 1 November 2011. The paddock where the study was conducted consisted of 8.55 hectares of permanent, irrigated kikuyu (*Pennisetum clandestinum*) and annual ryegrass (*Lolium multiflorum* var. *italicum*) pasture (annual ryegrass was the dominant stand during the study). The paddock is characterised by two distinct soil forms: an Estcourt form in the northern part, and a Witfontein form in the slightly downward-sloping southern part (Soil Classification Working Group, 1991).

Manual tensiometers were used to schedule the irrigation of the paddock. Irrigation was initiated at a tensiometer reading of -25 Kpa, and was ended at a reading of -10 Kpa (Botha, 2002). The paddock was divided into 39 strips – where each strip had a length of 150 m, and a width of 15 m. Each strip was top-dressed with 42 kg nitrogen (LAN, limestone ammonium nitrate) per hectare, after each grazing. Pasture dry-matter (DM) yield, per area, was estimated by using the rising plate meter (RPM) with a disk area of 0.098 m^2. This was done by taking the mean of 100 RPM readings in a zigzag pattern on each pasture strip the day before, and after, grazing. A seasonal regression was used as part of the pasture DM yield measurement.

Some 48 multiparous, high producing Jersey cows [4% fat-corrected milk (FCM), 27.2 ± 4.1 kg day^{-1}; days in milk (DIM), 83.5 ± 41.3; lactation number, 3.9 ± 1.8; (mean ± SD)] were blocked according to FCM, DIM and lactation number, and were randomly allocated to three treatments (control, low PKE, and high PKE). The PKE inclusion in the control, low PKE, and high PKE treatment concentrates, were 0, 20 and 40%, respectively. The PKE replaced part of the maize and protein sources in the concentrate. Milk yield was recorded daily, and milk composition was determined in two-week intervals over a 60-day period – after a 21-day adaptation period (7 days on the pasture with *ad libitum* access to PKE, followed by 14 days of feeding-allocated treatments in the milking parlour). In addition, eight rumen-fistulated lactating dairy cows were randomly allocated to the control and high PKE treatment, in a two-period crossover design. Rumen pH, volatile fatty acids (VFA), and rumen ammonia nitrogen (NH_3-N), were measured.

Cows received 6 kg (as is basis) of the allocated treatment concentrate, per day, split over two milking periods, and strip-grazed the pasture – which was allocated at 10 kg DM cow^{-1} day^{-1} above 30 mm (RPM reading of 6). An after-grazing height of 50 mm (RPM reading of 10) was maintained by adjusting the allocated kilogram DM pasture, per cow, given the DM yield per hectare calculated by the seasonal regression. Fresh drinking water was available *ad libitum* at all times.

The nutrient composition of PKE (imported from Indonesia by Pieter Brönn, Intelact (Pty) Ltd, Eastern Cape, 2011) was determined before treatment concentrates were mixed (Animal Production Laboratory, University of Stellenbosch, 2011) – as is shown in Table 1. Treatment groups only differed in the composition of the allocated concentrate (Table 2). Concentrates were balanced so as to be *iso*-nitrogenous. Molasweet (Nutec Explicit Nutrition, Hilton Quarry Office Park, Hilton, KwaZulu-Natal), a powdered palatant, was added at 160 g per ton to each of the three concentrate treatments, in order to increase palatability.

NOVA feeds (Nova Feeds George, Industrial Area, George, Western Cape) formulated, mixed and bagged (50 kg) ten tons, of each of the three treatment concentrates. The concentrates could not be pelleted, because the PKE inclusion levels exceeded those recommended by NOVA feeds, and were therefore fed in a meal form. A maximum of 4% PKE can be included in the feed for it to be pelleted – given the detrimental impact of small stones in PKE on the pellet machine.

Table 1. Nutrient composition of palm-kernel expeller that was included at different levels in each of the three concentrate treatments fed to Jersey cows grazing kikuyu-ryegrass pasture in spring

Nutrient[1] (DM basis)	PKE[2]
DM (%)	89.8
Ash (%)	4.7
CP (%)	19
NDF (%)	77.8
ADF (%)	55.2
EE (%)	10.2
Ca (%)	0.56
P (%)	0.74
Ca : P	0.76

[1] DM – Dry matter; CP – Crude Protein; NDF – Neutral Detergent Fibre; ADF – Acid Detergent Fibre; EE – Ether Extract; Ca – Calcium; P – Phosphorous; Ca : P – calcium/phosphorous ratio
[2] PKE – Palm-Kernel Expeller

Table 2. Ingredient and nutrient composition of each of the three treatment concentrates fed to Jersey cows grazing kikuyu-ryegrass pastures in spring

Ingredient[1]	Treatment concentrates[2] (n = 4)			Pasture (n = 8)
	Control	Low PKE	High PKE	
Ground maize	81.6	65.7	49.9	
PKE	0	20	40	
Soybean oilcake	10.5	6.6	2.5	
Molasses	5	5	5	
Feedlime	1.5	1.4	1.3	
Salt	0.6	0.6	0.6	
MgO	0.3	0.25	0.2	
Vitamin and Mineral Premix[3]	0.5	0.5	0.5	
Nutrient[4] (DM bases)				
DM (%)	88.6	89.3	90.1	12.9
OM (%)	94.6	94.2	94.1	89.4
IVOMD (%)	92.0	87.2	81.6	80.2
ME (MJ kg^{-1})	13.2	12.7	12.2	11.5
CP (%)	12.3	12.1	12.3	21.5
NDF (%)	10.3	18.8	29.5	49.4
ADF (%)	4.13	10.5	18.2	30.2
ADL (%)	1.15	3.03	5.82	2.12
Starch (%)	60.8	51.0	39.5	1.32
EE (%)	2.62	3.92	5.39	12.5
Ca (%)	0.67	0.85	0.84	0.38
P (%)	0.29	0.34	0.39	0.34
Ca : P ratio	2.31	2.48	2.12	1.12

[1] PKE – Palm Kernel Expeller; MgO – Magnesium Oxide; [2] Control – 0% PKE; Low PKE – 20% PKE; High PKE – 40% PKE.
[3] Premix (Coprex Dairy Premix) – (per unit of premix), 6 million IU vitamin A; 1 million IU vitamin D3; 8000 IU vitamin E; 100 g zinc; 50 g manganese; 20 g copper; 1.7 g iodine; 1 g cobalt; 300 mg selenium; [4] DM – Dry matter; OM – Organic Matter; IVOMD – *In vitro* Organic Matter Disappearance; ME – Metabolisable Energy; CP – Crude Protein; NDF – Neutral Detergent Fibre; ADF – Acid Detergent Fibre; ADL – Acid Detergent Lignin; EE – Ether Extract; Ca – Calcium; P – Phosphorous; Ca : P – calcium/phosphorous ratio; Molasweet added at 160 g ton^{-1}, in each concentrate treatment.

The production study data were analysed statistically as a randomised block design, with three treatments randomly allocated to 16 blocks using the GLM model (Statistical Analysis System, 2012) – for the average effects over time. The rumen study data were analysed statistically using the GLM model (Statistical Analysis System, 2012) in a cross-over design, which ensured that both treatments were present in both periods. Means and standard error were calculated, and significance of difference ($p<0.05$) between means was determined by Fischers test (Samuels, 1989).

Results and discussion

The rumen parameters of the rumen-fistulated cows that had received 0% PKE (control) and 40% PKE (High PKE) inclusions in their concentrate, are presented in Table 3. The total volatile fatty acid (VFA) concentration did not differ between treatments. This concurs with the findings of Bargo *et al.* (2003) and Ranathunga *et al.* (2010) – where a fibre-based concentrate was compared with a starch-based concentrate. The specified VFAs, rumen NH_3-N, and mean ruminal pH, fell within the ranges specified by Bargo *et al.* (2003) for grazing cows supplemented with a concentrate – however, none differed ($p>0.05$) between treatments. Propionic acid did, however, show a tendency to differ between treatments. Sayers (1999) found that fibre-based concentrates increased the molar proportion of acetic acid and butyric acid, and decreased the molar proportion of propionic acid. The acetic to propionic acid ratio did differ ($p<0.05$) between the treatments. This was as a result of the difference in the relative proportions of each of the VFAs – compared to the total VFA concentration. This all indicates that rumen fermentation was maintained, resulting in a healthy rumen environment for both treatments.

Table 3. Average daily ruminal volatile fatty acids, rumen NH3-N, and pH measurements of rumen-fistulated Jersey (n = 8) cows fed 6 kg (as is) of allocated PKE concentrate, per day, grazing kikuyu-ryegrass pasture in spring

Rumen parameter[1]	Concentrate treatment[3]		SEM[4]	P-value
	Control	High PKE[2]		
Total VFA (mmol L^{-1})	120.7	118.3	3.44	0.63
Acetic acid (mmol L^{-1})	76.6	75.9	2.09	0.82
Propionic acid (mmol L^{-1})	24.2	22.8	0.60	0.14
Butyric acid (mmol L^{-1})	17.3	16.5	0.67	0.43
Acetic : Propionic acid ratio	3.22	3.40	0.03	<0.01
NH_3-N (mg dL^{-1})	13.8	14.6	0.59	0.39
pH	6.42	6.33	0.08	0.48

[1] VFA – Volatile Fatty Acids; NH_3-N – rumen ammonia nitrogen.
[2] PKE – Palm-Kernel Expeller.
[3] Control – concentrate containing 0% PKE; High PKE – concentrate containing 40% PKE.
[4] SEM – Standard Error of Mean.

The milk-production parameters are presented in Table 4. Milk yield and 4% fat-corrected milk did not differ ($p>0.05$) between treatments. As PKE inclusion increased, the maize inclusion decreased in the concentrate, which resulted in a lower metabolisable energy content in the concentrate. It could have been postulated that the milk yield should have decreased as the PKE inclusion in the concentrate increased, but this was not the case. Several authors have recorded similar milk-yield responses of cows grazing pasture, when fibre-based concentrates were compared to starch-based concentrates (Garnsworthy, 1990; Sayers, 1999; Delahoy *et al.*, 2003).

Milk-fat percentage did not differ ($p>0.05$) between treatments, even though an increase in milk-fat percentage was predicted in the low and high PKE treatments, due to the higher NDF level of these concentrates. These findings concur with other authors (Garnsworthy, 1990; Sayers, 1999; Delahoy *et al.*, 2003), who found that there was no effect on milk-fat percentage when fibre-based concentrates were compared to starch-based concentrates. However, Sayers (1999) and Meeske *et al.* (2009) did find a difference ($p<0.05$) in milk-fat percentage between fibre- and starch-based concentrates. Milk-protein percentage, somatic cell count (SCC), and milk urea nitrogen (MUN), did not differ (p>0.05) between treatments. The milk lactose percentage of the high PKE treatment was higher (p<0.05) than that of the control treatment. This could be correlated to the tendency of propionic acid to show a difference between the control and the high PKE treatment groups. There was no difference (p>0.05) in milk lactose percentage between the control and low PKE treatment groups. These results suggest that milk yield and milk composition of cows grazing kikuyu-ryegrass pasture, can be sustained by including a high fibre byproduct, such as PKE, with lower metabolisable energy levels, in the supplemented concentrate.

Live body weight (LW) and body condition score (BCS) parameters are depicted in Table 4. The LW and BCS did not differ (p>0.05) between treatments. These results are similar to those of several authors (Sayers, 1999; Meeske *et al.*, 2009; Lingnau *et al.*, 2010) – indicating that concentrate supplementation has little effect on LW or BCS of lactating dairy cows. This suggests that cows did not lose LW or BCS at the expense of maintaining milk yield in the low and high PKE treatment groups. Therefore, the allocated pasture and concentrate provided sufficient energy to maintain the milk yield.

The daily concentrate refusals did not differ (p>0.05) between treatments, even though a tendency can be seen. This is because the treatment groups had a high level of variation – resulting in high standard error means. There are two potential reasons for the refusals of the concentrates. Firstly, they were fed in a meal form where the cows are used to having pelleted concentrates, and secondly because of the inclusion of less palatable PKE. Milk yield was sustained in the low and high PKE treatment groups – regardless of the concentrate refusals.

Table 4. Milk yield, milk composition, live body weight, body condition score, and average daily concentrate refusals of Jersey cows (n = 16) fed 6 kg (as is) of allocated PKE concentrate per day, grazing kikuyu-ryegrass pasture in spring

Parameter[1]	Treatment[3]			SEM[4]	P-value
	Control	Low PKE	High PKE[2]		
Milk yield (kg cow^{-1} day^{-1})	21.3	21.3	20.7	0.68	0.78
4 % FCM (kg cow^{-1} day^{-1})	23.2	23.2	22.7	0.69	0.83
Milk Fat (%)	4.63	4.65	4.66	0.13	0.98
Milk Protein (%)	3.54	3.46	3.50	0.05	0.52
Milk Lactose (%)	4.73[a]	4.66[ab]	4.58[b]	0.03	0.01
SCC (x 103 mL^{-1})	166.3	162.3	162.7	33.4	1.00
MUN (mg N dL^{-1})	17.7	18.6	19.1	0.50	0.14
LW Before (kg)	376	363	373	9.96	0.64
LW After (kg)	412	396	412	10.8	0.49
LW change (kg)	+ 36.5	+ 33.3	+ 39.2	2.85	0.36
BCS Before	2.4	2.3	2.3	0.08	0.41
BCS After	2.6	2.5	2.5	0.10	0.68
BCS change	+ 0.2	+ 0.2	+ 0.2	0.06	0.90
AM Refusal (%)	3.4	3.1	9.2	2.28	0.12
PM Refusal (%)	6.0	5.4	11.2	2.63	0.24
Daily Refusal (%)	9.4	8.5	20.4	2.43	0.17

[1] FCM – Fat-Corrected Milk; SCC – Somatic Cell Count; MUN – Milk Urea Nitrogen; LW – Live Body Weight; BCS – Body Condition Score; AM – morning; PM – afternoon.

[2] PKE – Palm-Kernel Expeller.

[3] Control – concentrate containing 0% PKE; Low PKE – concentrate containing 20% PKE; High PKE – concentrate containing 40% PKE.

[4] SEM – Standard Error of Mean.

[a, b] Means in the same row with different superscripts differ (p<0.05).

Conclusion

Partial replacement of maize with 20 and 40% PKE in lactating dairy cow concentrates, did not affect milk yield, milk-fat percentage, milk-protein percentage, SCC, LW, or BCS. Rumen fermentation was unaffected, and a healthy rumen environment was sustained. The possibility of replacing maize with PKE – and the savings associated with the change – is subject to maize and PKE price. It is, however, not recommended to include PKE at 40% in the concentrate, due to the increased time spent by cows in the milking parlour, and the low palatability of PKE – which could lead to the tendency of increased concentrate refusals. It can be extrapolated from the data obtained from the study, that PKE can be fed to cows on pasture at 2.4 kg cow^{-1} day^{-1}, whilst reducing the concentrate fed in the milking parlour (6 kg) by 2.4 kg cow^{-1} day^{-1}.

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22.

Overcoming roughage shortages during the winter months in the southern Cape of South Africa

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Introduction

Kikuyu over-sown with ryegrass is the most widely used pasture system in the southern Cape of South Africa. As kikuyu remains dormant during the winter months (June to September), ryegrass is over-sown to fill the fodder-flow gap during these months. For this purpose, annual ryegrass types are preferred over perennial ryegrass types, as perennial ryegrass only establishes well into the spring, and cannot support intensive grazing during the coldest winter months (Dickinson *et al.*, 2004; Van der Colf, 2011). Due to the low temperatures and low light intensities experienced in the southern Cape region during the winter months, the growth of the ryegrass pasture is slightly inhibited, and growth rates can be as low as 30 kg DM ha^{-1} – whereas growth rates can be as high as 70 kg DM ha^{-1} during the summer (Fulkerson & Donaghy, 2001; Dickinson *et al.*, 2004). During the winter months, ryegrass pasture is characterised as having a very high nutritive content, a low concentration of structural components, and a low dry matter (DM). This translates into high crude protein and non-structural carbohydrate (NSC) concentrations, and low neutral-detergent fibre (NDF) and acid-detergent fibre (ADF) concentrations (Meeske *et al.*, 2006; Van der Colf, 2011).

Due to the low growth rate of ryegrass pasture during the winter months, the pasture has a longer growth cycle, and takes longer to mature – resulting in roughage shortages. Two main strategies have been developed to overcome these roughage shortages – namely, feeding additional lucerne hay, or some type of silage. Lucerne has to be bought in from outside, and the cost is very high (R2000 – R2600 ton^{-1}). The price of lucerne hay varies widely according to quality and demand, so further complicating financial planning during the already difficult winter months. Furthermore, smaller farms often do not have the capacity to store a large amount of lucerne hay. Silage can also be bought in for additional feeding, but is not always readily available, and is also costly. Ideally, excess pasture, or a cereal crop, should be ensiled on the farm itself, but many farms do not have the implements or excess roughage available to do this. Lucerne hay or silage is then commonly fed using ring feeders – resulting in a 10–20% wastage. In addition to the feeding of lucerne hay or silage, cows are put out to graze for half of the day, and also receive a concentrate supplement in the milking parlour. Concentrate supplements often have a high energy content which is readily available to the cow (Bargo *et al.*, 2003). This is achieved by including high levels of maize in the concentrate – but this makes the concentrate supplement expensive. The return on milk production decreases as level of concentrate feeding increases.

It has been shown that it is possible to replace a high starch concentrate supplement that is highly digestible, with a low starch and high fibre concentrate supplement that is less digestible – without negatively impacting on milk production or rumen health (Lingnau, 2011). The lower digestibility of the high fibre concentrate supplement and the high NDF concentration, helps to maintain the pH of the rumen, so optimising microbial activity. Due to these characteristics of a high fibre concentrate supplement, it could be possible to feed this concentrate supplement at higher levels, at the expense of pasture intake (Bargo *et al.*, 2003). Pasture is the cheapest feed source available, and should therefore be used to its full potential. However, the lower pasture availability during the winter months is a gap in the feeding programme.

The aim of the study was to determine whether feeding a high fibre concentrate supplement at higher levels, and restricting pasture allowance, could maintain a high level of milk production and rumen health and also overcome winter roughage shortages.

Materials and Methods

The study was carried out at the Outeniqua Research farm near George in the Western Cape Province of South Africa. The farm is situated at 22º 25' 222" E and 33º 58' 702" S. The study was conducted from July 2011 to September 2011 – spanning a period of 92 days. The mean temperatures experienced during the study were: 18.85°C (maximum) and 7.92°C (minimum) (ARC, 2011). The area received 247 mm rainfall during the study period (ARC, 2011), and a total area of 8.876 ha was used during the research. The pasture consisted of kikuyu (*Pennisetum clandestinum*) over-sown with annual Italian ryegrass (*Lolium multiforum*). The kikuyu portion of the pasture remained dormant during the research period (winter and early spring months), and therefore mainly ryegrass was available to the cows. The soil of the 8.876 ha area used for the study was characterised by a Katspruit soil form, of the family Lammermoor. Camps were fertilised with 42 kg N (LAN, limestone ammonium nitrate) ha^{-1}, after each grazing.

Forty eight lactating Jersey cows were blocked according to a 4 % fat-corrected milk yield (19.09 ± 2.23 kg), days in milk (103.9 ± 62.66), and lactation number (4.38 ± 1.82). Cows within blocks were then randomly allocated to one of the three treatments. These cows were used to determine the effect of the treatments on milk production and quality. Treatments were defined according to the amount of high fibre concentrate supplement allocated, as well as the level of pasture allocated (Table 1). The composition and nutritive content of the high fibre concentrate used during the study is shown in Table 2. Eight canulated Jersey cows were also used in the study. These cows were used to determine the effect of the treatments on rumen activity and health. Cows were divided into two groups, and allocated to either the LC or HC treatment. They were used in a cross-over design, where all cows were subjected to both treatments – LC and HC.

Table 1. Treatment specifications according to high fibre concentrate supplement intake, and pasture allowance

Parameter[1]	Treatment[2]		
	LC	MC	HC
Concentrate supplement intake (kg as is day^{-1})	4	7	10
Pasture allowance (kg DM day^{-1})	10	7	5
Farmlet size (ha)	3.57	2.92	2.2

[1] DM – Dry Matter
[2] LC – Low Concentrate; MC – Medium Concentrate; HC- High Concentrate

The three treatments were grazed separately – allowing for the pasture intake to be monitored and restricted. The total area of 8.876 ha was divided into 24 camps, and each camp was divided into two lanes. Each lane was measured before grazing using the rising plate meter (RPM) method, as first described by Castle (1976). The linear regression equation: $Y = 77.1 * H – 530$ – where Y = DM yield and H = RPM reading – was used to estimate the kg DM of pasture available per lane (Van der Colf, 2011). The total kg DM pasture available per lane, the pasture intake allocated to each treatment, and the number of cows per treatment were then used to determine the number of breaks in which the specific lane could be divided and grazed. Once the pasture had been measured, and the number of grazings calculated, polywire was used to lay out the strips for each grazing.

Once a lane of a camp had been grazed and the treatment had been moved to the next lane, the pasture yield was again measured using the RPM. During the adaptation period, the reading obtained from the RPM was used to determine how well the pasture had been used and how accurately the regression equation was able to allocate pasture. A reading between 10 and 12 is indicative of a pasture which had been used well; not too much pasture was wasted, neither was the pasture over-grazed.

Table 2. Ingredient and chemical composition of the high fibre concentrate supplement fed to all three high fibre concentrate supplement treatments

Ingredient	**g kg^{-1} (DM[1])**
Finely ground maize	130
Hominy chop	300
Wheat bran	391
Gluten 20	100
Molasses	40
Feed lime	22
Salt	6
Acid buff	6
Premix[2]	5
Nutrient	**g kg^{-1} (DM)**
Dry matter	898.84
Crude protein	145.30
Rumen undergradable protein (% CP)	380.79
Metabolisable energy (MJ ME/kg DM)	10.94
Neutral detergent fibre	230.61
Acid detergent fibre	87.21
Ether extract	41.59
Ash	74.07
Calcium	12.38
Phosphorous	6.94
Magnesium	3.82

[1] DM – Dry Matter

[2] Premix – 4 mg kg^{-1} Copper; 10 mg kg^{-1} Manganese; 20 mg kg^{-1} Zinc; 0.34 mg kg^{-1} Iodine; 0.2 mg kg^{1} Cobalt; 0.06 mg kg^{-1} Selenium; 6 x 10^6 IU Vitamin A; 1 x 10^6 IU Vitamin D_3; 8 x 10^3 IU Vitamin E

Milk yield was measured at every milking session, and milk samples were collected every second week. Pasture and high fibre concentrate supplement samples were collected on a weekly basis, and were pooled over two weeks for analysis at a later stage. Live weight and body condition score were also recorded at the commencement and completion of the study. A rumen study was carried out, where rumen pH and rumen activity was determined.

Milk production, milk composition, live weight and BCS data were subjected to an appropriate analysis of variance (ANOVA). Volatile fatty acids, in sacco Dacron bag study, and rumen pH data were subjected to a main effects ANOVA. All analyses were done with using the GLM procedure of SAS, Version 9.2 (SAS, 2008).

The null hypothesis was: Ho: $\mu_1 = \mu_2 = \mu_3 = \mu_a$. It was rejected where P<0.05. Student's t tests were used to confirm the results of the ANOVA and to compare the treatment means at a 5% significance level. Least squares means were used to calculate a pooled standard error of treatment means. Shapiro-Wilk tests were used to test for normality (Shapiro & Wilk, 1965).

Results and discussion

Milk-yield results are recorded in Table 3. Cows in treatment HC produced more milk than cows in treatment LC, due to the higher level of metabolisable energy consumed. It is known that the increase in milk production, per kg concentrate supplement, decreases as the level of concentrate supplement feeding increases (Kellaway & Harrington, 2044; Sairanen *et al.*, 2006) As such, the milk response of cows in treatment HC was not as large as expected – compared to cows in treatment LC – and did not differ at all from cows in treatment MC.

Milk-composition data collected during the study are recorded in Table 3. The milk-fat % of cows in treatment LC and MC did not differ, but were high according to breed standards. This is due to the high NDF concentration of the high fibre concentrate supplement, which results in increased acetate and butyrate production – which ultimately increases the milk-fat % (McDonald *et al.*, 2000; Bargo *et al.*, 2003; Lingnau, 2011). However, the milk-fat % of cows in treatment HC was lower than that in treatment LC and MC. This is because of the high levels at which the concentrate supplement was fed; when a concentrate supplement (even a high fibre concentrate) is fed at such high levels, a drop in rumen pH is experienced and cellulolytic bacteria become less active, acetate and butyrate concentration decreases, and milk-fat % decreases (Hoover, 1986; Van Soest *et al.*, 1991). Milk-protein % does not respond readily to dietary manipulation (Bargo *et al.*, 2003; Kellaway & Harrington, 2004), and as such no differences were found between either of the treatments. Somatic cell count (SCC) of cows did not differ between either of the treatments; furthermore, udder health was maintained even under high stocking rates.

Changes in body condition score (BCS) are shown in Table 3. BCS change did not differ between either of the treatments. BCS did improve slightly for all three treatments – which is expected of cows in mid to late lactation.

Table 3. Mean milk yield and milk-composition parameters (fat, protein, lactose, SCC and MUN) and LW and BCS of cows before and after the study of all three high fibre concentrate supplement treatments

Parameter[1]	Treatment[2]			SEM[3]	p-value
	LC	MC	HC		
Milk yield (kg cow^{-1} day^{-1})	16.18[a]	17.25[ab]	18.12[b]	0.486	0.029
4 % FCM (kg cow^{-1} day^{-1})	18.37	19.66	19.6	0.473	0.110
Fat (%)	4.92[a]	4.96[a]	4.58[b]	0.092	0.014
Protein (%)	3.61	3.63	3.54	0.042	0.306
Lactose (%)	4.67[a]	4.63[a]	4.5[b]	0.028	< 0.001
SCC (x 1000 mL^{-1})	174.8	211.26	206.13	24.842	0.602
MUN (mg dL^{-1})	11.62[a]	11.55[a]	9.95[b]	0.369	0.004
BCS before	2.34	2.30	2.23	0.062	0.461
BCS after	2.66	2.58	2.42	0.107	0.301
BCS change	0.31	0.28	0.19	0.082	0.537

[1] FCM – Fat Corrected Milk; SCC – Somatic Cell Count; MUN – Milk Urea Nitrogen; BCS – Body Condition Score
[2] LC – Low Concentrate; MC – Medium Concentrate; HC – High Concentrate; [3] SEM- Standard Error of the Mean
[a, b] Means in the same row with different superscripts differ ($p < 0.05$)

The rumen data collected during the rumen study period are shown in Table 4. The total VFA concentration of treatment LC and HC did not differ – although the acetate concentration and the acetate to propionate ratio of treatment HC was lower than treatment LC. This corresponds to the lower milk-fat % of treatment HC. There was no difference in the pH of the rumen of the two treatments, or in the NH_3-N concentrations. This all indicates that rumen function and health were maintained – even at such high levels of concentrate supplement and low pasture allowance levels.

Table 4. Average daily total volatile fatty acid, acetate, propionate, butyrate and ammonia nitrogen concentration, as well as acetate : propionate ratio and pH of the rumen – of eight canulated Jersey cows grazing kikuyu-ryegrass pasture

Parameter[1]	Treatment[2]		SEM[3]	p-value
	LC	HC		
Total VFA (mM L^{-1})	58.03	55.42	1.1730	0.167
Acetate (mM L^{-1})	30.04^{a}	25.98^{b}	0.7001	0.006
Propionate (mM L^{-1})	11.83	12.65	0.3763	0.173
Butyrate (mM L^{-1})	8.31	8.42	0.4098	0.850
Acetate : Propionate	2.67^{a}	2.15^{b}	0.0863	0.005
pH	6.38	6.11	0.1270	0.286
NH_3-N (mg dL^{-1})	24.82	23.26	1.6545	0.529

[1] VFA – Volatile Fatty Acids; NH3-N – Ammonia Nitrogen
[2] LC – Low Concentrate; HC – High Concentrate
[3] SEM – Standard Error of the Mean
[a, b] Means in the same row with different superscripts differ ($p < 0.05$)

Pasture allowance was lower for treatment HC than for treatments MC and LC, and pasture allowance for treatment MC was lower than for treatment LC. Lower pasture allowance corresponds to a higher stocking rate; this is reflected in Table 5. The % pasture saved was calculated in relation to treatment LC – which is typical of the grazing situation during the summer months. The pasture requirement of cows on the HC and MC treatment was reduced by 36.7% and 22.3% respectively, during the winter months – compared to the LC treatment.

Table 5 The mean stocking rates and % pasture saved, of three high fibre concentrate supplement treatments

Parameter	Treatment[1]			SEM[2]	p-value
	LC	MC	HC		
Stocking rate (cows ha^{-1})	5.07^{a}	6.07^{b}	7.64^{c}	0.278	<0.001
% Pasture saved	0	22.3	36.7	-	-

[1] LC – Low Concentrate; MC – Medium Concentrate; HC – High Concentrate
[2] SEM - Standard Error of the Mean
[a, b] Means in the same row with different superscripts differ ($p < 0.05$)

Conclusion

Milk production was increased when cows were fed >7 kg of a high fibre concentrate, while limiting pasture intake. Milk composition was slightly compromised, which could lead to a lowered milk price.

Overall, cow health and rumen health was maintained – as can be seen from the increase in BCS and the rumen data. By lowering pasture intake, it is possible to pace the grazing of pasture to match its slower growth cycle, i.e. one will not 'run out' of pasture. The higher levels of high fibre concentrate feeding did increase the time that cows spent in the milking parlour, although they were able to adapt 4 to 5 weeks after the new feeding programme started. As such, it is possible to overcome roughage shortages during the winter months by feeding high levels of a high fibre concentrate supplement, and lowering pasture allocation – although a drop in milk-fat % could be expected.

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23. Supplementing live yeast to lactating Jersey cows grazing ryegrass/kikuyu pastures

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Introduction

Commercial and emerging dairy farmers are under financial pressure as a result of low milk prices and increased input costs. Energy is the first-limiting nutrient for cows grazing pasture; therefore, energy supplementation is necessary for high-producing animals (Bargo *et al.*, 2002; Bargo *et al.*, 2003; Kolver & Muller, 1998).

In pasture-based systems, the concentrate is fed during the milking procedure. Consumption of large amounts of fermentable carbohydrates may lead to rumen acidosis (Slyter, 1976). Its effects may lead to reduced intake, lower fibre digestion (Owens *et al.*, 1998), and depressed milk yield.

Direct-fed microbials have become increasingly popular since the ban of antibiotics from the animal-feed industry in the European Union (EU). A direct-fed microbial such as live yeast, has the potential to stabilise rumen pH (Chaucheyras-Durand *et al.*, 2008; Desnoyers *et al.*, 2009), and stimulate enzymatic and cellulolytic rumen activities (Guedes *et al.*, 2008; Harrison *et al.*, 1988). Yeast cultures offer great potential in stabilising the rumen fermentation patterns, and, therefore for improving dry-matter intakes (DMI) (Desnoyers *et al.* 2009). This may increase milk production, milk composition parameters, and rumen volatile fatty acid concentrations (VFA) – which leads to higher profits (Desnoyers *et al.*, 2009).

The dairy industry and animal-feed manufacturers need controlled studies to determine if supplementation of yeast will be cost-effective. The aim of this study is to determine the effect of supplementing live yeast to lactating Jersey cows which are grazing kikuyu/ryegrass pasture during spring.

Materials and Methods

The study was done at the Outeniqua Research Farm in George, Western Cape Province, South Africa. Thirty multiparous, high-producing Jersey cows, between 30 and 120 DIM, were selected for the study. Cows were blocked according to their milk production on a 4 % fat-corrected milk basis, and their days in milk and lactation number. The cows within blocks were randomly assigned to one of the two treatment groups. Additionally, 10 cannulated animals were randomly allocated to one of the two treatment groups in a cross-over design, for the rumen study.

The treatment groups assigned were a no-yeast (control) and a yeast-treatment group – each consisting of 20 cows (15 cows and 5 cannulated cows). The 40 cows were weighed, and their body condition score (BCS) was determined at the beginning (31 August 2009 & 1 September 2009) and end (23 & 24 November 2009) of the experimental period.

Italian ryegrass (*Lollium multiflorum*), of the cultivar Jeane, was oversown (20 kg seed/ha) during March 2009, into kikuyu pasture under permanent irrigation. The Jersey cows were allowed to strip graze the Italian ryegrass pastures, and were allocated to a new strip after each milking – with clean water available *ad libitium* at all times. Fertiliser was applied post-grazing at 56 kg N (limestone ammonium nitrate) per ha. Pasture allocation was managed by conducting pasture height measurements before and after grazing – with an Ellinbank rising plate meter (RPM) (Fulkerson, 1997; Stockdale, 1984). Pasture regressions were done every seven days on the camp to be grazed the preceding day. In addition, a weekly pasture sample was taken at random on the strip to be grazed, and was pooled for every two weeks. All samples were analysed at the UP-Nutrilab (Department of Animal and Wildlife Sciences, University of Pretoria, Pretoria).

The concentrate that was supplemented was produced, mixed and pelleted at Nova feeds (Nova Feeds George, Industrial Area, George, Western Cape). The ingredients of the concentrate on a DM basis, were 82.4% maize meal; 10% soybean oilcake meal; 4% molasses syrup; 2% feedlime; 0.5% salt; 0.5% monocalcium phosphate; 0.3% magnesium oxide, and 0.33% dairy premix (contained Vitamin A, D3 and E; Zn; Mn; Cu; Se; Co and I). The nutrient composition of the concentrate was: ME of 12.41 MJ/kg DM; CP% of 12.43; Ca% of 0.; and P% of 0.47. The control and yeast-treatment concentrate had the same nutrient composition, with the yeast added to the yeast treatment before pelleting. The group of cows were sorted and split at each milking into their two groups – after which they received 3 kg of a dairy concentrate. The cows were milked twice daily. Milk yields were recorded daily, and milk samples were taken every two weeks. A composite milk sample (24 ml) of morning and afternoon milkings was sampled to determine, milk fat, protein, lactose, milk urea nitrogen (MUN), and somatic cell count (SCC).

The yeast product Levucell SC 10ME – Titan (containing *Saccharomyces cerevisiae* CNCM I-1077) was supplied by Lallemand S.A.S (19 rue des Briquetiers, 31702 Blagnac cedex, France). The Levucell SC 10ME is a micro-encapsulated formulation for premix and pelleted feeds. The yeast-treatment group had the yeast pelleted in with the dairy concentrate at a concentration of 167 g of yeast per ton of concentrate. This supports the requirement of an intake of 1 g yeast, per cow, per day, as specified by Lallemand. The yeast has a concentration of 1×10^{10} colony-forming units per gram (cfu/g). The cows in the yeast-treatment group therefore ingested 1×10^{10} cfu of yeast per day, and the concentrate contained 1.67×10^{6} cfu yeast, per gram of dairy-feed concentrate.

The cannulated cows were adapted to their respective diets and treatments for 15 days. Thereafter, the first run of sampling was done – which consisted of the pH and rumen-fluid sampling, and the *in sacco* study. A cross-over of treatments followed the first run, with a 21-day adaption period. The second run of the rumen-study sampling then commenced, where the same procedures were repeated.

Automatic pH/temperature loggers were inserted through the cannula of cows. The automatic pH loggers measure the pH throughout the day, over a period of four days, and at ten-minute intervals.

Rumen-fluid samples were extracted at 08:00, 14:00 (before milking), 20:00, and 02:00. Cannulated cows were safely restrained, their cannula plug was removed, and a handheld suction pump was inserted into the contents in the rumen to remove the liquid portion of the contents into a sample bottle. This was done for all 10 cannulated cows. The pH of the collected sample was measured immediately with a portable pH meter. Rumen samples were analysed for VFA and ammonia-N analysis.

The *in sacco* study involved the freshly cut ryegrass being placed into an oven, dried at 60°C for 72 hours, and then cut into lengths of 5 mm (Botha, 2003). Five grams of ryegrass was weighed and placed into a dacron bag, and sealed. Six dacron bags were placed in stockings (three bags per stocking), and the two stockings were inserted in each of the ten cannulated cows (Cruywagen, 2006). Three bags were removed after a 12 and 24 hour rumen incubation, washed, and then dried at 60°C for 72 hours (Botha, 2003). The residues from 3 bags incubated – per 0, 12 and 24 hours – were pooled for that hour. This was done for each of the ten cannula cows. The samples were analysed at the UP-Nutrilab for DM, OM, and NDF.

The ANOVA model (Statistical Analysis Systems Institute, 2009) was used to evaluate the differences between the control and yeast-treatment groups. Proc GLM repeated measures analysis of variance (Statistical Analysis Systems Institute, 2009). A P-value (P) ≤ 0.05 is considered significant (Samuels, 1989) – where a P ≤ 0.1 represents a tendency.

Results and discussion

The chemical composition of dairy concentrates and ryegrass pasture is shown in Table 1. The control and yeast concentrate consisted of identical ingredients, and the chemical analysis represents the similarities between the concentrates.

Table 1 Chemical composition of dairy concentrates fed, and ryegrass pasture grazed, by Jersey cows during the study (n = 6)

	Concentrate[2]		
Nutrient[1]	**Control**	**Yeast**	**Pasture**
DM (g/kg as is)	884	884	155[3]
CP (g/kg DM)	104	105	233
NDF (g/kg DM)	88.0	81.7	512
NDIN (g/kg DM)	25.5	24.0	247
ADF (g/kg DM))	34.3	32.4	305
ADIN (g/100g N)	37.1	40.5	165
EE (g/kg DM)	34.2	32.7	34.3
GE (MJ/kg)	17.2	17.1	17.4
IVOMD (%DM)	93.1	92.0	76.1
ME MJ/kg DM[4]	13.1	12.9	10.8
Ca (g/kg DM)	9.2	9.1	4.0
P (g/kg DM)	9.2	8.7	3.7

[1] DM – Dry Matter; CP – Crude Protein; NDF – Neutral Detergent Fibre; NDIN – Neutral Detergent Insoluble Nitrogen; ADF – Acid Detergent Fibre; EE - Ether Extract; GE - Gross Energy; IVOMD - *In Vitro* Organic Matter Digestibility; ME - Metabolisable Energy; Ca - Calcium; P – Phosporus.

[2] Control: dairy concentrate containing no yeast; Yeast: dairy concentrate containing yeast at 167g/ton.

[3] n = 11.

[4] ME = 0.82 × GE × IVOMD (Robinson *et al.*, 2004).

The milk yield, milk composition, somatic cell count, body weight, and body condition score, is presented in Table 2. Milk yield, the 4% FCM yield, milk protein and lactose percentages, the somatic cell count, body condition score, weights and their changes, did not differ significantly between treatments ($P > 0.05$). The milk-fat % however, was significantly higher ($P < 0.05$) for the yeast-supplemented cows at 4.24% – compared to the control group of cows of 3.99%. This is consistent with other authors who found a higher response in milk-fat parameters (Abd El-Ghani, 2004; Kalmus *et al.*, 2009; Longuski *et al.*, 2009; Moallem *et al.*, 2009; Piva *et al.*, 1993). Longuski *et al.* (2009), therefore concludes that the milk-fat depression occurring due to a high fermentable starch inclusion, can be lessened with yeast supplementation.

The average ruminal parameters such as the total and individual VFA concentration, individual VFA molar percentages, ammonia-N and pH measurements for the control and yeast treatments – are represented in Table 3. The average acetic and total VFA concentrations (mmol/L) for the control treatment was significantly higher ($P < 0.05$) than the yeast treatment. There was no difference in the fermentation patterns of other VFA, the pH, and the ammonia-N values, measured between treatments.

Higher VFA (Desnoyers *et al.*, 2009), pHs (Thrune *et al.*, 2009), ammonia-N (Kung *et al.*, 1997) and other acids such as acetic (Guedes *et al.*, 2008), propionic (Besong *et al.*, 1996) and butyric (Guedes *et al.*, 2008; Thrune *et al.*, 2009) have been measured due to yeast supplementation. Marden *et al.* (2008) and Guedes *et al.* (2008) illustrated that the simultaneous decrease in lactate and increase in propionate concentrations, may be a result of the greater conversion of lactate to propionate and the subsequent higher measure of ruminal pH.

Previous studies have shown no difference between treatments for yeast supplementation for ruminal parameters of VFA (Lehloenya *et al.*, 2008); pH; ammonia-N (Longuski *et al.*, 2009); acetic acid (Erasmus *et al.*, 2005); propionic acid (Thrune *et al.*, 2009), and butyric acid (Lascano & Heinrichs, 2009; Marden *et al.*, 2008; Wiedmeier *et al.*, 1987).

Table 2 Effect of live yeast supplementation on milk yield, milk composition, somatic cell count, body weight, and body condition score of cows grazing ryegrass pasture supplemented with 6 kg of dairy concentrate (as is), per day (n = 15)

Parameter	Experimental treatment[1]		SEM[2]	P
	Control	Yeast		
Milk yield (kg/d)	20.1	19.7	0.534	0.59
4 % FCM (kg/d)	20.1	20.3	0.513	0.72
Milk fat (%)	3.99[a]	4.24[b]	0.080	0.04
Milk protein (%)	3.51	3.58	0.049	0.31
Milk Lactose (%)	4.68	4.73	0.033	0.28
MUN (mg/dL)	10.7	11.0	0.390	0.58
SCC	254	155	76.466	0.38
BW beginning (kg)	335	331	6.232	0.65
BW end (kg)	371	369	2.320	0.59
BW change (kg)	37.8	36.4	2.259	0.67
BCS beginning	2.08	2.09	0.032	0.77
BCS end	2.27	2.23	0.052	0.65
BCS change	0.18	0.15	0.050	0.62

[1] Control: dairy concentrate containing no yeast; Yeast: dairy concentrate containing yeast at 167g/ton fed at 1g/cow/day.
[2] Standard Error of the Mean, FCM – 4 % fat-corrected milk; MUN – Milk urea N; BW – body weight; BCS – body condition score scale 1-5.
[ab] Means in the same row with different superscripts differ ($P<0.05$).

Table 3. Effect of live yeast supplementation on the average daily ruminal volatile fatty acids, ammonia-N, and pH measurements of cows grazing ryegrass pasture supplemented with 6 kg of dairy concentrate (as is) per day (n = 10)

Parameter	Experimental diets[1]		SEM[2]	P
	Control	Yeast		
Total VFA (mmol/L)	106.3[a]	99.3[b]	2.030	0.04
Acetic acid (mmol/L)	65.8[a]	61.3[b]	1.283	0.04
Propionic acid (mmol/L)	24.7	23.3	0.513	0.09
Butyric acid (mmol/L)	13.4	12.5	0.442	0.23
Valeric acid (mmol/L)	1.60	1.36	0.097	0.11
Iso butyric acid (mmol/L)	0.84	0.78	0.037	0.32
Total VFA molar (%)				
Acetic acid	62.0	61.8	0.348	0.69
Propionic acid	23.3	23.4	0.433	0.91
Butyric acid	12.4	12.7	0.286	0.53
Valeric acid	1.49	1.35	0.066	0.17
Iso butyric acid	0.79	0.79	0.030	0.94
NH3-N (mg/dL)	10.1	9.54	0.642	0.58
pH				
Portable average	6.01	6.06	0.044	0.52
Logger average	6.09	6.11	0.069	0.84

[1] Control: dairy concentrate containing no yeast; Yeast: dairy concentrate containing yeast at 167g/ton.

[2] Standard Error of the Mean.

[ab] Means in the same row with different superscripts differ ($P<0.05$).

The average percentage *in sacco* disappearance of DM, OM and NDF, of ryegrass, at 12 and 24 hours of ruminal incubation for the average, over both runs, is represented in Table 4. The average NDF, OM and DM disappearance was significantly higher ($P < 0.05$) for the yeast-treatment group of cows after a 12 and 24 hour incubation, compared to the control group. The average ruminal NDF disappearance of ryegrass in cows, supplemented with yeast, increased by 11.9% and 6.3% – compared to the control at the 12 and 24-hour incubation periods, respectively. This is consistent with previous studies, in which higher NDF digestibilities were measured (Plata *et al.*, 1994). Wiedmeier *et al.* (1987) state that yeast itself is not celluloytic, and that increasing numbers of cellulolytic bacteria found as a result – may be either from the yeast providing stimulatory factors (B vitamins), or branched chain-VFA. Plata *et al.* (1994) had measured higher protozoal numbers, which were stated to be the result of higher digestibilities.

Table 4. Effects of live yeast supplementation on the average percentage disappearance *in sacco* of neutral detergent fiber NDF, organic matter OM, and dry matter DM, of ryegrass, at 12 and 24 hours of ruminal incubation – for cows grazing ryegrass pasture supplemented with 6 kg dairy concentrate (as is), per day (n = 10).

Parameter	Experimental treatments[1]		SEM[2]	p
	Control	Yeast		
NDF 12h	46.6[a]	52.2[b]	0.963	0.004
NDF 24h	65.1[a]	69.2[b]	1.142	0.04
OM 12h	60.5[a]	64.3[b]	0.697	0.01
OM 24h	76.1[a]	78.4[b]	0.723	0.05
DM 12h	63.8[a]	67.2[b]	0.632	0.01
DM 24h	77.9[a]	80.0[b]	0.660	0.05

[1] Control: dairy concentrate containing no yeast; Yeast: dairy concentrate containing yeast at 167g/ton.
[2] Standard Error of the Mean.
[ab] Means in the same row with different superscripts differ ($P < 0.05$).

The assumptions of the mode of action of yeast, originate from results obtained over several experiments. The most widely supported theory is that the yeast culture stimulates the growth of certain microflora (Arakaki *et al.*, 2000; Nisbet & Martin, 1991). These collectively are the cellulolytic (Dawson *et al.*, 1990; Newbold *et al.*, 1996), amylolytic (Arakaki *et al.*, 2000), proteolytic (Kung *et al.*, 1997) and bacteria and protozoa (Arakaki *et al.*, 2000; Ishler *et al.*, 1996; Plata *et al.*, 1994). In the current study, though not measured, the results suggest that yeast had stimulated fibre- digesting microflora – either cellulolytic bacteria or protozoa.

Results between experiments vary widely, and the great variation – environmental influences excepted – could be because yeasts differ in their type of strain, the dosage effect between different products, the diet (forage and concentrate ratio), the genetic potential of the animal, the metabolic status of the animal, and the cfu of the yeast.

Conclusion

Live-yeast supplementation for Jersey cows on pasture, improved digestion with respect to higher disappearances of DM, OM and NDF proportions of the pasture. With higher digestibilities in the rumen, the yeast effects on stimulating the cellulolytic bacteria in the rumen, may be a possible explanation for the results in the current study – and this is well documented in previous studies. The milk-fat percentage was increased by live yeast supplementation.

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24. High fibre concentrate supplementation for Jersey cows on kikuyu/ ryegrass pasture systems

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Introduction

Dairy production systems are of great importance to human society. The increasing demand for milk and milk products exerts great pressure on dairy producers to increase their productivity and efficiency. Towards the end of 2009, South Africa had an estimated 540 000 dairy cows – with an average herd size of some 280 cows. Approximately 65% of the total milk production, during this same period, was produced from a pasture-based system (2010, K. Coetzee, pers. comm., Milk Producers' Organisation).

Increased pasture intake or supplementation of animals with protein and energy, are two ways to maintain high productivity of high-producing dairy cows (Schwarz *et al.*, 1995; Fulkerson *et al.*, 1998). According to Meeske *et al.* (2006) concentrates can contribute up to two thirds of the total cost of the dairy ration in pasture-based systems. Thus, costs within a pasture-based dairy system could be lowered, and profitability maximised, if pasture intake is increased, input costs are decreased by managing feed costs – while still maintaining nutrient levels. The recent increase in the cost of maize and soybean oilcake, has dramatically increased the input costs related to concentrates. Possible alterations to the concentrate – such as replacing high starch (high maize) concentrates with low starch concentrates (based on byproducts such as cottonseed hulls, soy hulls, beet pulp, distiller's grains, citrus pulp, wheat middlings, and whole cottonseed) – could markedly reduce input costs (Muller *et al.*, 2001). It could also uphold dairy production (Kibbon & Holmes, 1987; Spörndly, 1991; Fisher *et al.*, 1996; Sayers *et al.*, 2003) and possibly improve milk composition (Meijs, 1986; Khalili & Sairanen, 2000; Meeske *et al.*, 2009a).

The aim of this study was to determine the effect on milk production and milk composition, when supplementing dairy cows grazing kikuyu-ryegrass pasture – with low starch concentrate.

Materials and Methods

The study was conducted at the Outeniqua Research Farm, near George, in the Western Cape Province of South Africa (longitude 22º25.222' E, Latitude 33º58.702'S, altitude 193 m). The study took place from 30 July 2009 to 22 October 2009. The trial area consisted of 8.6 ha of pastures based on kikuyu (*Pennisetum clandestinum*) over-sown with annual ryegrass (*Lolium multiflorum* var. *italicum*, cv. Jeanne), and characterised by an Estcourt soil type (Soil Classification Workgroup, 1991). During the trial period – which was from late winter to early spring – the kikuyu component was largely dormant and pastures consisted predominately of ryegrass. Pastures were fertilised with 56 kg N (LAN, limestone ammonium nitrate)/ha, after each grazing by dairy cows.

Forty-five multiparous, high producing, lactating, Jersey cows [body weight, 340 ± 34.7 kg; milk yield, 19.6 ± 2.23 kg/d; days in lactation, 153 ± 33.5; lactation number, 3.6 ± 1.85; (mean ± SD)] from the Outeniqua Research Farm herd – were used in the production study of the trial. A randomised block design was used. The 45 cows were allocated to 15 groups of 3 each (blocking), on the basis of lactation number, DIM, and milk yield (MY). The three cows from each group were randomly allocated to one of three treatment groups (high starch, medium starch, and low starch). Ten lactating, cannulated Jersey cows [body weight, 332 ± 56.3 kg; milk yield, 17.3 ± 1.73 kg/d (mean ± SD)] were used during the rumen study. The ten cannulated cows were divided into two groups of five each – based on lactation number, DIM, and milk yield (MY). The five cows from each group were randomly allocated to one of two treatment groups (high starch and low starch).

Table 1. Composition of concentrates and pasture fed to Jersey cows grazing kikuyu/ryegrass pasture during the trial in spring (n = 6 for concentrate, n = 12 for pasture)

Ingredient[1]	Concentrate[2]			Pasture
	High starch	Medium Starch	Low starch	
Maize	80.37	40.67	20.67	
Hominy chop	0	25	35	
Wheat bran	0	11	18	
Gluten 20	0	11	18	
Soybean oilcake	11	4	0	
Molasses	4	4	4	
Feed lime	2	2.2	2.2	
MCP	0.5	0	0	
Salt	1	1	1	
Sodium bicarbonate	0.5	0.5	0.5	
MgO	0.3	0.3	0.3	
Vit and Min Premix	0.33	0.33	0.33	
Nutrient				
DM (g/kg)	880	874	869	147
Ash (g/kg)	75.3	85.1	95.1	135
OM (g/kg)	925	915	905	865
CP (g/kg)	146	140	143	259
EE (g/kg)	37.6	50.7	53.5	44.7
NDF (g/kg)	186	263	322	541
NDIN (g/kg NDF)	17.3	15.1	13.5	25.5
ADF (g/kg)	59.8	90.3	100	261
ADIN (g/kg ADF)	32.3	20.4	13.1	9.90
Hemicellulose (g/kg)	126	172	222	280
ADL (g/kg)	13.6	18.3	28.7	80.3
IVOMD	938	872	836	846
Starch (g/kg)	517	427	371	-
Starch : Hemicellulose	4.09	2.47	1.67	-
GE (MJ/kg)	15.3	15.5	15.6	16.6
ME MJ/kg DM	12.04	11.36	10.95	11.36

[1] DM – Dry Matter; OM – Organic Matter; CP – Crude Protein, EE – Ether Extract; NDF – Neutral Detergent Fibre; NDIN – Neutral Detergent Insoluble Nitrogen; ADF – Acid Detergent Fibre; ADIN – Acid Detergent Insoluble Nitrogen; ADL – Acid Detergent Lignin; IVOMD – *In Vitro* Organic Matter Digestibility; GE – Gross Energy; ME – Metabolisable Energy.
[2] High starch: Dairy concentrate containing 80% maize; Medium starch: Dairy concentrate containing 40% maize; Low starch: Dairy concentrate containing 20% maize.

The experimental period for the production study consisted of an adaption period of 14 days – followed by an experimental period of 70 days. The duration of the rumen study trial was 42 days, and consisted of a 14-day adaptation period and a 7-day data-collection period, whereafter cows were turned around on treatments and the same procedure was followed. Each cow received both concentrates during the course of the rumen study. All experimental animals grazed the same strip of pasture, with fresh pasture being allocated after each milking. Cows were given kikuyu/ryegrass pasture *ad lib* 24 hours a day, except for the duration of milking. The 45 cows were allocated a strip of 15 m by 150 m (depending on pasture DM yield of the specific strip) of fresh pasture daily. All cows grazed on the same pasture. Drinking water was available *ad lib* at all times. Treatment groups only differed in the composition of the concentrate supplementation (Table 1) fed at 6 kg/cow/day.

Crude protein content was similar for all three concentrates, at 143 g/kg DM, and high in pasture at 259 g/kg DM. Neutral detergent fibre increased from 186 g/kg DM in the high starch concentrate – to 322.1 g/kg DM in the low starch concentrate. Starch content decreased from 516.6 g/kg DM in the high starch concentrate, to 371.4 g/kg DM in the low starch concentrate. Similarly, the metabolisable energy content of the high starch concentrate was the highest at 12.04 MJ ME/kg DM, while it was the lowest at 10.95 MJ ME/kg DM with the low starch concentrate. The hemicellulose content of the high starch concentrate was low, and increased in the medium and low starch concentrate treatments. This – combined with the decrease in starch content of the low starch concentrate – resulted in a decrease in the starch to hemicellulose ratio, from 4.09 in the high starch concentrate, to 1.67 in the low starch concentrate.

An analysis of variance was performed using SAS 9.2 (2003–2009) for continuous variables. Assumptions of normality were tested to determine significant difference between means, and the student t-test was conducted at a 5% significance level.

Results and discussion

The rumen parameters of cows receiving high starch or low starch concentrate, are shown in Table 2. The total volatile fatty acid (VFA) concentration for high starch treatment was higher ($P < 0.05$) than that of low starch treatment. The rumen acetic acid, propionic, and butyric acid concentration, was higher ($P < 0.05$) in cows on the high starch concentrate treatment. Although there were differences in volatile fatty acid concentrations between the treatments, there was no difference ($P > 0.05$) in the acetate to propionate ratios between treatments. This was because there was no difference in the relative proportions of each of the volatile fatty acids – compared to the total volatile fatty acid concentration. Rumen ammonia nitrogen (NH_3-N) did differ significantly between the two treatments, with the high starch concentrate having a higher concentration than the low starch treatment. The mean ruminal pH did not differ ($P > 0.05$) between the treatments.

Table 2. Average daily ruminal volatile fatty acids, rumen NH_3-N ,and pH measurements of 10 cannulated, high-yielding Jersey cows grazing kikuyu/ryegrass pasture, and fed 6 kg (as is) of high and low starch concentrates during October (n = 10).

Parameter	Treatment [1]		SEM [2]	P
	High starch	Low starch		
Total VFA (mM/L)	122[a]	113[b]	1.92	0.01
Acetic acid (mM/L)	87.7[a]	82.6[b]	1.72	0.05
Propionic acid (mM/L)	19.0[a]	17.3[b]	0.368	0.01
Butyric acid (mM/L)	11.9[a]	10.4[b]	0.281	0.01
Acetate : Propionate	4.90	4.99	0.102	0.56
NH_3-N (mg/dL)	21.2[a]	18.8[b]	0.687	0.04
pH	6.05	6.08	0.031	0.47

[1] High starch: Dairy concentrate containing 80% maize; Low starch: Dairy concentrate containing 20% maize.
[2] Standard Error of Mean
[ab] Means in the same row with different superscripts differ ($P < 0.05$).

The milk-production parameters are shown in Table 3. Milk yield and fat-corrected milk did not differ ($P > 0.05$) between treatments. It can be argued that the milk yield of the high starch treatment should have been higher because of the higher metabolisable energy content of the concentrate given – but this was not the case. The result concurred with several authors, who found no significant effect on milk production when low starch concentrates were compared to high starch concentrates (Kibbon & Holmes, 1987; Spörndly, 1991; Fisher *et al.*, 1996; Sayers *et al.*, 2003).

The milk-fat percentage of the low starch treatment was higher ($P < 0.05$) than that of the high starch treatment. There was no significant difference in the milk-fat percentage between the high starch and medium starch-treatment groups, although the medium starch-treatment group had a tendency to be higher. This concurred with the findings of Meeske *et al.* (2009a), where a significant difference in butterfat percentage between high starch and low starch treatments was reported. Most authors, however, found no effect of low starch versus high starch supplementation, on butterfat percentage (Meijs, 1986; Kibbon & Holmes, 1987; Schwarz *et al.*, 1995; Khalili & Sairanen, 2000; Sayers *et al.*, 2003). Milk-protein percentage, lactose percentage, milk urea nitrogen content, and somatic cell count did not differ significantly between treatments. These results indicate that it is possible to increase butterfat percentage of dairy cows on pasture while keeping the milk production constant – by feeding byproducts with lower metabolisable energy levels.

Body weight and body condition score parameters, for the duration of the trial, are also shown in Table 3. The bodyweight change and body-condition score change was similar (P > 0.05) over the period of the trial. These results are similar to previous studies, with most authors indicating that supplementation type has little effect on live-weight change or body-condition score of lactating dairy cows (Kibbon & Holmes, 1987; Spörndly, 1991; Fisher *et al.*, 1996; Khalili & Sairanen, 2000; Sayers *et al.*, 2003; Meeske *et al.*, 2009a). The fact that cows didn't lose bodyweight or body-condition score between treatments, indicates that cows did not use live weight to maintain milk production in the low starch treatment, and that the pasture and concentrate were capable of providing sufficient energy to maintain milk production.

Table 3. Milk production, milk composition, body weight, and body-condition score of high yielding Jersey cows grazing kikuyu/ryegrass pasture fed 6 kg (as is), with high, medium and low starch concentrates during October (n = 15).

Parameter [1]	**Treatment** [2]			**SEM** [3]	**P**
	High starch	**Medium Starch**	**Low starch**		
Milk yield (kg/cow/d)	19.9	20.2	19.0	0.522	0.28
4% FCM (kg/cow/d)	20.0	21.6	21.1	0.579	0.17
Milk Fat (g/100 g)	4.07[a]	4.49[ab]	4.75[b]	0.152	0.01
Milk fat yield (kg/d)	0.804[a]	0.901[b]	0.898[b]	0.031	0.05
Milk Protein (g/100 g)	3.53	3.63	3.59	0.065	0.53
Lactose (g/100 g)	4.59	4.71	4.69	0.041	0.11
MUN (mg/dL)	17.8	17.1	17.3	0.303	0.48
SCC	255	163	241	53.1	0.43
BW start (kg)	333	337	349	7.46	0.29
BW end (kg)	357	366	373	7.37	0.31
BW change (kg)	+23.5	+29.3	+23.8	3.02	0.32
BCS start	2.10	2.08	2.18	0.054	0.39
BCS end	2.42[a]	2.23[ab]	2.47[a]	0.074	0.08
BCS change	+0.32[a]	+0.15[ab]	+0.28[a]	0.054	0.09

[1] FCM – Fat Corrected Milk; MUN – Milk Urea Nitrogen; SCC – Somatic Cell Count; BW – Body Weight; BCS – Body Condition Score.
[2] High starch: Dairy concentrate containing 80% maize; Medium starch: Dairy concentrate containing 40% maize; Low starch: Dairy concentrate containing 20% maize.
[3] Standard Error of Mean.
[ab] Means in the same row with different superscripts differ (P < 0.05).

The metabolisable energy requirement for maintenance (based on the average live weight of each treatment group) and lactation (based on the average milk yield of each treatment group), and the body-condition score gain of each treatment group – as obtained from the NRC (2001) – is shown in Table 4. Using these requirements for each individual treatment group, a back calculation was made to estimate the pasture intake needed to maintain the level of production of each treatment group. The results indicated that a daily pasture intake of 9.07 kg DM pasture/cow/day, for the high starch treatment, 9.94 kg DM pasture/cow/day for the medium starch treatment, and 10.07 kg DM pasture/

cow/day for the low starch treatment – was required. Thus, cows supplemented with the low starch treatment would have taken in 1.00 kg DM/cow/day more pasture than the high starch treatment.

Table 4. The mean Metabolisable energy requirement for maintenance and lactation for each treatment group (high, medium and low starch concentrates) of high-yielding Jersey cows grazing kikuyu/ryegrass pasture, as well as the mean estimated pasture intake of each treatment group.

Parameter [1]	Treatment [2]		
	High Starch	Medium Starch	Low Starch
ME required for maintenance (MJ) [3]	56.40	57.28	58.45
ME required for lactation (MJ) [3]	104.81	113.19	109.00
ME required for BCS gain (MJ)	5.68	2.66	4.97
Total ME requirement (MJ)	166.89	173.13	172.42
ME obtained from concentrate (MJ)	63.81	60.21	58.04
ME required from pasture (MJ)	103.07	112.93	114.38
Pasture intake (kg DM/cow/day)	9.07	9.94	10.07

[1] ME – Metabolisable Energy; BCS – Body Condition Score.
[2] High starch: Dairy concentrate containing 80% maize; Medium starch: Dairy concentrate containing 40% maize; Low starch: Dairy concentrate containing 20% maize.
[3] Obtained from NRC (2001).

Economic Evaluation

During the economic evaluation of the three treatments, it was assumed that all factors were the same for all three concentrate treatments. Calculations were done for a herd consisting of 280 cows in milk. The only variables taken into account were feed price and milk price, based on milk composition, and the difference in pasture intake. The feed price was obtained from NOVA feeds at the start of the trial, milk price was obtained from Nestlé in September 2010, and the pasture price was derived from Meeske *et al.* (2009b). The milk price, feed price, and pasture price, for each treatment, are presented in Table 5.

Using the average milk production of each treatment group, the production, per day, for 280 cows in milk, was estimated. The high starch treatment would produce 5572 kg milk/day – amounting to an income of R17 106.04/day at the stated milk price. The medium starch treatment would produce 5656 kg milk/day and R18 155.76/day. The low starch treatment had the lowest yield, at only 5320 kg milk/day, but also achieved the highest milk price – which amounted to a total of R17 183.60/day. The highest daily income was obtained by the medium starch treatment, and the lowest by the high starch treatment. On a monthly basis, the medium starch treatment resulted in an increase in milk income of R32 016.46 for 280 cows in milk, compared to the high starch treatment. The difference between the high and low starch treatments would only be R2 365.58.

Cows were fed 6 kg of concentrate daily on an 'as is' basis. This amounted to a cost of R16.86, R 14.70, and R13.68, per cow, per day, for the high starch, medium starch, and low starch treatments, respectively. With 280 cows in milk, the daily concentrate cost of each treatment would be R 4720.80, R4116.00 and R3830.40, for the high starch, medium starch and low starch treatments, respectively. The medium starch treatment resulted in a decrease in input cost of R18 446.40 for 280 cows in milk, on a monthly basis. The decrease in input cost – when changing from the high starch to the low starch treatment – would be even larger, at R27 157.20. If only feed cost was taken into account, the low starch treatment would be the most economical option. This was, however, expected given the lower cost of byproducts.

As was calculated in Table 4, each treatment group had a different pasture intake. Pasture price was set at R1.11/kg DM (Meeske *et al.*, 2009b). For the medium starch treatment this resulted in a daily increase in costs of R 270.40 for 280 cows in milk over high starch treatment, and for low starch treatment the daily cost increase caused by increased pasture intake amounted to R 310.80 – compared to the high starch treatment.

When the milk-price calculation was combined with that of the feed cost and pasture cost, the medium starch treatment would have had a monthly net gain of R42 215.78 over that of the high starch treatment. Furthermore, the low starch treatment would have had a net gain of R20 043.38 over that of the high starch treatment. If both the gain in milk price, and the reduction in feed cost, were taken into consideration, the medium starch treatment would be the most economical option. The possibility of replacing maize with low starch (high fibre) byproducts, and the savings associated with the change, is subject to maize price and byproduct prices.

Table 5. Milk price according to milk composition, feed price, and pasture price, for high starch, medium starch and low starch concentrate treatments.

Parameter	**Treatment**		
	High starch	**Medium starch**	**Low starch**
Milk yield (kg/cow/day)	19.9	20.2	19.0
Milk yield (kg/280 cows/day)	5572	5656	5320
Milk Fat (g/100g)	4.07	4.49	4.75
Milk Protein (g/100g)	3.53	3.63	3.59
Lactose (g/100g)	4.59	4.71	4.69
MUN (mg/dL)	17.8	17.1	17.3
Milk price (R/L)	R 3.07	R 3.21	R 3.23
Milk income (R/280 cows/day)	R 17 106.04	R 18 155.76	R 17 183.60
Increase in daily income	R 0.00	R 1 049.72	R 77.56
Feed price (R/ton)	R 2 810	R 2 450	R 2 280
Feed price (R/cow/day)	R 16.86	R 14.70	R 13.68
Feed price (R/280 cows/day)	R 4 720.80	R 4 116.00	R 3 830.40
Decrease in daily input cost (R)	R 0.00	R 604.80	R 890.40
Pasture price (R/kg)	R 1.11	R 1.11	R 1.11
Pasture price (R/cow/day)	R 10.07	R 11.03	R 11.18
Pasture price (R/280 cows/day)	R 2 818.96	R 3 089.35	R 3 129.76
Increase in daily input cost (R)	R 0.00	R 270.40	R 310.80
Net daily profit	R 0.00	R 1 384.12	R 657.16
Net monthly profit	R 0.00	R 42 215.78	R 20 043.38

R = South African Rand.

Conclusion

At the current rate of supplementation (6 kg, per day, as is, divided into two feedings of 3 kg each) the rumen environment was unaffected. Although the volatile fatty acid concentrations were lower in the low starch treatment, this did not result in a higher rumen pH. If rumen pH is used as an indicator of a healthy and balanced rumen environment, then rumen environment was not improved by the low starch supplementation.

There were no differences ($P > 0.05$) found between treatments for daily milk yield (kg/cow/day). Thus, the low starch concentrate – with a lower metabolisable energy content – did not impact negatively on milk yield.

Butterfat content (g/100g) and butterfat yield (kg/cow/day) was increased ($P < 0.05$) by the low starch treatment, as was the milk-fat yield ($P < 0.05$) of the medium starch treatment. Furthermore, the higher butterfat results in a large impact on the milk price that dairy producers obtain. The milk protein content, milk urea nitrogen, and somatic cell count, showed no difference ($P > 0.05$) between the treatments.

The results suggest that it is possible for dairy producers in the southern Cape region to make use of byproducts such as hominy chop and wheat bran, as a main source of supplementation for dairy cows on pasture-based systems – without losing milk production. Because byproducts are usually cheaper, their inclusion can lead to lower input costs, while milk production output is maintained. The improved butterfat content of the milk from the low starch treatment, could result in a potentially higher milk price. In cases where milk buyers set an upper limit to producers for daily milk bought, this form of supplementation can be a mechanism whereby milk production is kept constant – while input costs are decreased. The data from the research also help the dairy producer make a decision based on several other factors. For example, if the maize price is high, the low starch concentrate would be a more feasible solution, but during times of low maize prices, no change would be required.

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25. High fibre concentrates for Jersey cows grazing kikuyu/ryegrass pasture

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Introduction

The cost of maize grain and soybean oilcake has increased drastically during the past year. Conventional dairy concentrates contain 70–80% maize grain and 8–12% soybean oilcake. Partial replacement of maize and soybean oilcake with high fibre byproducts like hominy chop, maize gluten, and bran, could be very cost effective if milk production can be maintained. Meijs (1986) found that feeding high fibre concentrates to cows grazing perennial ryegrass – instead of high starch concentrates – increased pasture intake and milk production. Sayers *et al.* (2003) showed that maize, barley and wheat can be replaced with citrus pulp, sugar-beet pulp, wheat middlings and cottonseed, in the concentrate for dairy cows grazing perennial ryegrass – without affecting milk production.

The aim of the study was to determine the effect of replacing maize and soybean oilcake with hemicellulose-rich byproducts like hominy chop, gluten 20, and wheat bran – in the concentrate fed to Jersey cows grazing high-quality ryegrass pasture from September to October.

Materials and Methods

Three concentrates were formulated to contain a high (80.4%), medium (40.7%), and low (20.7%) maize-grain content – as shown in Table 1. Maize grain was replaced by hominy chop, wheat bran and gluten 20. As byproducts replaced maize in the concentrate, the starch content decreased from 57% to 36%, and the hemicellulose content increased from 6% to 18%.

Forty five Jersey cows were divided into 15 blocks. The milk production, days in milk, and lactation number of cow within each block, were similar. Cows within blocks were randomly allocated to treatments – resulting in 15 cows/treatment. Cows were fed 6 kg as is, of dairy concentrate per day (3 kg at each of two milkings). Milk production was recorded daily, and milk composition every 14 days. Cows grazed as one group on ryegrass (cv Energa at 20 kg/ha over-sown into kikuyu during March 2008) – with a 28-day grazing cycle from September to October. Pasture was fertilised with 56 kg N (LAN) after each grazing. Cows were weighed and condition was scored (1–5 scale) on two consecutive days, at the start and end of the experimental period. The experimental period consisted of an adaptation period of 10 days, and a measurement period of 40 days (September to October).

Table 1. Ingredients and composition of dairy concentrates, with different levels of byproducts.

Ingredient	**High maize**	**Medium Maize**	**Low maize**
Maize	80.37	40.67	20.67
Hominy chop	0	25	35
Wheat bran	0	11	18
Gluten 20	0	11	18
Soybean oilcake	11	4	0
Molasses	4	4	4
Feed lime	2	2.2	2.2
MCP	0.5	0	0
Salt	1	1	1
Sodium bicarbonate	0.5	0.5	0.5
MgO	0.3	0.3	0.3
Premix	0.33	0.33	0.33
	91.37	91.67	91.67
Nutrient			
DM (%)	89.1	88.9	88.7
CP (%)	13.0	13.0	13.0
RUP (% of CP)[1]	60.2	54.2	50.3
ME (MJ/kg)	12.7	11.6	11.0
NDF (%)	11.1	22.0	27.8
ADF (%)	5.08	8.16	9.84
Hemicellulose (%)	6.04	13.78	17.98
NFC (%)[2]	64.1	52.0	45.4
Starch (%)	57.1	43.7	36.4
Fat (%)	4.53	5.95	6.5
Ca (%)	0.98	0.94	0.94
P (%)	0.43	0.50	0.60

[1]RUP: Rumen undegradable protein, [2]NFC: Non Fibre Carbohydrate

Results

The milk production, milk composition, live weight, and condition score – is shown in Table 1. Milk production did not differ between treatments. The milk fat % of cows on the low maize concentrate was higher ($P<0.05$) than that of cows on the high maize treatment. This resulted in a higher fat-corrected milk production for the low maize treatment. Milk protein and milk urea nitrogen did not differ between treatments. Live weight and condition score were not affected by concentrate treatments. Depending on the price of maize and byproducts, the cost of a concentrate may be reduced when maize is replaced with byproducts.

Table 2. Milk production, milk composition, live weight and condition score, of cows supplemented with 6 kg of concentrate – with a low, medium or high level of hemicellulose, while grazing annual ryegrass pasture (n = 15).

Parameter	High Maize	Medium Maize	Low Maize	LSD1
Milk production (kg/day)	21.0	20.8	20.1	1.37
FCM (kg/day)	19.9^{b}	20.7^{ab}	21.3^{a}	1.37
Milk fat %	3.66^{b}	4.03^{ab}	4.41^{a}	0.451
Milk protein %	3.45	3.55	3.42	0.168
MUN mg/dl	17.8	17.8	18.1	1.22
Live weight at start (kg)	385^{a}	354^{b}	358^{b}	27.3
Live weight at end (kg)	409	382	385	28.5
Live weight change (kg)	24	28	27	9.16
Condition score start (1–5)	2.38^{a}	2.27^{ab}	2.17^{b}	0.190
Condition score end (1–5)	2.40	2.27	2.23	0.207
Condition score change	0.02	0.00	0.06	0.142

[1]LSD = Least Significant Difference, ab Means in the same row with different superscripts, differ significantly ($P<0.05$).

Conclusion

It is concluded that lowering the starch content and increasing the hemicellulose content of a dairy concentrate – by replacing 75% of maize grain with hominy chop, wheat bran and gluten 20 – increased 4% fat-corrected milk production and milk-fat content. Including high-fibre feeds like hominy chop, wheat bran and gluten 20 in dairy concentrates for cows grazing high quality ryegrass pasture seems promising.

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26. Dairy research in the early years at the Outeniqua Research Farm

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Introduction

Dairy research at the Outeniqua Research Farm has been conducted for almost 50 years. In the early years, the emphasis of dairy research was to train and educate dairy farmers in the area, in order to apply better management practices. Experiments often had a clear demonstrative value – although scientific principles were not ignored in their design. At that stage, dairy farming was conducted mostly on a small scale. The milking of cows was more labour-intensive in comparison to present-day milking parlours – while some farmers were still using hand-milking. Cows were usually tied up in a barn – each at its own feed trough, where part of the daily feed was provided. Milking was often done while cows were eating. Milk was collected in cans and transported in them to the nearest dairy. Sometimes the milk was separated on the farm and the cream transported to the nearest creamery, by bus or train. Skimmed milk was fed to pigs because there was little demand for it. The dairy industry developed slowly and there was a concerted effort to increase production. Later – on-farm milk collection started, and farmers had to install bulk tanks. For this, milk buyers provided tanks to farmers on a rental basis. On farms making use a bucket-milk system, milk had to be poured into the bulk tank by hand. This was later replaced with inline systems, so reducing the manual labour required for milk collection.

The development of the dairy industry in the sourthern Cape was largely driven by the technical advisers of dairy companies, such as Nestlé. Because of the mild climate and relatively stable rainfall, progressive farmers recognised – early on – the potential of the area for dairy production. There were, however, production problems. A request was therefore put forward to the then Department of Agricultural Technical Services, for the establishment and development of a research farm to solve these problems. Problems included the poor quality of the soils because of trace-element shortages, while pasture production was poor because of soil quality and unsuitable pasture species.

Motivation for dairy research in the George-Knysna area was presented in 1972 – in probably the first dairy-research project proposal. The motivation included statements of successfull pasture production in the area, while milk powder, butter and cheese factories in the area provided a market for milk. Cultivated pastures such as ladino clover, ryegrass, lucerne and kikuyu, were abundantly available – especially in the spring. However, the milk yield of cows was low because of poor genetic merit – as the artificial insemination industry was only then being developed, with farmers using their own home-bred bulls for breeding. Possibly, some crossbred cows were also being milked, as well-bred, high producing cows were not readily available in the area, or were expensive. Farmers did not realy make use of concentrate feeding – as this increased the cost of milk production. Farmers, being conservative, were reluctant to feed “from the bag”.

First dairy research activities

Available information indicates that the first dairy-research project was initiated in the early 1970s. Research was administered from the head office of the Winter Rainfall Region in Stellenbosch – with Mr. Coenraad Brand the responsible officer for dairy research. Mr Gerrit van der Merwe was the technician responsible for the practical execution of research protocols. The dairy herd at the Outeniqua Research Farm was small, and departmental funds limited. This resulted in studies taking a long time to complete. A discussion of some of the early projects is now presented:

1. In 1974, approval was obtained for the project, W-Oq 18/2 – where the milk-production potential in the George-Knysna area was to be determined. The project involved the evaluation of different feeding programmes – comparing the feeding value of silage and pasture as roughages for

lactating dairy cows. This project must have been discussed or proposed earlier than this, as the title of the project appears on a 1969 list of projects of the Dairy Liaison Committee of the Winter Rainfall Region. The aim of the project was described as: "to evaluate procedures with regards to management, feeding and housing of dairy cows in order to find practical recommendations for the George-area". This indicates that it would have been a comprehensive project, with possibly a number of sub-projects. However, with the exception of the feeding part of cows, other study areas did not receive any attention, or were not reported on. It was also recommended that the economic implications of the results would be of great value in a dairy extension programme. Mr Johan Blomerus – a newly appointed agricultural economist in the southern Cape area – made himself available for such an analysis. The study involved 3 groups of 15 cows each from the Outeniqua dairy herd. Different feeding programmes were compared – i.e. (1) maize silage and lucerne hay fed during the day and cultivated pasture at night, (2) only lucerne hay during the day from 10:00 until the afternoon, ith milking and available pasture during the night and after morning milking, and (3) maize silage and lucerne hay during the day and night without any pasture. Lucerne hay was fed at 0.5% of live weight of cows, while maize silage was fed *ad libitum*. All cows received the same 14% CP concentrate at 6, 4 and 2 kg, per cow, per day – for the intervals 1-60, 61-150 and 151-300 days after calving respectively. The lactation milk production results from this study are presented in the following table:

		Treatments		
Phase	**Parameters**	**1**	**2**	**3**
1	Milk yield (kg)	3402	3777	2579
	Fat (%)	5.02	4.78	4.95
	Fat yield (kg)	171	181	128
2	Milk yield (kg)	3757	4142	2597
	Fat (%)	5.05	4.77	5.00
	Fat yield (kg)	190	198	130

Cows on pasture (Group 2) produced the most milk in both phases. The milk and fat yield of cows in Group 3 – receiving *ad libitum* maize silage and lucerne hay – was the lowest in both phases. These results demonstrated the potential value of cultivated pasture for the production of industrial milk. Although expected, because of the lower fibre content of pasture, the fat percentage of the milk of cows on pasture was reduced by only about 5% – while the fat yield was still high. The study further showed that the maize silage used in the study did not provide sufficient energy and protein to support a high milk yield. A cost analysis also indicated that the production cost, per hectare, on dry lands and fully-irrigated pastures were the lowest and highest respectively. A final report of this study was published in the Elsenburg Journal (Muller, 1982a).

2. A memorandum of 7 December 1976 stated that "at a previous Dairy Liaison Committee meeting it was decided that the study group should present descriptions of different calf rearing systems which could be used in a demonstration trial". The rearing of replacement heifers – according to an early weaning system developed by Prof Frans van der Merwe at Elsenburg, and using limited amounts of milk or milk replacer together with a calf starter meal – was introduced and explained to farmers at a number of farmers' days and short courses, with apparently limited application. For this reason, it was decided to conduct a demonstration trial using two systems generally used by farmers – in comparison to the recommended system. The project, W-Eb 93/7, with the title: Evaluation of calf rearing systems in the George-Knysna area" was proposed and accepted in 1978. As part of the motivation for the study it was mentioned that in 1972 there were 14 000 cattle in that area – of which 75% were dairy cattle. The calf-rearing project started in 1978 with 11 Jersey calves – with more to follow from cows calving down. The treatments were as follows: (1) calves kept in a group, fed chicken laying pellets *ad libitum* and pasture together with full-cream milk up to 12 weeks of age; (2) calves fed a milk replacer and chicken laying pellets up to 10 weeks of age, after which a home-mixed concentrate mixture was fed; and

(3) calves kept in individual crates, fed full-cream milk at 10% of body weight, up to one month of age, while a calf starter meal was fed *ad libitum* from two weeks to 12 weeks of age.

The average daily gain of Jersey heifers, from birth to 12 weeks of age, differed (P<0.05) between the three systems – being 0.49, 0.39 and 0.46 kg per day for groups 1 to 3 respectively. The feeding costs of the three systems were compared, and without taking the pasture cost into consideration, it seems that the cost for system 1 was about 28% higher than the early-weaning system (system 3). Although the feeding cost of system 2 was 14% lower than that of system 3, the growth rate of these heifers was also lower. The rearing cost per kg of live weight gain was 90.65, 74.32 and 73.42c/kg – for systems 1, 2 and 3 respectively. This demonstration trial showed that a calf-rearing system with limited milk feeding, and a commercial calf-starter meal, provided the best results for Jersey heifers. A final report of the study was later published in the Elsenburg Journal (Muller, 1982b).

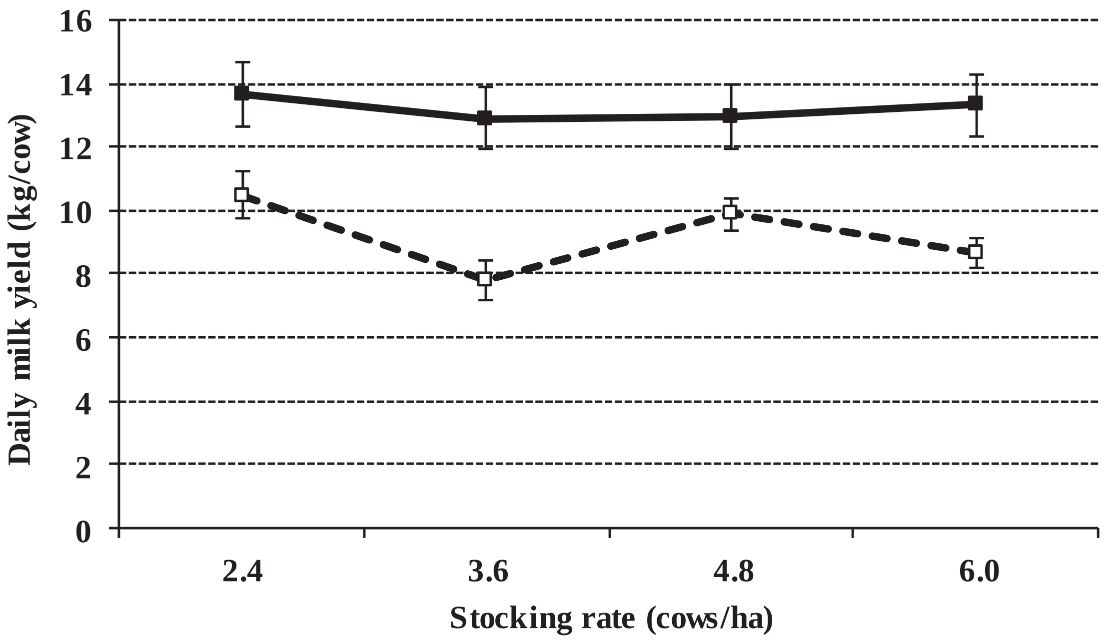
3. A study that is the basis of current research at the Outeniqua Research Farm, was started in 1979. The George-Knysna area was developing into an important dairy-producing area, although the amount of milk produced in the area was low. This was attributed to the erratic rainfall pattern and the inherent low milk production of cows. Although the cost of milk production on a pasture-based system is low, farmers were reluctant to feed large amounts of concentrates, as they were uncertain whether the response in milk yield would be economical. The aim of the study was to determine the effect of different levels of concentrate feeding on milk yield, and milk composition and profitability of Jersey cows. Some 45 Jersey cows from second to fifth lactation were used in the study – to be conducted over two lactation periods. Cows were fed a 12% CP concentrate at three levels – i.e. 0, 0.25 and 0.45 kg concentrate per kg of milk produced. Cows in the different treatments were put on cultivated grass-clover pastures, further supplemented with lucerne hay fed at 0.5% of the body weight of cows. The different amounts of concentrate were fed in the milking parlour. For high producing cows having to consume a large amount of concentrates – an additional feeding period was allowed outside the milking parlour. Results from this trial are presented in the following table:

Production parameters	**Lactation 1**			**Lactation 2**		
	Concentrate level (kg/kg milk)			**Concentrate level (kg/kg milk)**		
	0	**0.25**	**0.45**	**0**	**0.25**	**0.45**
Milk (kg)	3667	4494	4894	3610	4642	5112
Fat (%)	5.09	5.06	4.91	5.09	4.90	4.71
Fat (kg)	187	227	240	184	227	241
Protein (%)	4.08	4.28	4.27	4.19	4.31	4.30
Protein (kg)	150	192	209	151	200	220
Concentrate fed per cow (kg)	-	1221	2414	-	1349	2614
Response (kg milk/kg concentrate)	-	0.68	0.50	-	0.77	0.57
Gross margin over concentrate cost (R)	1165	1054	792	1147	1435	1544

As expected, milk yield increased with more concentrates in the total diet of cows. The response on milk yield also declined with more concentrates in the diet. At first glance, these results seem to question the profitability of feeding high levels of concentrates to cows on cultivated pastures. The results from this study was presented at the 1987 Congress of the South African Society for Animal Science (Muller, 1987). An article on the study was later published in the Elsenburg Journal (Muller, 1988). Earlier – an article appeared in the *Landbouweekblad* – which drew some comments from feed representatives. Notwithstanding some negative responses – further work at Outeniqua using a different strategy of concentrate feeding, provided similar results. This study further showed that the way in which the amount of concentrates to be fed was calculated, was of lesser importance than the amount of concentrates fed. The general recommendation from the first research still applies – that feeding high concentrate levels does not always make economic sense. Better economic results are possible in systems where pasture availability is limited – with concentrates supplementary to other feeds, instead of replacing the pasture in the total diet.

The replacement effect of pasture due to concentrate feeding was not considered in the original trial design – as the aim then was to improve the milk yield, per cow. Because of the replacement of pasture by more concentrates in the total diet, cows actually consume less pasture – resulting in an increase in the carrying capacity of the pasture system. This also applies to the supplementation of other forages, such as hay or silage. Therefore, in a pasture-based system, production per hectare is more important than the production per cow. This provided a new dimension into pasture-based dairy research. Increasing production per hectare is determined by stocking rate – i.e. the number of cows per hectare. As pasture production is affected by a number of factors – only guidelines are presented at present. In practice, however, the carrying capacity of cultivated pasture is the first question that farmers raise. In an attempt to address this issue, a short-term study (Muller & Van der Merwe, 1993) was conducted at the Outeniqua Research Farm. Two concentrate feeding levels (no concentrate and concentrate at 2% of live weight) were fed to cows on pasture at four stocking rates – i.e. 2.4, 3.6, 4.8 and 6.0 cows per ha. The impact of concentrate and stocking-rate levels on the average daily milk yield of Jersey cows, is presented in Figure 1. A higher concentrate-feeding level (on average 6.1 vs. 0 kg per cow, per day) resulted in a higher ($P<0.01$) milk yield, at all stocking-rate levels. Overall, the production response was 0.65 kg milk, per kg concentrate. Concentrate supplementation in this study was economical when the concentrate price was less than 65% of the milk price. The average milk yield of cows was not reduced ($P>0.05$) by higher stocking rates. A higher stocking rate would probably have been possible – because the typical reduction in milk production per ha was not observed, as suggested by Jones and Sandland (1974). A long-term study would provide a better insight into the effect of stocking rate and concentrate feeding level, on the milk yield of dairy cows.

Figure 1. The effect of stocking rate and concentrate-feeding level (zero = □ and 2% of body weight = ■) on the daily milk yield of Jersey cows.



Conclusion

Early research at the Outeniqua Research Farm was aimed at improving the knowledge of dairy farmers, and to address regional problems affecting the production of dairy cows. The same principle still applies today. For this reason, liaison with the local dairy industry is important. Research results give producers the confidence to apply specific management principles. The alternative would be for farmers to conduct their own trials, which is often a problem as they do not have the capacity to have a control treatment at farm level.

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27.

Sheep research at Outeniqua: 1980–2001

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Introduction

A comprehensive research programme on sheep was conducted for about 20 years on the Outeniqua Research Farm – from the 1980s to the turn of the century. Stock theft and the expansion of the dairy-research programme on the farm resulted in this programme being terminated in 2001. The research programme was highly productive – resulting in numerous scientific outputs despite limited funding (the total working capital allocated to the programme annually failed to exceed R10 000, at the height of the sheep research programme).

This contribution attempts to report highlights of the programme – while also drawing attention to those people who were responsible for the research.

Only key results are reported – per topic researched. Interested readers can gain further insight into what was achieved, by reading the references cited.

Nutrition research

Nutritional sheep research at Outeniqua focussed on enriched small grains for the feedlot-finishing of lambs, the evaluation of protein and roughage sources in feedlot diets, growth promoters, and the evaluation of production systems for slaughter lamb production.

Enriched small grains

Brand *et al.* (1993a) evaluated enriched barley and a commercial diet as creep feed for lambs, while grazing a dry land kikuyu and ryegrass pasture at Outeniqua. The study showed that the enriched barley improved performance and had an economical advantage compared to a commercial pelleted diet. Lambs on both treatments performed well above a control group. It was concluded that lambs grazing dry land kikuyu and ryegrass pasture, primarily had an energy shortage (proven by blood metabolite levels) – while high-grade protein (with a high level of bypass protein) was also essential for optimum growth of lambs grazing such pastures.

Different triticale cultivars (Usgen 7; 10; 14; 18; and 19) were compared with each other and to maize in enriched-grain mixtures for lambs in the feedlot (Brand *et al.*, 1994a). Lambs receiving enriched maize performed better in terms of feed conversion, than lambs receiving the different triticale cultivars as a main grain source. Lambs receiving Usgen 10 also tended to have lower growth rates and feed conversion, than those receiving the other triticale cultivars. It was concluded that triticale may be fed successfully in enriched whole grain mixtures for feedlot lambs – although their feed conversion may be lower – by approximately 15% – compared to maize.

The evaluation of protein and roughage sources

Whole canola seed was evaluated at different inclusion levels (0%, 6%, 12% and 18%) in the diets of growing-finishing South African (SA) Mutton Merino lambs (Brand *et al.*, 1996; Brand *et al.*, 2001). Feed intake was reduced by 36 g, per lamb, per day, with every increment of canola-seed inclusion, while an increase in whole canola-seed inclusion – up to 18% – had no negative influence on the growth rate or feed conversion of lambs. It was concluded that whole canola seed is a good source of protein and energy for small stock nutrition, although the overall fat content of the total diet should not exceed certain maximum levels.

Different protein sources, i.e. urea, fishmeal, cotton-seed oilcake meal and two levels (8 and 30%) of lupins were tested in enriched grain mixtures for fattening lambs (Brand *et al.*, 1993b). Feed intake was suppressed at an inclusion level of 30% lupins – although no other effect of protein source was detected on performance. Overall, it was concluded that grain-enriched mixtures were practical for the preparation of grain-based diets for the fattening of lambs – resulting in reduced diet costs.

Studies was done to evaluate grain residues like wheat straw, as well as thermally ammoniated wheat straw as a roughage component in the diets of finishing lambs (Brand *et al.*, 1991). It was concluded from these studies that the replacement of lucerne hay with wheat straw adversely affected dry-matter intake, as well as the growth rate of the lambs. The performance of lambs on diets with up to 26% of wheat straw, was still satisfactory – if it was included in a balanced diet. Such a diet could thus be recommended, provided that the slower growth rate and resultant longer feeding period of such lambs were not regarded as prohibitive.

Growth promoters

Zeranol implantations were evaluated in two experiments – to determine the effect thereof on the production of finishing South African Mutton Merino (SAMM) lambs on pastures, as well as in feedlots (Brand *et al.*, 1994b). Zeranol implantation had no effect on the growth rate of SAMM lambs on pasture, but tended to increase the dressing percentage of SAMM lambs in the feedlot (47.4% vs. 45.9%). It was concluded from this study that, although there was no effect of Zeranol on the backfat thickness of SAMM lambs, it may have a more obvious effect on types of sheep that are early maturing, and thus accumulating fat at an earlier age.

Production systems for slaughter lamb production

Different systems were evaluated as the system of choice for the raising of lambs in the George area (Brand *et al.*, 1993c). These systems included the provision of creep feed to lambs grazing pastures with their mothers, early weaning of lambs, and the provision of supplementary feed to lambs on pasture, the early weaning of lambs, the finishing of lambs in feedlots, as well as a control treatment where lambs were not weaned and stayed with their mothers. Growth rates of the lambs were respectively 162 g/lamb/day (control), 258 g/lamb/day (creep feed), 288 g/lamb/day (supplementary feed), and 290 g/lamb/day (feedlot). The study provided valuable guidelines for the economic evaluation of the different systems – where the economic merit of each system is dependent on the feed price and price of lamb at that stage.

Pure breeding and crossbreeding systems for sheep

This project was conducted by the late Mr L.S. (Boepie) Erasmus during the late 1970s and early 1980s. In many ways, the project was visionary – investigating aspects of terminal and maternal crossbreeding for commercial gain. Crossbreeding in South Africa was often used for breed formation (i.e. the Dorper, Dormer, Dohne Merino, and other synthetic breeds). Unfortunately, the crossbreeding phases of these exercises were not well reported in the literature.

Results of the crossbreeding experiments at Outeniqua were reported by Erasmus *et al.* (1983). The study reported an advantage of 11% in lamb output to the first cross, when compared to pure breeding. This advantage was increased to 39% relative to the purebred option in the second cross, involving crossbred ewes as dam lines. Although the outlay of this experiment did not sustain detailed analysis relating to the origin of these advantages (that could arguably be attributed to hybrid vigour, breed complementarity and/or sexual dimorphism) – it accords well with expectations based on the literature (see e.g. Fogarty (2006)). The work was in many ways ahead of its time, and Mr Erasmus did not receive the recognition he deserved during his lifetime. It is only now recognised that there is a need for the assessment of the wide and varied South African ovine genetic resource – not only for the accrual of additive gains due to genetic selection, but also for the exploitation of non-additive effects in structured crossbreeding systems for commercial gain.

Trace-element supplementation studies

An extensive research programme into the trace-element status of free-grazing sheep without additional concentrate supplementation, was set up by Mr N.M. (Klaas) Kritzinger during the 1980s. Various means of supplementing diagnosed deficiencies were also considered. Unfortunately, Mr Kritzinger resigned in 1986 to start a new career at the then South African Mohair board. The work he initiated was therefore never published under his name. After the resignation of Mr Kritzinger, his work was continued by the late Dr F.E. (Francois) van Niekerk. A number of key papers were published by Dr van Niekerk, as summarised below.

Responses of sheep to the oral supplementation of copper, cobalt and selenium

An extensive factorial experiment involving the supplementation of the above trace elements on their own, or in combination, with others – was set up from 1983 to 1986 on kikuyu-ryegrass pastures grown under supplemental irrigation, on relatively trace-element deficient soils at Outeniqua (Cloete *et al.*, 1994a). The soils were derived from a Table Mountain sandstone and granite basis, and were acid and low in trace elements. The animals used in the experiment were predominantly from a SA Mutton Merino type – since they were carried over from the earlier work of Erasmus *et al.* (1983) and upgraded with SA Mutton Merino rams for the interim period.

Analysis of blood and liver samples of un-supplemented tracer animals, confirmed a deficiency in copper and selenium in the study. Plasma copper and blood selenium concentrations were elevated to normal levels by the oral supplementation of ewes with 5 g of copper oxide needles every four months, or by the monthly drenching of 5 mg selenium as sodium selenite. No interactions were found between any of the trace elements. Oral supplementation of copper and selenium resulted in respective gains of 5.3% and 4.8% in ewe live weight during lactation. Oral copper supplementation resulted in a 6.0% gain in greasy fleece weight – while oral selenium supplementation caused a 37% improvement in weight of lamb weaned, per ewe mated (Cloete *et al.*, 1994a). Although the observed responses were established and the correction of trace-element deficiencies by oral treatment is recommended, it was also stated that the overall levels of sheep production in all treatments, were poorer than expected. This result could possibly be traced back to a lack of major nutrients (energy and protein) on the grass pasture. There was an attempt to rectify this with the establishment of subterranean clover and lucerne pastures in subsequent years – as these pasture types are known to have a better palatability than the grasses used in the study by Cloete *et al.* (1994a).

Responses of lambs to parenteral supplementation of copper and selenium in their dams

Based on the previous results, studies on the trace-element supplementation of sheep were continued. This was done in order to consider the effect of parenteral supplementation of SA Mutton Merino ewes with copper heptonate and barium selenate on their tissue trace-element status, as well as the trace-element status, growth and survival of their lambs (Van Niekerk *et al.*, 1995). The ewes and their offspring grazed lucerne and subterranean clover pastures in this experiment – which took place from 1991 to 1993. Kikuyu-ryegrass paddocks were only used occasionally.

Plasma, liver and blood trace-element concentrations of experimental animals declined to marginally deficient during spring. Parenteral treatment of ewes with copper heptonate resulted in plasma copper concentrations of pregnant ewes being elevated by 18% – while treatment with barium selenate failed to increase blood selenium concentrations. Maternal supplementation with selenium resulted in the 8-week live weight of their lambs being enhanced by 8%, compared to the un-supplemented control group. The survival of lambs born to copper-supplemented ewes was accordingly improved by 13% relative to control-group lambs. These biological advantages were supported by elevated liver trace-element concentrations in the lambs of treated ewes that died prior to weaning. It thus seems that parenteral treatment with suitable trace-element preparations is a highly effective way of supplementing these minerals to individual sheep.

During this experiment, it was observed that ewes treated parenterally with selenium prior to joining, had a poorer conception rate than control ewes in 1991 (Van Niekerk *et al.*, 1996). A similar trend was obtained in a subsequent smaller study – leading to the recommendation that parenteral supplementation with injectable selenium compounds should not be attempted at mating times or during the first 25 days after ovulation.

The evaluation of a selenium fertiliser

A selenium fertiliser was tested from 1995 to 1997 by Cloete *et al.* (1999). The selenium fertiliser consisted of a highly soluble sodium selenite coat on a core of lowly soluble sodium selenate. In contrast with previous studies where individuals were supplemented orally or parenterally, this study involved the treatment of specific paddocks. Paddocks just needed to be treated as the experimental unit – whereas individual animals were previously be regarded as experimental units.

Kikuyu-ryegrass paddocks fertilised with selenium sustained a markedly higher blood selenium concentration in ram lambs – compared to control paddocks – during both 1995 and 1996, under conditions considered to be marginally deficient. Selenium-fertilised paddocks also sustained higher liver-selenium concentrations when these lambs were slaughtered sequentially – compared to the control paddocks. Other paddocks cultivated with an oat-fodder crop were used to study the influence of selenium fertiliser on ewe reproduction, and lamb growth and survival. No evidence of subclinical selenium deficiency was seen in blood samples obtained from either the ewes, or their lambs, but those animals on fertilised paddocks still had elevated blood-selenium concentrations compared to contemporaries grazing control paddocks. No response in animal production was observed, although selenium-fertilised paddocks seemed to sustain a slightly better lamb survival. It was thus evident that the fertilising of paddocks with selenium is a highly effective and relatively affordable way to supplement this trace element.

Shearing prior to lambing or mating

Cloete *et al.* (1994b) reported the results of an experiment, where SA Mutton Merino ewes were either shorn prior to lambing, or prior to mating, in 1991 and 1992. The shearing regime failed to produce a difference in lamb birth weight, but the daily gain to 8 weeks of age of lambs born to ewes shorn prior to lambing, was improved by 8% relative to lambs that were born by ewes shorn prior to mating. During 1991, there was also a tendency for the progeny of ewes shorn prior to lambing, to have a better survival to weaning – than those ewes shorn prior to mating. Together, these effects resulted in the weight of lamb weaned per ewe joined – being improved by 19% in ewes shorn prior to lambing.

Conclusion

This paper summarised the results of the sheep-research programme at Outeniqua. As these outputs have been published in different media, it would be impossible to judge the scope of the programme – unless it is summarised in a broad review of this nature. We hope that this contribution will put the results in perspective, and that it will – in this way – be accessible for future generations of scientists.

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ISBN: 978-0-9922220-0-0

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