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Outeniqua Research Farm: Directorates Plant and Animal Sciences

Information Day 2019

Milk production from planted pastures

CONTENTS

INFORMATION DAY:

OUTENIQUA RESEARCH FARM

MILK PRODUCTION FROM PLANTED PASTURE

Wednesday, 18 September 2019

Presented by the Directorates Plant and Animals Sciences, Western Cape Department of Agriculture, Outeniqua Research Farm, George

Programme Director: Dr Ilse Trautmann (Chief Director: Research and Technology Development)		
08:00-09:00	Registration and viewing of exhibits	
09:00-09:10	Scripture reading and prayer	
09:10-09:15	Welcoming	Dr Ilse Trautmann
09:15-09:35	Cultivar evaluation results: Ryegrass and tall fescue	Sigrun Ammann
09:35-9:50	Supplementing protected methionine and lysine to cows grazing ryegrass pasture in Spring	Ranier van Heerden
09:50-10:10	Forage herb cultivar evaluation results	Sigrun Ammann
10:10-10:25	Farm system study: Development of dairy systems based on forage herb pastures in the southern Cape	Janke van der Colf
10:25- 10:40	High fibre concentrates for cows grazing plantain and	Robin Meeske
10:40–11:10	Tea	
11:10-11:40	Plantain as forage herb: A New Zealand perspective	Stephen Bennett
11:40-12:10	Panel discussion: Plantain on three South African farms, focus on establishment, grazing management and contribution to the dairy farming system.	Sigrun Ammann
12:10-12:15	Concluding remarks	George Kuyler
12:15-13:15	Visit to Forage herb Cultivar trials and research projects Cultivar evaluation forage herbs Systems trial- plantain, tall fescue and mixtures Plantain and high fibre concentrates	 Sigrun Ammann Janke van der Colf Zander Pretorius
13:15	Lunch	

VOORWOORD

Nog 'n jaar is verby waarin landbou sy deel van uitdagings moes oorkom. Droogtes, hoër insetkostes, laer winsgrense en die bedreiging van klimaatsverandering wat landbou op alle vlakke in die toekoms verder gaan beinvloed.

In hierdie "druk" tyd is dit uiters nodig om nuut, vars en innnoverend na ons probleme te kyk. En nog meer belangrik is om jou te omring met kundiges wat saam met jou probleme gaan aanpak in die soeke na volhoubare oplossings.

Ons bring met vanjaar se Outeniqua inligtingsdag 'n paar vars en opwindende oplossings ten opsigte van weiding- en melkproduksie uitdagings en ons buitelandse spreker gaan beslis ook ons navorsingsinligting verder uitbrei. Hierdie inligtingsdag is een van ons vlagskip tegnologie-oordrag geleenthede en ons spesialis navorsers, navorsers en jong wetenskaplikes poog jaarliks om die nuutste en mees toepaslike navorsingsresultate met ons boere en ander rolspelers in die Suid-Kaap te deel in 'n poging om die Suid-Kaap en sy boerdery gemeenskap se volhoubare toekoms te help verseker. Ons weiding- en suiwelnavorsingspan is van die bestes in die land, en ons nuwe generasie navorsers en navorsingstegnici word ook op Outeniqua opgelei om seker te maak dat die navorsingsprogramme met die nodige kundigheid voortgesit kan word.

Ons hoop die nuwe inligting gaan u versterk met u ondernemings, en dat die praktiese "loop en vra (walk en talk)" sessie saam met die navorsers u nog verder gaan aanspoor om nuwe kultivars en produksie tegnieke te ondersoek. Kom ons soek saam na nuwe oplossings vir bedryfsprobleme.

Geniet die dag saam met ons!

Dr. Ilse Trautmann

HOOFDIREKTEUR: NAVORSING EN TEGNOLOGIE ONTWIKKELING, DEPARTEMENT LANDBOU WES-KAAP

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Westerwolds ryegrass production results

Dalena Lombard[1], Sigrun B Ammann[1]

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Introduction

Lolium multiflorum can be divided into two types, namely Italian ryegrass and Westerwolds ryegrass. Unlike Italian ryegrass, Westerwolds do not need cold night temperatures to induce flowering. An increase in day length and/or temperature will prompt flowering in the Westerwolds type. Westerwolds varieties are generally early flowering but some tend to persist longer. Therefore, Westerwolds ryegrass can also be divided into short and long season varieties. The very short season Westerwolds are true annuals going from vegetative to reproductive in the shortest possible time within the prevailing climatic conditions.

Over the past three years, three Westerwolds small plot trials were conducted on the Outeniqua Research Farm. The aim of all three of these trials was to determine the production potential of Westerwolds ryegrass varieties under irrigation. The parameters measured were dry matter yield, rust, flowering and persistence. Here the yield results are presented.

Results and discussion

The Westerwolds trial established in 2017 (Lm 4) was the only trial where the long season cultivars managed to produce a yield beyond the first year, up until the spring of the second year (2018). Lm 2 (2016) and Lm 8 (2018) were harvested ten and nine times, respectively, while the 2017 trial was harvested 22 times.

Table 1. Lm 2 trial (2016): Seasonal and total dry matter production (ton DM ha^{-1}) of Westerwolds varieties

Variety	Type	Autumn	Winter	Spring	Summer	Total
Andes	T	2.70^{abc}	3.48^{abc}	1.73^{de}	0	7.91^{fgh}
Barspectra II	T	2.31^{d}	3.07^{bcde}	3.25^{c}	0.03^{d}	8.66^{f}
Barspectra II 40*	T	2.65^{abc}	3.65^{ab}	3.45^{c}	0.23^{c}	9.98^{e}
Big Boss	T	2.61^{abcd}	2.63^{e}	1.72^{de}	0	6.96^{hi}
Bullet	T	2.45^{cd}	3.58^{ab}	5.28^{a}	0.56^{b}	11.88^{bc}
Centurion	T	2.63^{abcd}	3.50^{ab}	4.71^{b}	1.56^{a}	12.40^{ab}
Florida 4N	T	2.50^{cd}	2.77^{de}	1.49^{e}	0	6.75^{i}
Hogan	T	2.62^{abcd}	4.05^{a}	5.48^{a}	1.54^{a}	13.68^{a}
Mispah	D	2.41^{cd}	3.35^{bcd}	4.57^{b}	0.40^{b}	10.74^{de}
Mispah 35*	D	2.55^{bcd}	3.21^{bcde}	4.93^{ab}	0.42^{b}	11.10^{cd}
Passeral Plus	D	2.90^{a}	3.50^{ab}	1.74^{de}	0	8.15^{fg}
Passeral Plus 35*	D	2.92^{a}	2.86^{cde}	2.21^{d}	0	7.99^{fgh}
Striker	T	2.61^{abcd}	2.66^{e}	1.79^{de}	0	7.06^{hi}
Striker 40*	T	2.84^{ab}	3.29^{bcd}	1.86^{de}	0	7.98^{fgh}
Tetrastar	T	2.67^{abc}	3.08^{bcde}	1.50^{e}	0	7.25^{ghi}
VO 12	T	2.54^{bcd}	3.23^{bcde}	1.45^{e}	0	7.22^{ghi}
LSD (0.05)		0.32	0.61	0.57	0.19	1.06

^{abcde} Means with no common superscript differ significantly (P<0.05)

LSD = Least significant difference T = Tetraploid D = Diploid *Number indicates seeding rate (kg/ha)

Table 2. Lm 4 trial (2017): Seasonal and total dry matter production (ton DM ha^{-1}) of Westerwold varieties

Variety	Type	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Total
Andes	T	2.97^{b}	2.79^{ef}	0	0	0	0	0	7.31^{f}
Big Boss	T	3.89^{ab}	3.00^{def}	0	0	0	0	0	8.53^{ef}
Bruiser	D	3.50^{ab}	2.61^{f}	0	0	0	0	0	7.63^{ef}
Bullet	T	3.11^{b}	3.47^{cd}	5.65^{a}	2.40^{b}	1.48^{c}	2.77^{ab}	4.29^{b}	23.16^{c}
Centurion	T	3.74^{ab}	3.41^{cde}	5.03^{b}	3.24^{a}	2.29^{b}	2.45^{b}	4.42^{ab}	24.59^{bc}
Hogan	T	3.05^{b}	4.42^{a}	5.32^{ab}	2.90^{ab}	3.23^{a}	3.01^{ab}	4.82^{a}	26.74^{a}
Jivet	T	3.93^{ab}	3.77^{bc}	3.77^{d}	0	0	0	0	12.37^{d}
Maximus	T	3.81^{ab}	2.60^{f}	0	0	0	0	0	8.06^{ef}
Performer	D	3.78^{ab}	4.33^{ab}	4.54^{c}	0	0	0	0	13.94^{d}
Prompt	D	3.42^{ab}	4.66^{a}	5.41^{ab}	2.99^{a}	2.27^{b}	3.08^{a}	4.29^{b}	26.11^{ab}
Ribeye	D	3.31^{ab}	2.88^{def}	0	0	0	0	0	7.73^{ef}
Spicer	T	3.89^{ab}	2.61^{f}	0	0	0	0	0	6.88^{f}
Striker	T	3.85^{ab}	2.59^{f}	0	0	0	0	0	7.37^{f}
Tetrastar	T	4.17^{a}	3.28^{cde}	0	0	0	0	0	9.38^{e}
Vespolini	T	3.81^{ab}	3.77^{bc}	4.96^{bc}	0	0	0	0	13.80^{d}
VO 10	T	3.77^{ab}	3.06^{def}	0	0	0	0	0	8.53^{ef}
LSD (0.05)		1.01	0.64	0.48	0.56	0.41	0.59	0.43	1.87

^{abcde} Means with no common superscript differ significantly (P<0.05)

LSD = Least significant difference T = Tetraploid D = Diploid

Table 3. Lm 8 trial (2018): Seasonal and total dry matter production (ton DM ha^{-1}) of Westerwold varieties

Variety	Type	Autumn	Winter	Spring	Summer	Total
Andes	T	2.94^{abcd}	2.90^{ef}	2.00^{efgh}	0	7.84^{fg}
Big Boss	T	2.84^{abcde}	2.94^{ef}	2.21^{efg}	0	7.99^{fg}
Bruiser	D	3.23^{a}	2.62^{fg}	2.38^{ef}	0	8.24^{fg}
Grazer Nova	D	2.75^{bcde}	2.10^{h}	0.90^{i}	0	5.76^{i}
Hogan	T	2.97^{abc}	3.84^{ab}	5.92^{a}	0.75^{a}	13.48^{a}
Jivet	T	2.57^{cdef}	3.20^{de}	4.03^{bc}	0.16^{cd}	9.95^{cd}
Lolan	T	2.54^{def}	3.10^{de}	4.19^{b}	0.17^{cd}	9.99^{cd}
Performer	D	2.95^{abcd}	4.14^{a}	5.73^{a}	0.23^{cd}	13.06^{a}
Puigmal	D	2.49^{ef}	3.36^{cd}	4.76^{b}	0.28^{bc}	10.90^{bc}
Ribeye	D	3.00^{ab}	2.40^{gh}	1.78^{fgh}	0	7.17^{gh}
Salam	D	2.19^{f}	3.74^{abc}	4.84^{b}	0.39^{b}	11.16^{b}
Sanchez	T	3.08^{ab}	3.16^{de}	3.28^{cd}	0.10^{d}	9.62^{de}
Spicer	T	3.08^{ab}	2.29^{gh}	1.19^{hi}	0	6.56^{h}
Striker	T	3.15^{ab}	3.14^{de}	1.42^{ghi}	0	7.71^{fg}
Vespolini	T	2.81^{abcde}	3.47^{bcd}	4.81^{b}	0.16^{cd}	11.24^{b}
Vortex	D	2.83^{abcde}	3.17^{de}	2.74^{de}	0	8.75^{ef}
LSD (0.05)		0.42	0.41	0.83	0.14	1.09

^{abcde} Means with no common superscript differ significantly (P<0.05)

LSD = Least significant difference T = Tetraploid D = Diploid

Table 1 shows the results for the 2016 Westerwolds evaluation trial (Lm 2). Hogan achieved the highest ($p<0.05$) or similar to the highest dry matter production yield for all four seasons. Centurion managed to produce the highest ($p<0.05$) or similar to the highest dry matter yield for three of the four seasons. Hogan produced the highest ($p<0.05$) total dry matter yield, followed by Centurion.

Table 2 shows the results for the 2017 Westerwolds evaluation trial (Lm 4). Although no variety was able to produce a constant high yield over all seven seasons, Hogan managed to produce the highest ($p<0.05$) or similar to the highest dry matter yield for six of the seven seasons. Prompt managed to achieve the highest ($p<0.05$) or similar to the highest dry matter yield for five of the seven seasons. Hogan produced the highest ($p<0.05$) total dry matter yield, followed by Prompt.

Table 3 shows the results for the 2018 Westerwolds evaluation trial (Lm 8). Hogan achieved the highest ($p<0.05$) or similar to the highest dry matter production yield for all four seasons. Performer achieved the highest ($p<0.05$) or similar to the highest dry matter yield for three of the four seasons. Hogan and Performer produced the highest ($p<0.05$) total dry matter yield.

Considering the results from these Westerwolds evaluation trials it was possible to compile table 4, grouping the varieties evaluated into two groups, namely short season varieties and long season varieties.

Table 4. Westerwolds varieties grouped according to production duration (table compiled using data from Lm 2, Lm 4 and Lm 8)

Short season		Long season	
Variety	Type	Variety	Type
Andes	T	Barspectra	T
Big Boss	T	Bullet	T
Bruiser	D	Centurion	T
Florida 4N	T	Hogan	T
Grazer Nova	D	Jivet	T
Maximus	T	Lolan	T
Passeral	D	Mispah	D
Ribeye	D	Performer	D
Spicer	T	Prompt	D
Striker	T	Puigmal	D
Tetrastar	T	Salam	D
VO10	T	Sanchez	T
VO12	T	Vespolini	T
Vortex	D		

T = Tetraploid D = Diploid

Conclusions

Westerwolds ryegrass varieties can be grouped into two categories, namely short season and long season. The variety Hogan, a long season variety, was the highest producing Westerwolds variety in each of the three yield trials discussed. Short season Westerwolds can be taken advantage of as an additional winter pasture where summer producing pasture is planted.

References

Ammann SB. 2018. Ryegrass breeding and ryegrass types. Pasture course 2018. Outeniqua Research Farm, Directorates Plant and Animal Sciences. Pp 41-42.

Donaldson CH. 2001. A practical guide to planted pastures. Chapter 4, p 33.

Snyman HA. 2012. Gids tot die volhoubare produksie van weiding. Chapter 15, p 399.

Elite cultivar evaluation: *Lolium* species (Italian and perennial ryegrass)

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Introduction

The Elite evaluation trials are aimed at evaluating agronomic traits such as DM yield, disease tolerance and forage quality and also provide data on interaction traits (seasonal yield distribution, flowering, growth form, persistence) for what can be considered modern and high-end varieties. This information provides local data for choice of pasture cultivars. The interactions traits can be used to assist in selecting varieties for pasture mixes. It is important to determine the genetic potential of varieties and in that way evaluate all varieties on equal terms in an unbiased way:

- Evaluate high-end varieties with modern genetics and special traits
- Characterize into types
- Determine agronomic and interaction traits to assist with choosing varieties for mixtures aiming at complementarity within the mixture

Parameters measured/assessed:

- DM yield (harvested according to leaf-stage)
- Seasonal yield patterns
- Dry matter (DM) content
- Disease incidence (mainly rust)
- Flowering behaviour
- Persistence/ plant population
- Forage quality
- General growth form

Species evaluated in the trials

The following *Lolium* species are evaluated in the trials

- *Lolium multiflorum (Italian ryegrass)*
- *Lolium hybridum* – perennial and Italian ryegrass type hybrids
- *Lolium perenne (perennial ryegrass)*
- *Cultivars are either diploid or tetraploid*

The aim of the cultivar evaluation trials is to determine the genetic potential for the various parameters. The *Lolium* trials are cut when the first cultivars reach the three-leaf stage or in spring at canopy closure. Leaf appearance rate is determined mainly by temperature and hence most varieties reach the three-leaf stage at a similar time.

Table 1: Italian ryegrass (*Lolium multiflorum*) and hybrid ryegrass (Lm 7, 2018), Elite Evaluation, Outeniqua Research Farm
Planted: 13 March 2018 Yield (t DM/ha) trial is continuing

Cultivars	Type	Cut 1 4/5/18	Cut 2 30/5/18	Cut 3 30/7/18	Cut 4 2/8/18	Cut 5 4/9/18	Cut 6 3/10/18	Cut 7 1/11/18	Cut 8 3/12/18	Cut 9 4/1/19	Cut 10 5/2/19	Cut 11 6/3/19	Cut 12 8/4/19	Cut 13 9/5/19	Cut 14 12/6/19
Asset	DI	1.24	1.15^{ab}	0.83^{f}	0.78^{def}	1.13^{bcd}	1.57^{bcd}	*1.88^{abcd}	1.19^{e}	1.13^{abc}	*0.62^{abcd}	0.59^{abc}	1.13^{a}	0.85^{ab}	0.94^{abc}
Barcrespo	TI	1.52	1.27^{a}	*1.02^{abcde}	**1.12^{a}	*1.40^{abcd}	1.98^{a}	*1.96^{abc}	1.52^{abcd}	1.19^{abc}	*0.75^{abc}	0.95^{a}	1.29^{a}	1.24^{a}	1.19^{a}
Barmultra II	TI	1.56	1.25^{a}	*1.14^{ab}	*1.00^{abcde}	0.95^{d}	1.65^{bc}	*1.93^{abc}	1.70^{a}	1.39^{a}	*0.60^{abcd}	0.53^{abc}	1.03^{a}	0.87^{ab}	0.73^{bc}
Escarpio	TI	1.27	1.22^{ab}	0.95^{cdef}	0.83^{cdef}	*1.26^{abcd}	1.72^{abc}	*1.66^{cde}	1.31^{de}	0.87^{cd}	0.37^{d}	0.36^{bc}	0.92^{a}	0.73^{b}	0.65^{ab}
Fox	DI	1.28	1.29^{a}	1.03^{abcde}	*0.92^{abcde}	*1.29^{abcd}	1.77^{ab}	*1.99^{ab}	1.77^{a}	1.09^{abc}	*0.74^{abc}	0.74^{ab}	1.20^{a}	1.12^{ab}	1.25^{a}
Green Spirit	Mix	1.31	1.28^{a}	**1.15^{a}	0.83^{cdef}	**1.75^{a}	1.66^{bc}	**2.13^{a}	1.79^{a}	1.28^{abc}	**0.92^{a}	0.81^{a}	1.32^{a}	1.25^{a}	1.02^{abc}
Icon	DI	1.59	1.28^{a}	0.91^{def}	0.86^{bcde}	*1.28^{abcd}	1.66^{bc}	*1.85^{abcd}	1.61^{abc}	1.02^{abcd}	*0.78^{ab}	0.81^{a}	1.39^{a}	1.15^{ab}	1.09^{ab}
Itaka	DI	1.25	1.31^{a}	*1.10^{abc}	0.78^{def}	*1.46^{abcd}	1.60^{bcd}	*1.98^{abc}	1.74^{a}	1.13^{abc}	*0.82^{ab}	0.84^{a}	1.27^{a}	1.02^{ab}	1.00^{abc}
Merlin	TH	1.27	1.26^{a}	*1.02^{abcde}	*0.92^{abcde}	*1.58^{abc}	1.48^{cdef}	1.77^{bcde}	1.36^{cde}	0.65^{de}	0.53^{bcd}	0.31^{c}	1.08^{a}	1.20^{a}	1.02^{abc}
Mona	TI	1.27	1.16^{ab}	0.88^{ef}	0.85^{bcde}	*1.17^{abcd}	1.24^{fgh}	*1.94^{abc}	1.70^{a}	1.13^{abc}	*0.76^{ab}	0.81^{a}	1.32^{a}	1.03^{ab}	0.95^{abc}
Solita	TI	1.20	1.06^{b}	*1.05^{abcd}	*1.00^{abcde}	*1.54^{abcd}	1.07^{h}	1.59^{de}	1.39^{bcde}	0.35^{e}	0	0	0	0	0
Storm	TH	1.16	1.25^{a}	0.92^{def}	0.61^{f}	*1.18^{abcd}	1.17^{gh}	1.77^{bcde}	1.65^{abc}	1.03^{abcd}	*0.62^{abcd}	0.60^{abc}	1.07^{a}	0.88^{ab}	1.08^{ab}
Sukari	DI	1.59	1.32^{a}	*1.11^{abc}	*1.06^{ab}	*1.57^{abc}	1.37^{defg}	1.75^{bcde}	1.69^{a}	1.00a^{bcd}	*0.59^{abcd}	0.84^{a}	1.51^{a}	1.16^{ab}	0.97^{abc}
Tabu Plus	DI	1.49	1.15^{ab}	0.98^{cdef}	*1.01^{abc}	1.06^{cd}	1.52^{cde}	*2.00^{ab}	1.68^{ab}	1.35^{ab}	*0.58^{abcd}	1.22^{a}	1.40^{a}	1.05^{ab}	1.01^{abc}
Thumpa	TI	1.49	1.20^{ab}	*1.01^{abcde}	*1.06^{ab}	*1.46^{abcd}	1.69^{bc}	1.45^{e}	1.55^{abcd}	0.96^{bcd}	0.42^{cd}	0.53^{abc}	1.19^{a}	0.97^{ab}	1.12^{ab}
Yolande	DI	1.25	1.24^{ab}	*0.99^{abcdef}	0.75^{ef}	*1.73^{ab}	1.26^{efgh}	*2.07^{ab}	1.69^{a}	1.06^{abcd}	*0.73^{abc}	0.77^{ab}	1.27^{a}	1.06^{ab}	0.95^{abc}
LSD (0.05)		NS	0.18	0.16	0.22	0.61	0.26	0.32	0.29	0.41	0.33	0.43	0.60	0.45	0.41
CV %		24.7	8.7	9.5	14.3	26.8	10.1	10.2	11.1	23.4	32.5	38.1	31.1	27.9	26.0

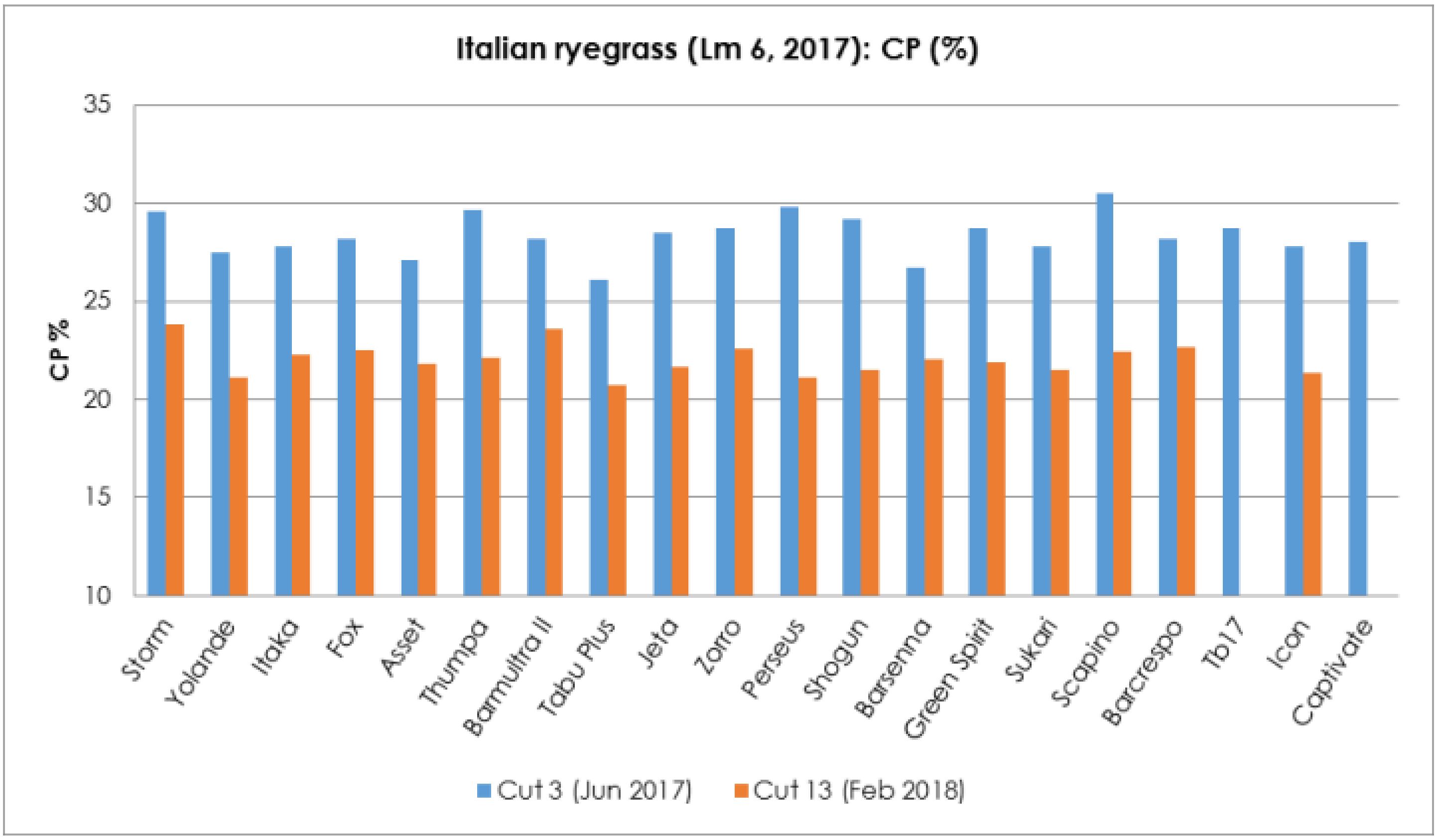
Types: D = Diploid, T = Tetraploid, I = Italian ryegrass, H = Hybrid ryegrass, Note: treatments with the same letter are not significantly different.
** = highest yielding * = similar to the highest

Table 1 cont.: Italian ryegrass (*Lolium multiflorum*) and hybrid ryegrass (Lm 7, 2018), Elite Evaluation, Outeniqua Research Farm
Planted: 13 March 2018 Yield (t DM/ha) trial is continuing

Cultivars	Type	Autumn 2018	Winter 2018	Spring 2018	Summer 2018/19	Autumn 2019	Total Year1 (end Feb 2019)	14 Months (end May 2019)
Asset	DI	2.39^{ab}	2.60^{d}	4.63^{de}	*2.33^{abc}	2.70^{ab}	11.96^{de}	14.66^{bc}
Barcrespo	TI	2.79^{ab}	*3.38^{abc}	**5.44^{a}	*2.83^{ab}	3.49^{a}	**14.43^{a}	17.92^{a}
Barmultra II	TI	2.81^{ab}	*2.98^{abcd}	*5.19^{abc}	*2.57^{ab}	2.48^{ab}	*13.55^{abcd}	16.03^{abc}
Escarpio	TI	2.49^{ab}	2.89^{bcd}	4.68^{cde}	1.65^{c}	2.15^{b}	11.71^{ef}	13.86^{c}
Fox	DI	2.57^{ab}	*3.08^{abcd}	**5.47^{a}	2.58^{ab}	3.28^{ab}	*13.69^{ab}	16.97^{ab}
Green Spirit	Mix	2.58^{ab}	*3.61^{ab}	**5.57^{a}	**3.00^{a}	3.39^{ab}	**14.67^{a}	18.06^{a}
Icon	DI	2.87^{ab}	2.89^{bcd}	*5.09^{abcd}	*2.60^{ab}	3.41^{ab}	*13.44^{abcd}	16.85^{ab}
Itaka	DI	2.57^{ab}	*3.16^{abcd}	*5.29^{ab}	*2.78^{ab}	3.11^{ab}	*13.80^{ab}	16.91^{ab}
Merlin	TH	2.53^{ab}	3.32^{abc}	4.64^{de}	1.56^{c}	3.00^{ab}	12.04^{cde}	15.04^{bc}
Mona	TI	2.43^{ab}	2.76^{cd}	4.81^{bcde}	*2.69^{ab}	3.14^{ab}	12.68^{bcde}	15.82^{abc}
Solita	TI	2.25^{b}	*3.40^{ab}	4.08^{f}	0.48^{d}	0	10.21^{f}	10.21^{d}
Storm	TH	2.41^{ab}	2.57^{d}	4.53^{ef}	*2.28^{abc}	2.78^{ab}	11.79^{ef}	14.57^{bc}
Sukari	DI	2.91^{a}	**3.55^{a}	4.79^{bcde}	*2.41^{abc}	3.47^{a}	*13.66^{abc}	17.14^{ab}
Tabu Plus	DI	2.65^{ab}	2.92^{bcd}	*5.13^{abcd}	**3.06^{a}	3.35^{ab}	*13.77^{ab}	17.12^{ab}
Thumpa	TI	2.68^{ab}	*3.36^{abc}	4.68^{cde}	1.95^{bc}	2.99^{ab}	12.67^{bcde}	15.66^{abc}
Yolande	DI	2.49^{ab}	*3.26^{abc}	*5.03^{abcde}	*2.56^{ab}	3.11^{ab}	*13.33^{abcde}	16.44^{abc}
LSD (0.05)		0.64	0.62	0.54	0.9	1.29	1.64	2.65
CV %		14.8	11.9	6.5	23.1	27.1	7.6	10.0

Types: D = Diploid, T = Tetraploid, I = Italian ryegrass, H = Hybrid ryegrass, Note: treatments with the same letter are not significantly different.
** = highest yielding * = similar to the highest

Figure 1: Forage Quality data for Italian ryegrass 2017 (Lm 6)



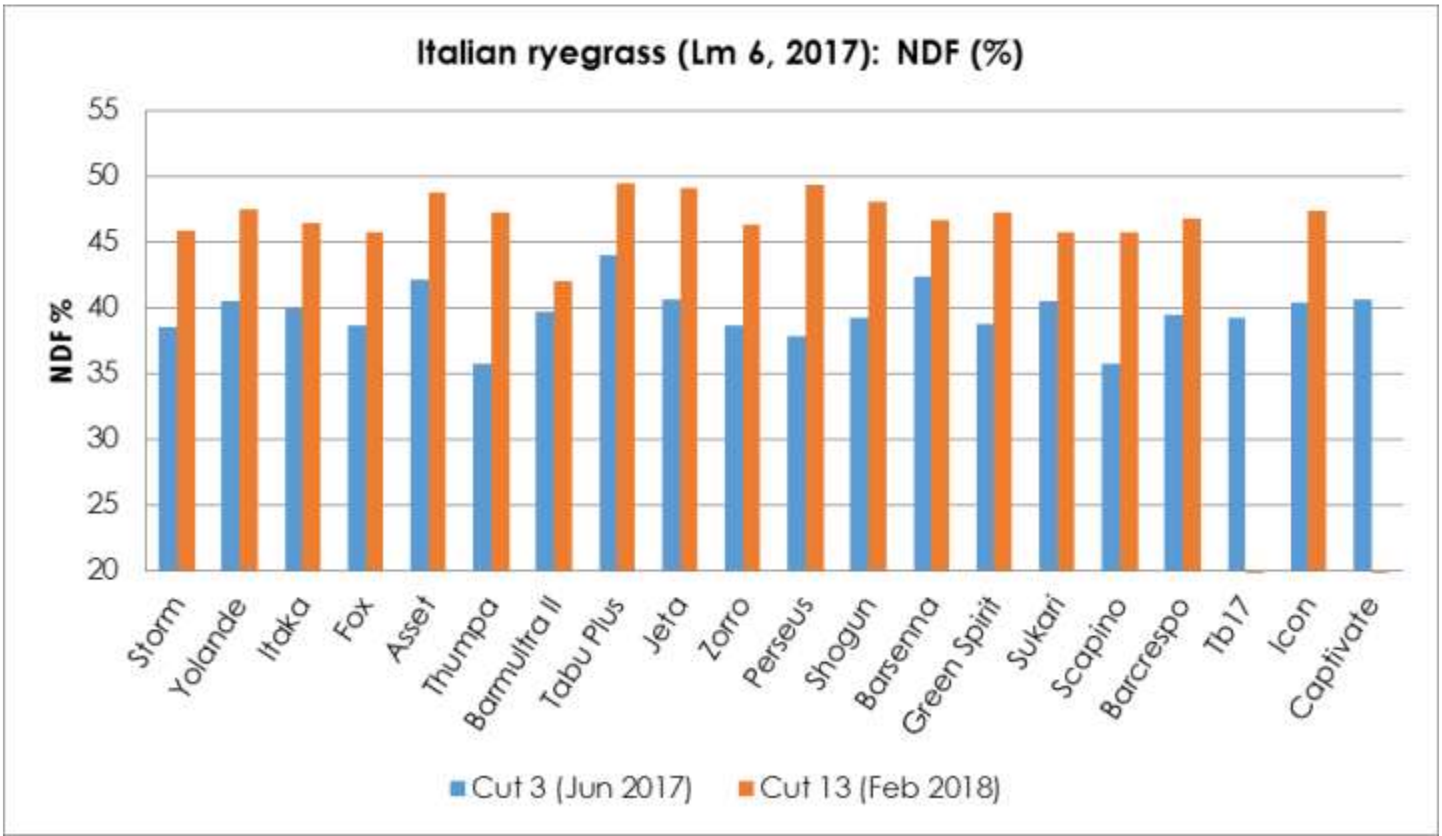


Table 2: Perennial ryegrass (*Lolium perenne*) (Lp 2, 2017), Elite Evaluation, Outeniqua Research Farm

Planted: 10 March 2017 Yield (t DM/ha) trial is continuing

Cultivars	Type	Cut 1 25/4/2017	Cut 2 18/5/2017	Cut 3 13/6/2017	Cut 4 24/7/2017	Cut 5 25/8/2017	Cut 6 18/9/2017	Cut 7 13/10/2017	Cut 8 9/11/2017	Cut 9 6/12/2017	Cut 10 4/1/2018
24Seven	D	0.95	1.35 ^{a}	1.35 ^{a}	1.03 ^{cde}	1.50 ^{abc}	1.45	1.37 ^{c}	2.00 ^{a}	1.57 ^{ab}	1.04 ^{de}
Base	T	0.84	1.26 ^{a}	1.16 ^{a}	1.44 ^{a}	1.51 ^{ab}	1.48	1.41 ^{bc}	1.98 ^{ab}	1.57 ^{ab}	1.39 ^{abc}
Delika	D	1.03	1.16 ^{a}	1.14 ^{b}	0.69 ^{fgh}	0.91 ^{de}	1.41	1.55 ^{abc}	1.95 ^{ab}	1.58 ^{abc}	1.04 ^{de}
Govenor	D	0.88	1.38 ^{a}	1.35 ^{a}	1.22 ^{abc}	1.75 ^{a}	1.63	1.45 ^{abc}	1.74 ^{abc}	1.38 ^{bc}	1.08 ^{cde}
Kingsgate	D	1.06	1.24 ^{a}	1.29 ^{a}	0.89 ^{def}	1.06 ^{bcde}	1.38	1.43 ^{bc}	2.03 ^{a}	1.48 ^{bc}	0.96 ^{de}
Lindor II	D	1.14	1.19 ^{a}	1.20 ^{a}	0.85 ^{defg}	1.02 ^{cde}	1.26	1.49 ^{abc}	1.65 ^{c}	1.22 ^{c}	0.87 ^{e}
Nui	D	0.84	1.26 ^{a}	1.24 ^{a}	1.38 ^{ab}	1.43 ^{abc}	1.19	1.36 ^{c}	1.70 ^{bc}	1.34 ^{bc}	1.09 ^{cde}
Sucral	T	0.84	1.30 ^{a}	1.29 ^{a}	0.76 ^{efgh}	0.96 ^{de}	1.25	1.59 ^{abc}	2.01 ^{a}	1.81 ^{a}	1.28 ^{bcd}
Tanker	T	0.77	1.18 ^{a}	1.18 ^{a}	1.09 ^{bcd}	1.34 ^{abcd}	1.29	1.51 ^{abc}	1.79 ^{abc}	1.44 ^{bc}	1.64 ^{a}
Telstar	D	0.86	1.16 ^{b}	1.13 ^{b}	0.56 ^{gh}	0.84 ^{e}	1.40	1.69 ^{a}	1.80 ^{abc}	1.53 ^{abc}	1.06 ^{de}
Tenace	T	0.89	1.20 ^{a}	1.14 ^{b}	0.47 ^{h}	0.72 ^{e}	1.37	1.64 ^{ab}	1.99 ^{ab}	1.39 ^{bc}	1.14 ^{cde}
Viscount	T	1.04	1.16 ^{b}	1.19 ^{a}	1.36 ^{ab}	1.62 ^{a}	1.53	1.44 ^{abc}	1.85 ^{abc}	1.44 ^{bc}	1.48 ^{ab}
LSD (0.05)		NS	0.20	0.20	0.30	0.48	NS	0.25	0.29	0.31	0.32
CV %		26.7	9.5	9.6	18.2	23.2	19.7	10.0	9.2	12.5	16.0

Note: treatments with the same letter are not significantly different. NS = Non-significant.
Type: D = Diploid, T = Tetraploid

Table 2 cont.: Perennial ryegrass (*Lolium perenne*) (Lp 2, 2017), Elite Evaluation, Outeniqua Research Farm.

Planted: 10 March 2017 Yield (t DM/ha) trial is continuing

Cultivars	Type	Cut 11 1/2/18	Cut 12 28/2/18	Cut 13 28/3/18	Cut 14 16/4/18	Cut 15 18/5/18	Cut 16 21/6/18	Cut 17 1/8/18	Cut 18 11/9/18	Cut 19 11/10/18	Cut 20 8/11/18
24Seven	D	1.36^{abc}	1.35	1.61^{ab}	0.98^{a}	1.20^{a}	0.87^{abc}	0.77^{def}	1.00^{cdef}	1.55^{abc}	1.63^{a}
Base	T	1.50^{a}	1.25	1.60^{ab}	0.88^{abc}	0.87^{cd}	0.93^{ab}	1.14^{a}	1.39^{abc}	1.44^{bc}	1.51^{ab}
Delika	D	1.31^{abc}	1.35	1.71^{a}	0.95^{ab}	1.09^{ab}	0.70^{c}	0.55^{fg}	0.83^{ef}	1.31^{bc}	1.56^{ab}
Govenor	D	1.42^{ab}	1.37	1.53^{abc}	0.89^{abc}	0.88^{cd}	0.93^{ab}	1.06^{ab}	1.75^{a}	1.84^{a}	1.56^{ab}
Kingsgate	D	1.09^{c}	0.99	1.50^{abc}	0.91^{abc}	0.95^{bc}	1.00^{a}	0.78^{cdef}	1.26^{bcd}	1.25^{c}	1.19^{b}
Lindor II	D	1.31^{abc}	1.23	1.40^{bc}	0.81^{bcd}	0.91^{cd}	0.72^{bc}	0.64^{efg}	0.93^{def}	1.40^{bc}	1.76^{a}
Nui	D	1.45^{ab}	1.00	1.54^{abc}	0.87^{abc}	0.76^{de}	0.79^{abc}	0.83^{bcde}	1.13^{cde}	1.33^{bc}	1.68^{a}
Sucral	T	1.20^{abc}	1.26	1.61^{ab}	0.92^{abc}	0.96^{bc}	0.70^{c}	0.40^{g}	0.63^{f}	1.35^{bc}	1.61^{a}
Tanker	T	1.39^{abc}	1.11	1.48^{abc}	0.67^{d}	0.85^{cd}	0.89^{abc}	1.03^{abcd}	1.18^{bcde}	1.53^{abc}	1.75^{a}
Telstar	D	1.08^{c}	1.12	1.48^{abc}	0.91^{abc}	1.11^{ab}	0.96^{a}	0.79^{cdef}	1.17^{bcde}	1.49^{bc}	1.40^{ab}
Tenace	T	1.18^{bc}	1.16	1.38^{bc}	0.95^{ab}	1.15^{a}	0.83^{abc}	0.52^{fg}	0.93^{def}	1.49^{bc}	1.63^{a}
Viscount	T	1.33^{abc}	1.05	1.29^{c}	0.76^{cd}	0.67^{e}	0.73^{bc}	1.05^{abc}	1.56^{ab}	1.86^{a}	1.56^{ab}
LSD (0.05)		0.31	NS	0.26	0.16	0.16	0.21	0.28	0.43	0.34	0.38
CV %		14.0	20.4	10.2	10.6	10.1	15.1	20.4	22.0	13.4	14.3

Note: treatments with the same letter are not significantly different.
Type: D = Diploid, T = Tetraploid

Table 2 cont.: Perennial ryegrass (*Lolium perenne*) (Lp 2, 2017), Elite Evaluation, Outeniqua Research Farm.

Planted: 10 March 2017 Yield (t DM/ha) trial is continuing

Cultivars	Type	Cut 21 5/12/18	Cut 22 4/1/19	Cut 23 31/1/19	Cut 24 27/2/19	Cut 25 28/3/19	Cut 26 25/4/19	Cut 27 30/5/19	Year 1	Year 2	Year 1+2
24Seven	D	1.27^{abc}	0.86^{bcde}	0.35^{cd}	1.05^{ab}	1.17^{ab}	1.03^{ab}	1.46^{ab}	14.22^{ab}	13.13^{abc}	27.36^{abcd}
Base	T	1.41^{ab}	1.06^{abc}	0.73^{a}	0.96^{bc}	1.38^{a}	0.99^{ab}	1.36^{ab}	14.96^{a}	14.72^{ab}	29.68^{ab}
Delika	D	1.15^{abcde}	0.90^{bcde}	0.45^{bcd}	0.77^{c}	0.98^{b}	1.04^{ab}	1.51^{a}	11.85^{bc}	12.00^{c}	23.86^{ef}
Govenor	D	1.26^{abc}	1.13^{ab}	0.76^{a}	1.23^{a}	1.37^{a}	1.08^{a}	1.34^{ab}	15.22^{a}	15.34^{a}	30.57^{a}
Kingsgate	D	0.85^{e}	0.82^{cde}	0.32^{d}	0.91^{bc}	1.07^{ab}	0.81^{b}	1.39^{ab}	12.19^{bc}	11.38^{c}	23.57^{ef}
Lindor II	D	0.92^{de}	0.97^{abcde}	0.61^{ab}	0.77^{c}	1.01^{b}	0.87^{ab}	1.30^{ab}	12.16^{bc}	12.12^{c}	24.27^{def}
Nui	D	0.97^{cde}	0.98^{abcde}	0.63^{ab}	0.81^{bc}	1.02^{b}	0.94^{ab}	1.36^{ab}	14.00^{ab}	12.69^{bc}	26.69^{bcde}
Sucral	T	1.22^{abcd}	1.04^{abcd}	0.59^{abc}	0.78^{c}	1.12^{ab}	1.07^{a}	1.34^{ab}	12.86^{abc}	10.76^{c}	25.29^{cdef}
Tanker	T	1.48^{a}	1.19^{a}	0.63^{ab}	0.85^{bc}	1.22^{ab}	0.95^{ab}	1.25^{b}	13.69^{ab}	14.64^{ab}	28.34^{abc}
Telstar	D	1.01^{cde}	0.69^{e}	0.44^{bcd}	0.85^{bc}	1.00^{b}	0.91^{ab}	1.26^{b}	10.80^{c}	12.15^{c}	22.95^{f}
Tenace	T	1.11^{cde}	0.75^{de}	0.35^{cd}	0.91^{bc}	1.06^{ab}	1.05^{ab}	1.25^{b}	10.65^{c}	11.99^{c}	22.64^{f}
Viscount	T	0.98^{cde}	1.05^{abc}	0.72^{a}	0.72^{c}	1.08^{ab}	1.06^{a}	1.27^{b}	15.29^{a}	12.89^{bc}	30.64^{a}
LSD (0.05)		0.34	0.29	0.25	0.26	0.34	0.24	0.24	1.64	2.44	2.77
CV %		17.5	18.0	27.1	17.4	17.6	14.6	10.6	10.9	11.2	7.16

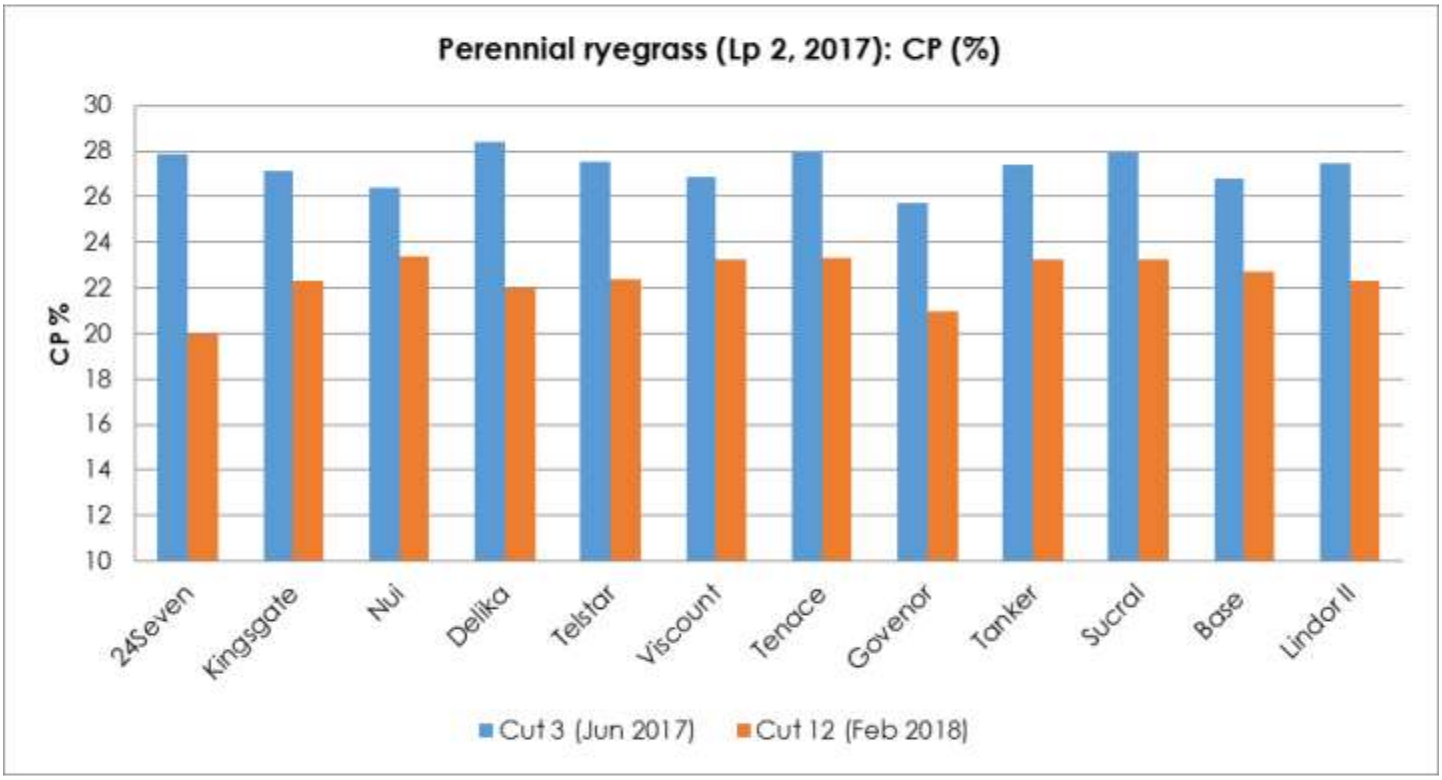
Note: treatments with the same letter are not significantly different.
Type: D = Diploid, T = Tetraploid

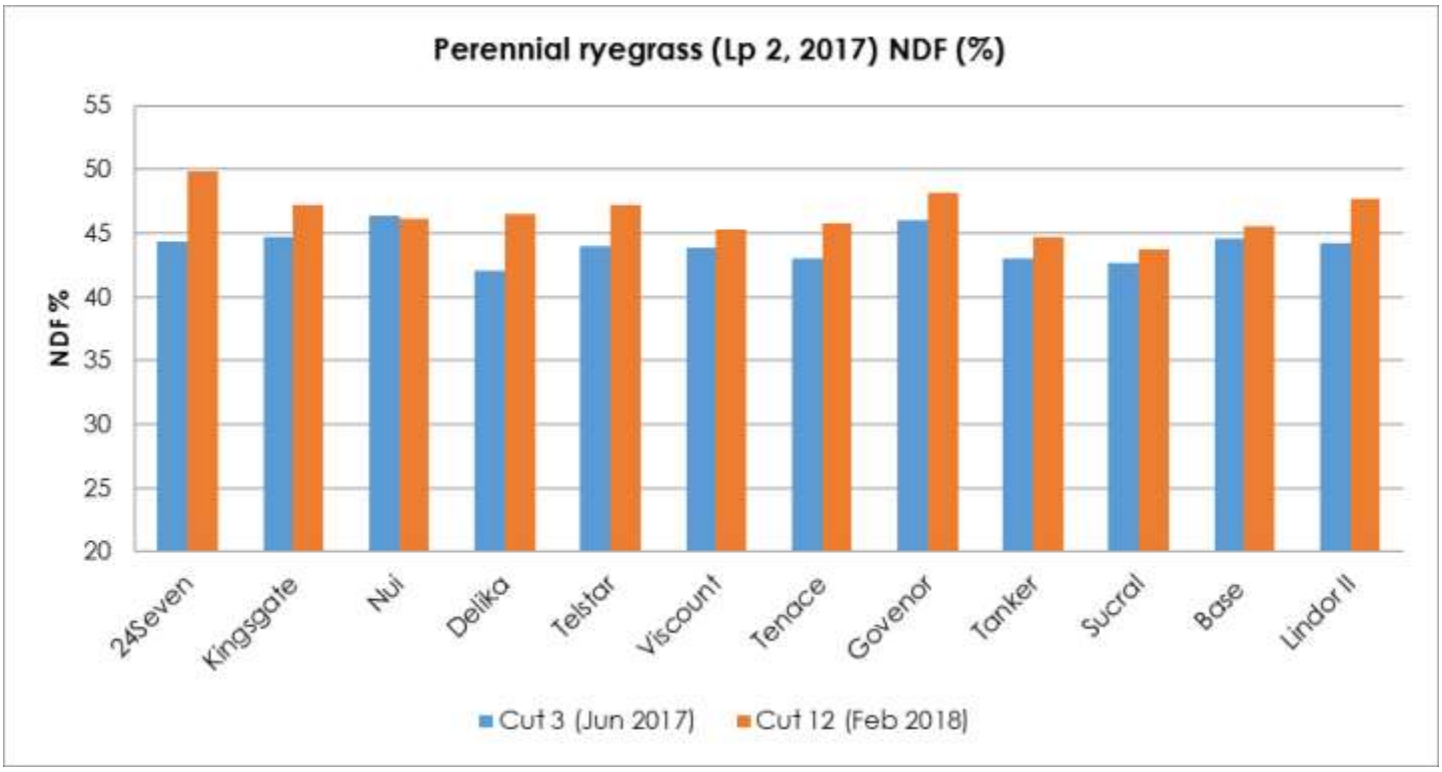
Table 2 cont.: Perennial ryegrass (*Lolium perenne*) (Lp 2, 2017), Elite Evaluation, Outeniqua Research Farm.

Planted: 10 March 2017 Yield (t DM/ha) trial is continuing

Cultivars	Autumn 2017	Winter 2017	Spring 2017	Summer 2017/18	Autumn 2018	Winter 2018	Spring 2018	Summer 2018/19	Autumn 2019	Total 1-27
24Seven	2.98	3.57^{ab}	5.68^{ab}	4.11^{ab}	3.78^{a}	2.05^{def}	4.48^{abcd}	2.49^{bc}	3.66	33.14^{abc}
Base	2.67	3.90^{a}	5.73^{a}	4.49^{a}	3.35^{bc}	2.74^{ab}	4.48^{abcd}	3.01^{ab}	3.73	34.38^{ab}
Delika	2.76	2.53^{de}	5.79^{a}	4.05^{abc}	3.75^{a}	1.58^{g}	4.04^{de}	2.34^{c}	3.53	30.67^{cd}
Govenor	2.94	4.05^{a}	5.48^{ab}	4.18^{ab}	3.31^{b}	2.91^{a}	4.90^{a}	3.35^{a}	3.78	35.26^{a}
Kingsgate	2.95	2.94^{bcd}	5.65^{ab}	3.37^{c}	3.36^{bc}	2.32^{bcd}	3.48^{e}	2.21^{c}	3.28	29.87^{d}
Lindor II	2.92	2.78^{bcde}	5.03^{b}	3.67^{bc}	3.11^{cd}	1.76^{efg}	4.17^{cd}	2.51^{bc}	3.18	29.45^{d}
Nui	2.72	3.72^{a}	4.99^{b}	3.83^{abc}	3.17^{cd}	$2.15c^{de}$	4.10^{cd}	2.60^{bc}	3.33	30.74^{cd}
Sucral	2.79	2.68^{cde}	5.94^{a}	4.15^{ab}	3.49^{ab}	1.28^{g}	4.12^{cd}	2.63^{bc}	3.52	30.93^{c}
Tanker	2.55	3.35^{abc}	5.39^{ab}	4.46^{a}	2.99^{de}	2.45^{abcd}	4.80^{ab}	2.94^{ab}	3.41	32.79^{abc}
Telstar	2.59	2.30^{de}	5.72^{ab}	3.60^{bc}	3.50^{ab}	2.23^{bcde}	4.14^{cd}	2.17^{c}	3.18	29.84^{d}
Tenace	2.66	2.11^{e}	5.74^{a}	3.78^{abc}	3.49^{ab}	1.71^{efg}	4.28^{cd}	2.22^{c}	3.36	29.68^{d}
Viscount	2.79	3.96^{a}	5.56^{ab}	4.18^{ab}	2.71^{e}	2.64^{abc}	4.63^{abc}	2.67^{cd}	3.42	32.84^{bc}
LSD (0.05)	NS	0.80	0.70	0.73	0.30	0.54	0.59	0.57	NS	2.77
CV %	11.2	15.0	7.5	10.80	5.40	14.9	8.1	12.9	11.1	4.9

Note: treatments with the same letter are not significantly different.
Type: D = Diploid, T = Tetraploid


Perennial ryegrass (Lp 2, 2017): CP (%)
CP %
30
28
26
24
22
20
18
16
14
12
10
24Seven
Kingsgate
Nui
Delika
Telstar
Viscount
Tenace
Govenor
Tanker
Sucral
Base
Lindor II
Cut 3 (Jun 2017)
Cut 12 (Feb 2018)


Perennial ryegrass (Lp 2, 2017) NDF (%)
NDF %
55
50
45
40
35
30
25
20
24Seven
Kingsgate
Nui
Delika
Telstar
Viscount
Tenace
Govenor
Tanker
Sucral
Base
Lindor II
Cut 3 (Jun 2017)
Cut 12 (Feb 2018)

Discussion and conclusions

The highest yielding cultivars in the Italian ryegrass trial of 2018 (Lm 7) were Green Spirit and Barcrespo with 14.7 and 14.4 t DM/ha ($p<0.05$) respectively. The cultivars with similar yield ($p<0.05$) were Itaka, Tabu Plus, Fox, Sukari, Barmultra II, Icon and Yolande. Although this particular trial yielded less than the 2017 trial, the exact same varieties were in the highest yielding group as in the 2017 trial (Lm 6), with Sukari, Icon and Yolande even being at the same rank. This does give the indication that even though conditions were less variable during 2018 than they were during 2017, it is still the same cultivars that perform best. In the 2018 trial (Lm 7), the yields were especially lower for winter and summer when compared to the previous year.

For the forage quality data of the Italian ryegrass cultivars, there was no apparent link between ploidy and NDF values. As expected the NDF values were higher during summer when the plants have some reproductive tillers.

The perennial ryegrass trial established in 2017 and having completed the second year at the end of summer 2018, showed a stable yielding capacity over the two years. The highest yielding cultivar over the two year period was Govenor with 30.57 t DM/ha ($P<0.05$). Base, Tanker and Viscount had a similar yield to Govenor ($P<0.05$) with 29.7, 28.3 and 28.2 t DM/ha respectively. However looking at the yields over the 26 month period up to end of autumn 2019 Governor is still the highest yielding at 35.3 t DM/ha (P,0.05) followed by Base (34.4 t DM/ha), 24 Seven (33.1 t DM/ha) and Tanker (32.8 t DM/ha) with ($p<0.05$). This was the result of good yields in autumn 2019 which represents the start of the third year. The largest yield differences between cultivars, as expected, is during winter and summer.

In terms of forage quality for the perennial ryegrass varieties there were less differences than for the Italian cultivars which could be linked to the lower flowering incidence in Italian ryegrass than is generally the case in perennial ryegrass. Unlike the Italian ryegrass cultivars, there is a slight indication of the tetraploid cultivars having a lower NDF than the diploid cultivars, although the differences are small.

Elite cultivar evaluation: Tall Fescue and Festulolium

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Introduction

The Elite evaluation trials are aimed at evaluating agronomic traits such as DM yield, disease tolerance and forage quality and also provide data on interaction traits (seasonal yield distribution, flowering, growth form, persistence) for what can be considered modern and high-end varieties. This information provides local data for choice of pasture cultivars. The interactions traits can be used to assist in selecting varieties for pasture mixes. It is important to determine the genetic potential of varieties and in that way evaluate all varieties on equal terms in an unbiased way.

- Evaluate high-end varieties with modern genetics and special traits
- Characterize into types
- Determine agronomic and interaction traits to assist with choosing varieties for mixtures aiming at complementarity within the mixture

Parameters measured/assessed:

- DM yield (harvested according to leaf-stage)
- Seasonal yield patterns
- Dry matter (DM) content
- Disease incidence (mainly rust)
- Flowering behaviour
- Persistence/ plant population
- Forage quality
- General growth form

Festuca species evaluated

The following Festuca species are evaluated

- *Festulolium* – loloid and festucoid
- *Festuca arundinacea* (tall fescue) – Continental and Mediterranean types

Tall fescue (*Festuca arundinacea*) characteristics

- Perennial grass with deep root system with good persistence
- Relatively good forage quality, especially modern varieties that have softer leaves (lower tensile strength)
- Tolerates waterlogging
- Tolerates high temperatures
- Tolerates low pH soils and salinity
- *Continental types*
  - o Summer active growth
- *Mediterranean types*
  - o Winter active (summer dormant)
- Soil temperature at sowing should >15°C for rapid germination and consequently successful establishment. Hence establishment should be done in early autumn or even late summer depending on the climate.

The aim of the cultivar evaluation trials is to determine the genetic potential for the various parameters. The *Festuca* trial is harvested when the first continental cultivars reach the 2 to 2.5 leaf stage or in spring at canopy closure if necessary. According to Chapman et al 2014, tall fescue carbohydrate reserves are replenished between the 2 and 4 leaf stage and maximum growth rate is achieved at the 2.5 leaf stage. Leaf appearance rate is determined mainly by temperature and hence most varieties reach the required leaf stage at a similar time. This harvest interval is used even though tall fescue is known to be a four-leaf plant, however with the larger root system and greater tolerance of higher temperatures the plants tend to have sufficient storage carbohydrates to be harvested before the maximum leaf number is reached.

Results

The tall fescue cultivar Easton was the highest yielding in both year 1 (16.9 t DM/ha) and year 2 (15.4 t DM/ha) as well as over the 28 month period (37.3 t DM/ha) ($p<0.05$). Of the continental tall fescue cultivars, Boschhoek, Duramax and Tuscany were similar in year 2 to Easton with 14,3 tDM/ha, 13.8 and 13.9 t DM/ha respectively ($p<0.05$). The Mediterranean cultivar Temora was similar to Easton in both year 1 and year 2 with 16.1 and 15.0 t DM/ ha.

The Mediterranean cultivars Temora, Resolute and Origin were significantly higher yielding (0.05) than all other cultivars in the second autumn and winter (see Table 2). This was also the case in the first winter although the continental cultivar Easton and the two loloid Festuloliums Achilles and Lofa were similar ($p<0.05$).

The two loloid Festuloliums Achilles and Lofa yield similar to the highest yielding cultivar Easton in the first year but their yield was significantly lower in the second year, with 13.2 and 11.7 t DM/ha respectively ($p<0.05$).

Forage quality data for CP and NDF is given in figure 1. The CP % was generally acceptable for all cultivars except for December 2017 when all cultivars were lower than the three other seasons with the two loloid Festulolium cultivars being notably lower than the rest with values below 14 %. The CP values were overall lower within seasons for the Mediterranean cultivars, especially during October and December. The NDF values for the Mediterranean cultivars Origin, Resolte and Temora are above all other cultivars for July 2017, June 2018 and October 2018.

Table 1: Tall Fescue (*Festuca arundinacea*) and Festulolium Fa 1, Outeniqua Research Farm, individual harvests
Planted: 10 March 2017 Yield (t DM/ha) trial is continuing

Cultivars	Type	Cut 1 26/4/17	Cut 2 31/5/17	Cut 3 11/7/17	Cut 4 21/8/17	Cut 5 27/9/17	Cut 6 1/11/17	Cut 7 6/12/17	Cut 8 11/1/18	Cut 9 8/2/18	Cut 10 27/3/18	Cut 11 8/5/18	Cut 12 20/6/18
Achilles	FL/L	1.04^{ab}	1.33^{ab}	1.44^{cd}	1.51^{ab}	2.67^{a}	2.42^{bc}	2.47^{ab}	1.72^{def}	0.95^{fg}	1.43^{ij}	1.61^{cde}	0.97^{bc}
Apalona	Fa/C	0.35^{d}	0.79^{d}	1.44^{cd}	0.75^{cde}	1.53^{d}	2.36^{bc}	2.37^{abc}	2.28^{ab}	1.49^{abcd}	1.91^{efg}	1.70^{cde}	0.89^{bcd}
BarDelice	Fa/C	0.41^{d}	0.78^{d}	1.39^{cd}	0.66^{cde}	1.92^{cd}	2.60^{abc}	2.50^{a}	2.37^{a}	1.58^{abc}	1.85^{fgh}	1.65^{cde}	0.86^{bcde}
Baroptima	Fa/C	0.62^{cd}	1.06^{abcd}	1.38^{cd}	0.63^{de}	1.65^{d}	2.49^{bc}	2.31^{abc}	2.16^{abc}	1.53^{abc}	2.22^{cde}	1.79^{cd}	0.85^{bcde}
Boschhoek	Fa/C	0.35^{d}	0.73^{d}	1.38^{cd}	0.98^{c}	1.93^{bcd}	2.30^{c}	1.99^{cd}	1.69^{def}	1.32^{cde}	1.36^{ij}	1.70^{cde}	0.75^{cdef}
Duramax	Fa/C	0.70^{bcd}	0.65^{d}	1.23^{de}	0.72^{cde}	2.32^{abc}	2.83^{ab}	2.19^{abcd}	1.86^{cde}	1.63^{ab}	2.24^{cd}	1.69^{cde}	0.66^{ef}
Easton	Fa/C	0.73^{bcd}	1.28^{ab}	1.51^{bc}	1.47^{ab}	2.56^{a}	2.31^{c}	2.17^{abcd}	2.37^{a}	1.61^{abc}	2.07^{def}	1.95^{bc}	1.01^{b}
Felina	FL/F	0.64^{cd}	0.66^{d}	1.21^{de}	0.54^{e}	1.80^{cd}	2.29^{c}	2.36^{abc}	1.80^{cde}	1.47^{abcd}	1.29^{j}	1.70^{cde}	0.67^{def}
Fojtan	FL/F	0.35^{d}	0.66^{d}	1.07^{e}	0.56^{e}	1.64^{d}	2.74^{abc}	2.34^{abc}	1.65^{def}	1.54^{abc}	2.30^{cd}	1.37^{e}	0.58^{f}
Iliade	Fa/C	0.47^{cd}	0.78^{d}	1.43^{cd}	0.70^{cde}	1.93^{bcd}	2.58^{abc}	2.39^{abc}	1.97^{bcd}	1.50^{abcd}	1.61^{fghj}	1.78^{cd}	0.76^{cdef}
Lofa	FL/L	1.47^{a}	1.56^{a}	1.73^{ab}	1.43^{b}	2.52^{ab}	2.32^{c}	2.00^{bcd}	1.55^{efg}	0.90^{g}	1.29^{j}	1.77^{cd}	1.03^{b}
Ninkoko	Fa/C	0.51^{cd}	0.87^{cd}	1.41^{cd}	0.93^{cd}	2.37^{abc}	2.59^{abc}	2.18^{abcd}	1.82^{cde}	1.41^{bcde}	1.92^{efg}	1.83^{cd}	0.84^{bcde}
Origin	Fa/M	0.69^{bcd}	1.23^{abc}	1.95^{a}	1.49^{ab}	2.10^{abcd}	1.62^{d}	1.76^{d}	1.19^{g}	1.23^{def}	2.72^{ab}	2.36^{a}	1.31^{a}
Resolute	Fa/M	0.64^{cd}	0.97^{bcd}	1.98^{a}	1.54^{ab}	2.38^{abc}	1.46^{d}	1.78^{d}	1.22^{g}	1.14^{efg}	2.53^{bc}	2.19^{ab}	1.47^{a}
Temora	Fa/M	0.81^{bc}	1.26^{abc}	1.96^{a}	1.79^{a}	2.67^{a}	1.68^{d}	2.00^{bcd}	1.40^{fg}	1.33^{cde}	2.93^{a}	2.24^{a}	1.31^{a}
Tuscany	Fa/C	0.51^{cd}	0.64^{d}	1.05^{e}	0.56^{e}	1.88^{cd}	2.98^{a}	2.39^{abc}	1.93^{abcd}	1.74^{a}	2.13^{def}	1.60^{de}	0.65^{ef}
LSD (0.05)		0.37	0.43	0.26	0.32	0.59	0.47	0.46	0.39	0.29	0.31	0.34	0.22
CV %		34.3	27.1	10.5	19.0	16.8	12.1	12.6	13.1	12.3	9.4	11.3	14.4

Fa = *Festuca arundinacea* (Tall fescue), C = Continental type, M = Mediterranean type, FL = *Festulolium*, L = loloid, F = festucoid
Note: treatments with the same letter are not significantly different.

Table 1 cont.: Tall Fescue (*Festuca arundinacea*) and Festulolium Fa 1, Outeniqua Research Farm, individual harvests
Planted: 10 March 2017 Yield (t DM/ha) trial is continuing

Cultivars	Type	Cut 13 22/8/18	Cut 14 1/10/18	Cut 15 2/11/18	Cut 16 13/12/18	Cut 17 17/1/19	Cut 18 21/2/19	Cut 19 2/4/19	Cut 20 14/5/19	Cut 21 28/6/19	Total Cuts 1-21 Mar17-Jun19
Achilles	FL/L	0.77^{b}	1.92^{bc}	2.19^{a}	2.23^{bcd}	1.15^{ef}	1.25^{de}	1.44^{f}	1.40^{fg}	0.79^{de}	32.70^{bc}
Apalona	Fa/C	0.51^{cde}	0.56^{i}	1.50^{cd}	1.89^{cde}	1.67^{abcd}	1.65^{abc}	1.83^{cde}	1.77^{bcdef}	0.75^{de}	29.99^{bcd}
BarDelice	Fa/C	0.42^{de}	0.82^{hi}	1.78^{abc}	2.23^{bcd}	1.50^{cde}	1.59^{bc}	1.86^{cde}	1.71^{cdef}	0.73^{def}	31.21^{bcd}
Baroptima	Fa/C	0.34^{e}	1.03^{fgh}	2.01^{ab}	2.20^{bcde}	1.55^{bcd}	1.66^{abc}	1.79^{de}	1.68^{cdef}	0.66^{efg}	31.64^{bc}
Boschhoek	Fa/C	0.61^{cde}	1.56^{cde}	2.06^{a}	2.83^{a}	1.91^{ab}	1.70^{abc}	2.01^{bcde}	1.87^{abcd}	0.69^{defg}	31.74^{bc}
Duramax	Fa/C	0.44^{de}	1.45^{def}	2.10^{a}	2.35^{abc}	1.68^{abcd}	1.82^{ab}	2.09^{abcd}	1.72^{cdef}	0.57^{fg}	32.93^{b}
Easton	Fa/C	0.69^{bc}	1.32^{efg}	2.12^{a}	2.84^{a}	1.99^{a}	1.89^{a}	2.36^{a}	2.03^{abcd}	1.00^{bc}	37.28^{a}
Felina	FL/F	0.41^{de}	0.81^{hi}	1.40^{cd}	2.22^{bcd}	1.79^{abc}	1.68^{abc}	2.22^{ab}	1.79^{bcde}	0.71^{def}	29.45^{cd}
Fojtan	FL/F	0.31^{e}	0.93^{ghi}	1.87^{abc}	1.72^{de}	1.32^{de}	1.48^{dc}	1.74^{ef}	1.48^{efg}	0.53^{g}	28.17^{d}
Iliade	Fa/C	0.40^{de}	0.74^{hi}	2.02^{ab}	2.46^{ab}	1.70^{abc}	1.74^{abc}	1.91^{bcde}	1.66^{def}	0.64^{efg}	31.16^{bcd}
Lofa	FL/L	0.79^{b}	1.78^{bcd}	2.18^{a}	1.72^{de}	0.83^{f}	0.67^{g}	1.10^{g}	1.19^{g}	0.80^{de}	30.64^{bcd}
Ninkoko	Fa/C	0.48^{cde}	1.06^{fgh}	2.23^{a}	2.40^{abc}	1.49^{cde}	1.65^{abc}	1.91^{bcde}	2.04^{abc}	0.86^{cd}	32.80^{bc}
Origin	Fa/M	1.95^{a}	2.12^{b}	1.25^{d}	0.87^{f}	0.27^{g}	0.84^{fg}	1.98^{bcde}	2.10^{ab}	1.31^{a}	32.33^{bc}
Resolute	Fa/M	2.08^{a}	2.01^{bc}	1.15^{d}	0.97^{f}	0.17^{g}	0.55^{g}	1.90^{bcde}	1.85^{abcde}	1.18^{ab}	31.15^{bcd}
Temora	Fa/M	1.95^{a}	2.69a	1.55^{bcd}	1.65^{e}	0.45^{g}	1.11^{ef}	2.36^{a}	2.20^{a}	1.26^{a}	36.59^{a}
Tuscany	Fa/C	0.30^{e}	$1.18e^{fgh}$	2.24^{a}	2.36^{abc}	2.00^{a}	1.92^{a}	2.14^{abc}	1.72^{cdef}	0.56^{fg}	32.48^{bc}
LSD (0.05)		0.24	0.44	0.49	0.56	0.37	0.30	0.33	0.37	0.18	2.93
CV %		18.9	19.4	15.7	16.4	16.5	12.2	10.4	12.7	13.2	5.5

Fa = *Festuca arundinacea* (Tall fescue), C = Continental type, M = Mediterranean type, FL = *Festulolium*, L = loloid, F = festucoid
Note: treatments with the same letter are not significantly different.

Table 2: Tall Fescue (*Festuca arundinacea*) and Festulolium (Fa 1), Outeniqua Research Farm, seasonal yield
Planted: 10 March 2017 Yield (t DM/ha) trial is continuing

Cultivars	Type	Autumn 2017	Winter 2017	Spring 2017	Summer 2017/18	Autumn 2018	Winter 2018	Spring 2018	Summer 2018/19	Autumn 2019	Year 1 2017/18	Year 2 2018/19
Achilles	FL/L	2.37^{b}	3.67^{b}	6.41^{a}	3.69^{gh}	2.96^{def}	1.61^{bc}	5.25^{a}	3.37^{e}	2.88^{fg}	16.15^{ab}	13.18^{cdef}
Apalona	Fa/C	1.14^{ef}	2.61^{cdef}	5.44^{bcde}	4.99^{abc}	3.28^{bcde}	1.03^{ef}	3.24^{f}	4.25^{bcd}	3.55^{de}	14.17^{defg}	11.93^{efg}
BarDelice	Fa/C	1.18^{ef}	2.58^{cdef}	6.08^{abc}	5.17^{ab}	3.18^{cdef}	0.98^{ef}	3.96^{cdef}	4.13^{cd}	3.51^{de}	14.99^{bcde}	12.26^{defg}
Baroptima	Fa/C	1.68^{cd}	2.46^{defg}	5.61^{abc}	5.06^{abc}	3.52^{bc}	0.94^{ef}	4.34^{bcd}	4.24^{bcd}	3.40^{def}	14.78^{bcdef}	13.04^{cdef}
Boschhoek	Fa/C	1.09^{f}	2.88^{cd}	5.36^{cde}	3.98^{efg}	2.88^{ef}	1.27^{cde}	5.24^{a}	4.87^{ab}	3.78^{cd}	13.26^{g}	14.27^{abc}
Duramax	Fa/C	1.35^{def}	2.57^{cdefg}	6.35^{ab}	4.93^{abc}	3.33^{bcd}	1.04^{ef}	4.86^{ab}	4.61^{abc}	3.65^{d}	15.09^{bcd}	13.84^{abcd}
Easton	Fa/C	2.01^{bc}	3.67^{b}	5.98^{abc}	5.26^{a}	3.68^{b}	1.42^{bcd}	5.11^{ab}	5.20^{a}	4.34^{ab}	16.90^{a}	15.41^{a}
Felina	FL/F	1.31^{def}	2.23^{efg}	5.56^{abcd}	4.21^{defg}	2.80^{f}	0.88^{f}	3.57^{def}	4.57^{abc}	3.88^{bcd}	13.21^{fg}	11.82^{efg}
Fojtan	FL/F	1.01^{f}	2.07^{g}	5.88^{c}	4.64^{bcd}	3.01^{def}	0.76^{f}	3.79^{def}	3.66^{de}	3.11^{ef}	13.52^{efg}	11.22^{g}
Iliade	Fa/C	1.24^{def}	2.65^{cde}	5.96^{abc}	4.60^{cd}	3.11^{cdef}	0.90^{f}	4.30^{bcde}	4.56^{abc}	3.46^{de}	14.42^{defg}	12.87^{cdef}
Lofa	FL/L	3.03^{a}	3.84^{b}	5.82^{c}	3.40^{h}	3.07^{def}	1.63^{b}	4.79^{abc}	2.25^{fg}	2.39^{g}	16.04^{abc}	11.73^{g}
Ninkoko	Fa/C	1.38^{def}	2.99^{c}	6.13^{abc}	4.49^{de}	3.38^{bcd}	1.08^{def}	4.71^{abc}	4.25^{bcd}	3.93^{bcd}	14.91^{bcde}	13.43^{bcde}
Origin	Fa/M	1.92^{bc}	4.01^{ab}	4.61^{e}	3.86^{fgh}	4.63^{a}	2.99^{a}	3.54^{def}	1.74^{gh}	4.21^{abc}	14.41^{defg}	12.89^{cdef}
Resolute	Fa/M	1.62^{cde}	4.16^{ab}	4.67^{de}	3.69^{gh}	4.43^{a}	3.16^{a}	3.42^{ef}	1.37^{h}	3.85^{bcd}	14.19^{defg}	12.38^{defg}
Temora	Fa/M	2.08^{bc}	4.47^{a}	5.28^{cde}	4.26^{def}	4.62^{a}	3.09^{a}	4.82^{abc}	2.50^{f}	4.62^{a}	16.14^{ab}	15.04^{ab}
Tuscany	Fa/C	1.16^{ef}	2.12^{fg}	6.33^{ab}	5.09^{ab}	3.17^{cdef}	0.84^{f}	4.78^{abc}	5.05^{a}	3.68^{cd}	14.60^{cdefg}	13.85^{abcd}
LSD (0.05)		0.49	0.50	0.92	0.55	0.44	0.35	0.89	0.70	0.54	1.50	1.64
CV %		18.30	9.70	9.70	7.40	7.60	14.4	12.2	11.1	8.6	6.1	7.5

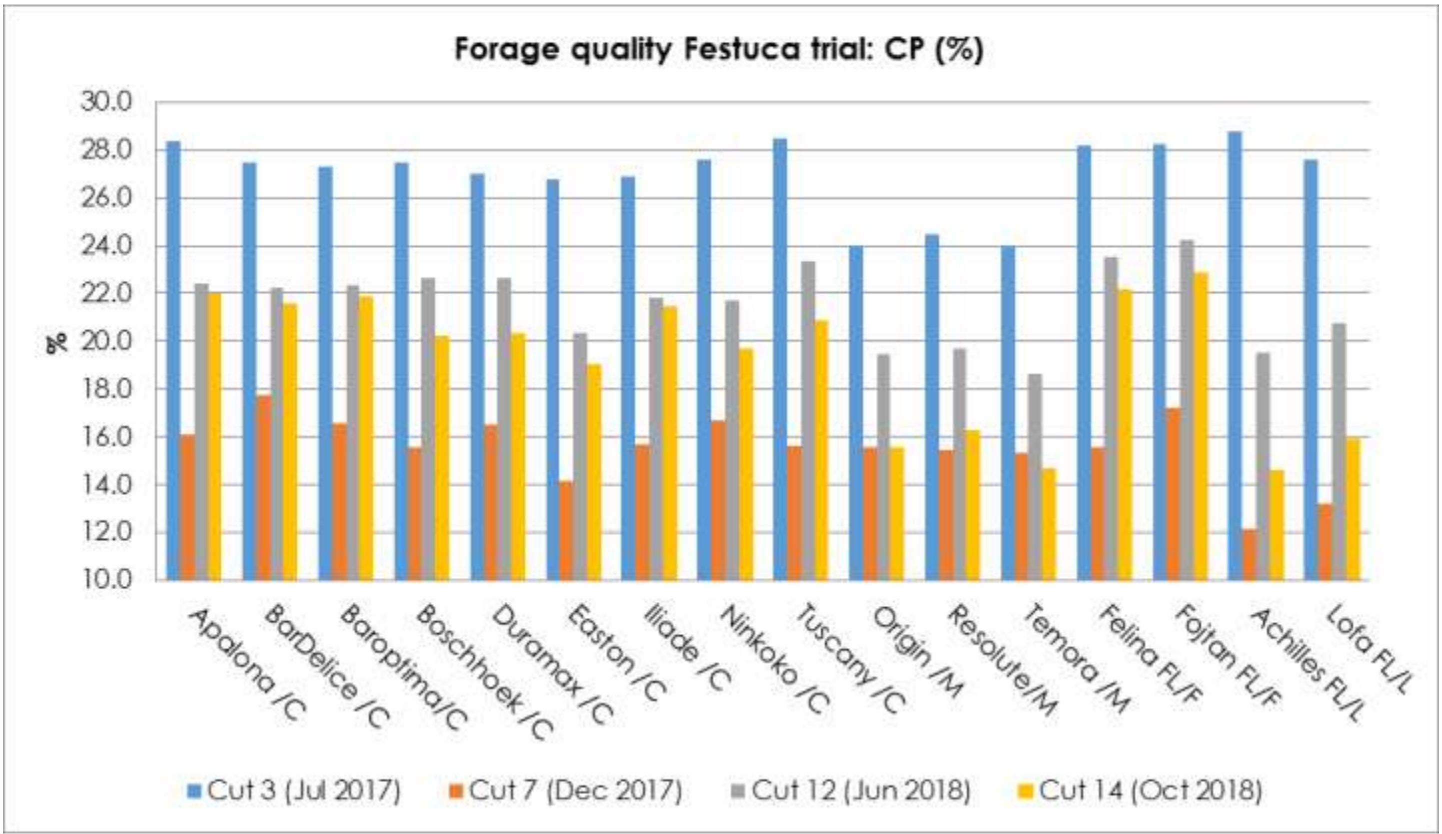
Fa = *Festuca arundinacea* (Tall fescue), C = Continental type, M = Mediterranean type, FL = *Festulolium*, L = loloid, F = festucoid
Note: treatments with the same letter are not significantly different.

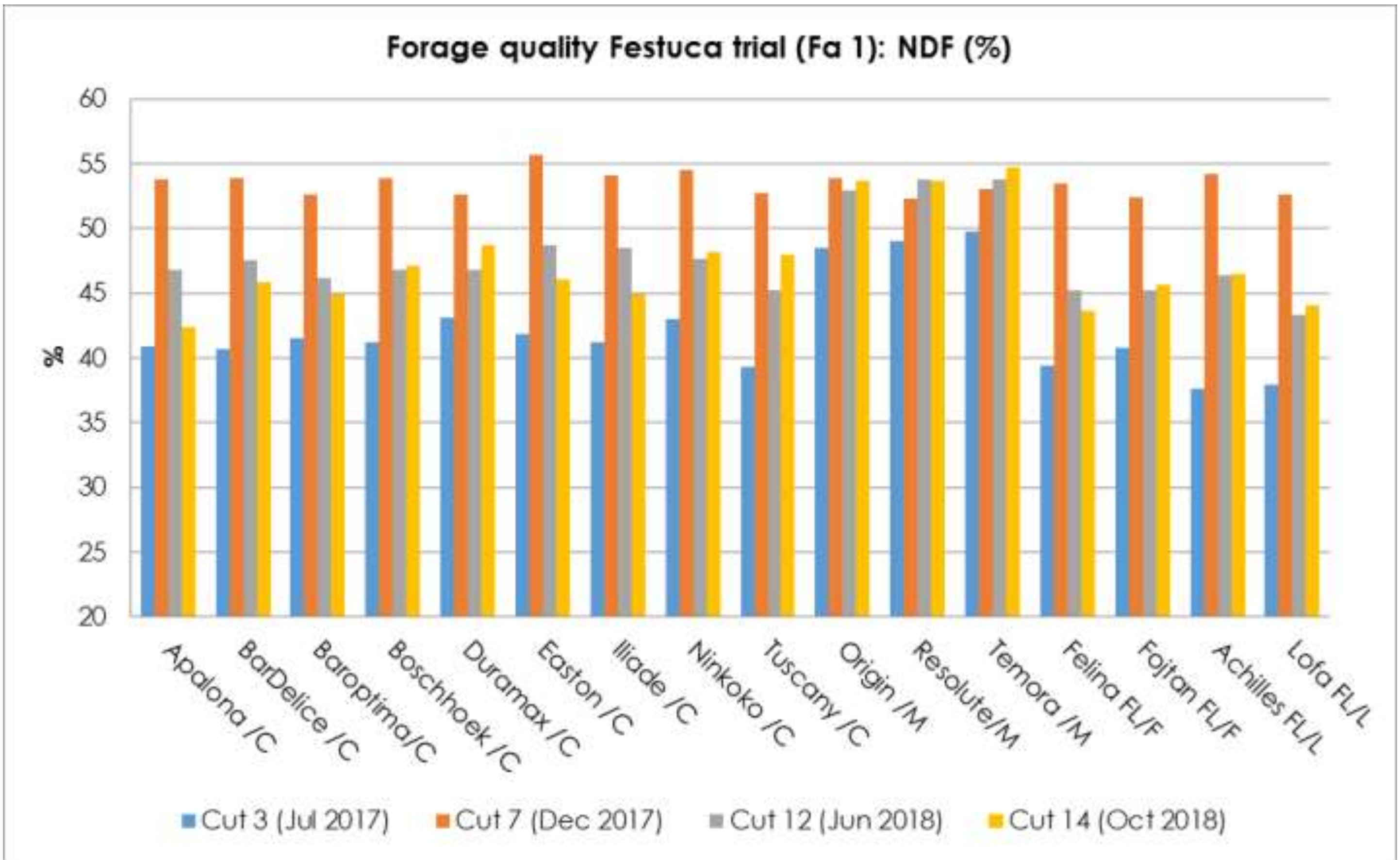
Table 3: Tall Fescue (*Festuca arundinacea*) and Festulolium (Fa 1), Outeniqua Research Farm, seasonal growth rates
Planted: 10 March 2017 Growth rate (kg DM/day) trial is continuing

Cultivars	Type	Autumn 2017	Winter 2017	Spring 2017	Summer 2017/18	Autumn 2018	Winter 2018	Spring 2018	Summer 2018/19	Autumn 2019
Achilles	FL/L	29.3^{b}	39.9^{b}	70.4^{a}	41.1^{hi}	32.1^{def}	17.4^{bc}	57.7^{a}	37.4^{e}	31.4^{gh}
Apalona	Fa/C	14.1^{ef}	28.3^{cdef}	59.8^{bcde}	55.5^{abc}	35.6^{bcde}	11.2^{ef}	35.6^{f}	47.2^{bcd}	38.6^{def}
BarDelice	Fa/C	14.6^{ef}	28.0^{cdef}	66.8^{abc}	57.3^{a}	34.5^{cdef}	10.7^{ef}	43.6^{cdef}	45.9^{cd}	38.1^{def}
Baroptima	Fa/C	20.8^{cd}	26.8^{defg}	61.7^{abc}	55.9^{ab}	38.23^{bc}	10.3^{ef}	47.7^{bcd}	47.1^{bcd}	36.9^{efg}
Boschhoek	Fa/C	13.4^{f}	31.3^{cd}	58.9^{cde}	43.7^{fgh}	31.3^{ef}	13.8^{cde}	57.6^{a}	54.1^{ab}	41.1^{cde}
Duramax	Fa/C	16.6^{def}	28.0^{cdef}	69.7^{ab}	53.6^{abcd}	36.2^{bcd}	11.3^{ef}	53.4^{ab}	51.2^{abc}	39.7^{de}
Easton	Fa/C	24.8^{bc}	39.9^{b}	65.7^{abc}	58.2^{a}	40.0^{b}	15.5^{bcd}	56.2^{ab}	57.8^{a}	47.2^{ab}
Felina	FL/F	16.1^{def}	24.3^{efg}	61.1^{abcd}	46.8^{efgh}	30.4^{f}	9.6^{f}	39.2^{def}	50.7^{abc}	42.1^{bcde}
Fojtan	FL/F	12.4^{f}	22.5^{g}	64.6^{abc}	50.7^{bcde}	32.7^{def}	8.3^{f}	41.6^{def}	40.7^{de}	33.8^{fg}
Iliade	Fa/C	15.4^{def}	28.8^{cde}	65.5^{abc}	50.7^{bcde}	33.8^{cdef}	9.8^{f}	47.2^{bcde}	50.7^{abc}	37.7^{def}
Lofa	FL/L	37.4^{a}	41.7^{b}	64.0^{abc}	37.2^{i}	33.3^{def}	17.7^{b}	52.6^{abc}	25.0^{fg}	25.9^{h}
Ninkoko	Fa/C	17.0^{def}	32.5^{c}	67.3^{abc}	49.1^{cdef}	36.8^{bcd}	11.8^{def}	51.8^{abc}	47.2^{bcd}	42.7^{bcd}
Origin	Fa/M	23.7^{bc}	43.6^{ab}	50.6^{e}	43.1^{fghi}	50.3^{a}	32.5^{a}	38.9^{def}	19.3^{gh}	45.8^{ab}
Resolute	Fa/M	20.0^{cde}	45.2^{ab}	51.3^{de}	41.6^{ghi}	48.1^{a}	34.4^{a}	37.6^{ef}	15.2^{h}	41.8^{bcde}
Temora	Fa/M	25.6^{bc}	48.6^{a}	58.1^{cde}	47.9^{defg}	50.2^{a}	33.6^{a}	53.0^{ab}	27.8^{f}	50.2^{a}
Tuscany	Fa/C	14.3^{ef}	23.0^{fg}	69.6^{ab}	55.4^{abc}	34.5^{cdef}	9.2^{f}	52.6^{abc}	56.1^{a}	40.0^{cde}
LSD (0.05)		6.00	5.40	10.12	6.42	4.76	3.84	9.73	7.81	5.83
CV %		18.3	9.7	9.7	7.8	7.6	14.3	12.2	11.1	8.8

Fa = *Festuca arundinacea* (Tall fescue), C = Continental type, M = Mediterranean type, FL = *Festulolium*, L = loloid, F = festucoid
Note: treatments with the same letter are not significantly different.

Figure 1: Forage quality values for CP and NDF Tall Fescue and Festulolium cultivars (Fa1)





Conclusions

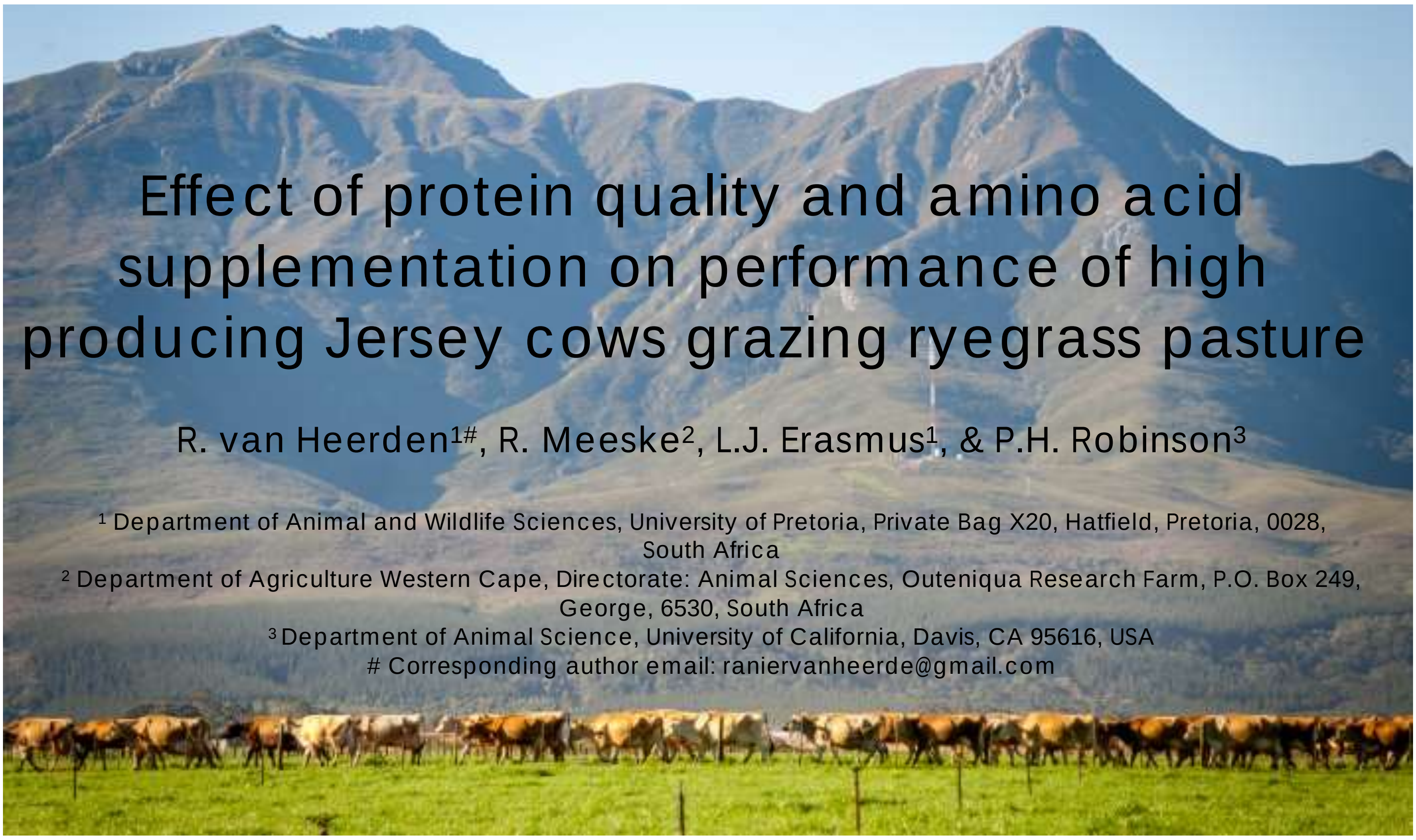
Amongst the continental tall fescue cultivars, there are some cultivars with improved winter yield which make them more suitable for our dairy pasture systems. There is though a considerable yield difference between the first and second winter. The continuation of this trial will be important to determine longer term trends. The Mediterranean cultivars have a very high yielding capacity during autumn and winter but this is associated with higher NDF and lower CP values.

The yield data shows that in total the best cultivars can yield similar to perennial ryegrass but with longer harvest intervals (see perennial ryegrass article). This may make them more suitable for combinations with other pasture species that also have longer grazing intervals. The leaf number is also more flexible than perennial ryegrass. The forage quality of tall fescue in terms of NDF in the seasons when the plants are flowering, is less favourable than perennial ryegrass. It will thus be important to choose other species to combine with tall fescue that have a low NDF value during summer. Chicory and plantain could for instance be suitable.

This data shows that tall fescue can have a roll in dairy pasture systems but it is important to understand the limitations and the differences in seasonal production compared to ryegrass as well as which combinations with other species will be most suitable in mixtures or pure stands. The deeper root system of tall fescue is a definite advantage over perennial ryegrass in water stressed environments as well as its higher temperature tolerances. There are differences in survival strategy between tall fescue and perennial ryegrass in water stressed environments which favours tall fescue.

References

Chapman DF, Lee JM and Waghorn GC. 2014. Interaction between plant physiology and pasture feeding value: a review. Crop and Pasture Science 65: 721 – 734



Effect of protein quality and amino acid supplementation on performance of high producing Jersey cows grazing ryegrass pasture

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Introduction

The performance of high producing dairy cows grazing high quality pasture and fed a maize based concentrate might be limited by metabolisable protein (MP). Well managed ryegrass pastures are usually high in crude protein (CP) content, nitrogen (N) degradability, soluble protein content and dry matter digestibility and low in non-fibre carbohydrates (NFC), effective neutral detergent fibre (peNDF) and metabolizable energy (ME). Due to the high rate of protein degradation, relative to available fermentable energy, the formation of rumen ammonia exceeds the ability of the rumen microbes to synthesise microbial protein. As a result, the excess ammonia is converted to urea in the liver and excreted in urine. This is an energy costing process which reduces the nitrogen use efficiency (NUE) of grazing dairy cows and negatively impacts the environment and the economics of the farm (Apelo et al., 2014).

As ME is most frequently reported to be the first liming nutrient for milk production in pasture based systems, providing fermentable metabolisable energy (FME) in the form of fermentable carbohydrates may improve the utilization of pasture and improve microbial protein synthesis (Bargo., 2003). Therefore, farmers incorporate maize as an energy rich grain, but when milk production is high and more than 200g of grain/kg of diet is being fed to meet the cow's ME requirements, amino acids (AA), particularly Lysine (Lys), may limit cow performance (NRC, 2001, Kolver, 2003). The reason for this limitation is due to the maize CP content being low and the AA profile is also not ideal, especially Lys (NRC. 2001). Roche (2018), Meeske et al. (2006) and van Vuuren et al. (1992) reported that ryegrass has an undesired RDP: rumen undegradable protein (RUP) ratio, including a poor AA profile. Robinson, (2010) further reported that when pasture is being fed, Met tend to decrease in the cow's duodenal digesta, but when maize are fed Lys tend to decrease. The inadequate percentage of Met and Lys in metabolizable protein (MP) flowing to the cow's duodenum affects cow performance, especially high producing cows in early-and mid-lactation that has higher AA requirements (Socha et al., 2008).

In dairy cow protein- and AA nutrition, both essential amino acids, Met and Lys, have consistently been identified as the two most limiting AA's, as assessed from response measures of physiological AA levels, milk yield, or milk component yield in various production systems utilizing different rations (NRC, 2001, Rulquin et al., 2006, Socha et al., 2008, Schwab and Broderick, 2017). Measures include duodenal and ileal AA flow, microbial protein synthesis, milk nitrogen fractions (casein and whey) and milk protein concentration (Erasmus et al., 1994, Lapierre et al., 2006, Rulquin et al., 2006).

Several studies have been conducted to determine the effects of Lys supplementation upon these parameters with variable responses reported, some positive and some negative (Robinson et al., 1995, Doepel and Lapierre, 2010, Schwab and Broderick, 2017). However, most of these studies have been undertaken with total mixed rations (TMR), using different types of preserved forages and different ratios of forage to concentrate as opposed to grazed pasture (Tylutki et al., 2008). Thus, there is a lack of literature and experimental data available on the effects AA supplementation has on the grazing dairy cow's performance.

According to Schwab (2009), the ideal concentration of Lys and Met for milk protein yield in high producing dairy cows as a percentage of MP should be 6.8 and 2.2 %, respectively. This ration reflects a Lys to Met ratio of 3:1 as reported by Rulquin (1993) and the (NRC, 2001). Although, this ratio may not be met on pasture alone and could explain why pasture yields lower milk volume and milk protein content, or milk component percentages than TMR rations. Achieving this Lys: Met ratio with alternative protein sources high in RUP yields inconsistent results and usually result in an oversupply of dietary CP or cause an imbalance in the RDP: RUP ratio or AA content (Clark et al., 1992). Therefore, it would be expected that an individual supply of post-ruminal Met and/or Lys, in addition to the cow's ME requirements being met with high inclusion levels of maize, will have a positive effect on cow performance. The aim of this study was to determine the effects rumen protected Met and/or Lys supplementation has on cow performance, rumen microbial protein flow and plasma AA levels of high producing Jersey cows grazing ryegrass pastures and fed high levels of a maize based concentrate.

Materials and methods

Study location, climatic conditions and duration. The study was conducted at the Outeniqua Experimental Farm in the Western Cape Province of South Africa (SA) near George with an altitude, latitude and longitude of 204 m above sea-level, 33˚58´38´´S and 22˚25´16´´E, respectively. This area is classified as having a temperate climate with a long term (52 years) mean annual rainfall of 719.8 mm (range 449.7 to 1028.8 mm) and a mean spring season rainfall of 70.3 mm (range 30.7 to 184.5 mm) (ARC, 2018). Daily mean maximum and minimum temperatures for the trial period was 18.62 and 7.5 ˚C during September and, 23.1 and 11.9 ˚C during October, respectively. The study was conducted during late winter through mid-spring of 2018 (27 August to 8 November). Data collection took place from 10 September to the 8 November 2018 for a total of 60 days. Cows entering the trial were selected on 24 August 2018 and started an adaptation period on 27 August 2018 for 14 days until 10 September 2018.

Grazing camp design, pasture and soil. The grazing camp on which the study was conducted at the Outeniqua Experimental Farm consists of 8.55 ha permanent kikuyu/Italian rye grass pasture. Italian ryegrass (*Lolium multiflorum* var. *italicum*) cv. Fox, an annual ryegrass species was over-sown into the permanent kikuyu (*Pennisetum clandestinum*) pasture at a seeding density of 25 kg/ha on 27 March 2018. Pasture was top-dressed after each grazing with 100 kg/ha of limestone ammonium nitrate (LAN) which contains 28 % nitrogen (N), resulting in an application of 28 kg N/ha. Irrigation was done according to tensiometer readings to maintain a kilopascal (kPa) level between -10 and -25 kPa (Botha, 2002). The grazing camp primarily consist of two distinct soil types namely Estcourt and Witfontein (Soil Classification Working Group. 1991). Estcourt is found more north of the grazing camp and Witfontein more south where the grazing camp is slightly downward sloping.

Experimental design, cow management and cow welfare. Sixty high producing multiparous Jersey cows [BW, 408.2 ± 42.81 kg; milk yield, 22.1 ± 2.53 kg/d; parity 4.4 ± 1.75; DIM, 100.1 ± 64.78; (mean ± SD)] from the Outeniqua Experimental Farm herd were used in the study. The herd (367 lactating cows) average for milk production from which the study cows were selected was 17.4 ± 4.37 kg/d; (mean ± SD) in August 2018. The experimental design was a randomized complete block design (RCBD), and cows were blocked according to milk production (of the previous 21 days), DIM and lactation number. Cows were randomly allocated to three groups within each block. Subsequently, each group was randomly allocated to three experimental treatments; 1) Control (C), 2) rumen protected Lysine (RPL) and 3) rumen protected Methionine plus Lysine (RPML)). The cows strip grazed pre-allocated ryegrass pasture twice a day after each milking, so that the cows had access to fresh pasture after each milking. Cows were milked twice a day at 0500 and 1330 h and were allowed to graze 24 hours per day, excluding milking times, and clean water was freely available throughout the day. All the cows grazed as a single herd together to ensure equal pasture allocation. This study and the use of animals was approved by the University of Pretoria's Animal Use and Care Ethics Committee (EC041-18).

Experimental treatments and diet. All cows received 8 kg/day (as is) of the respective concentrate treatments during milking, divided between morning and afternoon milking at 0500 and 1330 h (4kg/cow/milking). Treatment 1: Control concentrate with no supplemented rumen protected AA (RPAA). Treatment 2: concentrate with rumen protected Lysine (RPL) providing 53.12 g LysiGEM™/cow/day (Kemin Industries©., Inc., USA., Reg No, V27404, Act 36 of 1947) Treatment 3: concentrate with RPL providing 53.12g LysiGEM™/cow/day plus rumen protected Methionine (RPM) providing 41.68g MetaSmartDRY®/cow/day (Adisseo, France, S.A.S., Reg No, V19417, Act 36 of 1947). All diets were formulated to be Iso-nitrogenous using urea as a nitrogen supplement (Table 1).

Experimental data collection, analytical methods and calculations. Pasture yield, intake and allocation were determined using a rising plate meter with a standard calibration equation. A pasture allowance (PA) of 11kg DM/cow/day was aimed for to ensure optimum intake of pasture DM. A linear regression equation Y = 91.6 H – 345 (R^2 = 0.74) were obtained during the study where Y=pasture yield kg DM/ha and H= average rising plate meter (RPM) reading. Pre-and post-grazing RPM heights were 27.4 ± 5.8 and 10.9 ± 1.62 (mean ± SD), respectively. Cows consumed on average 9.04 kg DM/cow/d and were allowed 12.85 kg DM/cow/d. Weekly ryegrass and concentrate samples were taken on Monday, Wednesday and Friday and pooled weekly for the ryegrass samples and biweekly for the concentrate samples and analysed for nutrient composition (Table 1) and AA concentrations (Table 2). Daily milk production (kg/cow/d) was measured throughout the study. Composite milk samples were collected bi-weekly. The cows, in addition to daily weighing, were also weighed on two consecutive days in the beginning and at the end of the trial. Body condition score (BCS) of the cows were determined after milking both at the beginning and end of the trial on the first of the two consecutive days when cows were weighed. A representative group of cows were selected for faecal, blood, urine and milk collection which consisted of all three cows in every second block from block 1-20. Thus, ten representative blocks were selected (30 cows in total), constituting of a representative portion of cow variation. Composite faecal samples were taken by means of rectal palpation or grab samples when cows defecate in the holding area on Monday, Wednesday and Friday on two different sampling periods. Spot urine samples were collected during six sampling periods to be analysed for purine derivatives to determine microbial protein flow. Blood was collected from the tail vein (Coccygeal) to be analysed for plasma AA composition. Composite milk samples for milk nitrogen analyses were taken on the second and forth milk sampling period to be analysed for non-protein nitrogen (NPN), casein and whey.

Statistical analysis. Data were analysed statistically as a RCBD with an ANOVA model (Statistical Analysis System, 2001) to determine differences between experimental treatment and measured parameters. Significance of difference was determined using Duncan's test (Samuels et al., 2010). The experimental units were divided into two groups and the difference between milk production, milk composition, microbial protein synthesis and body measurement for the treatments were analysed with Proc GLM Repeated Measures Analysis of Variance (Statistical Analysis Systems, 2001). Means and standard error were calculated and significance of difference between means was determined by Fischer's test (Samuels et al., 2010). Differences were considered significant at $P \leq 0.05$ and tendencies were indicated at $P \leq 0.1$.

Results and discussion

The ingredients and chemical composition of the concentrates, including the chemical composition of the ryegrass pasture are presented in Table 1. Table 2 presents the essential amino acid composition of both the pasture and concentrate, respectively.

Table 1. Ingredients and chemical composition of the C, RPL and RPML concentrate pellets fed, including the chemical composition of the ryegrass pasture grazed during the in the trial

	Experimental treatment[1]			Pasture
	C	RPL	RPML	
Ingredient composition. DM %				
Maize meal	77	77	77	
Soybean oilcake meal	8.00	8.00	8.00	
Wheat bran	6.09	5.50	5.00	
Molasses	4.88	4.88	4.88	
Feed lime	2.50	2.50	2.50	
LysiGEM™	0	0.75	0.75	
MetaSmartDRY®	0	0	0.57	
Mono-Calcium Phosphate	0.4	0.4	0.4	
Salt	0.50	0.50	0.50	
Magnesium Oxide	0.30	0.30	0.30	
Urea	0.23	0.07	0	
Premix	0.1	0.1	0.1	
Chemical composition. DM %				
DM %	90.6	90.6	91.0	15.0
OM	94.1	93.9	93.4	89.5
Ash	5.84	6.25	6.62	10.5
CP	12.7	13.3	12.7	18.8
NDF	9.25	9.35	9.95	42.1
ADF	3.22	3.22	3.14	24.9
IVOMD	95.2	92.3	94.7	77.4
GE (MJ/kg DM)	16.4	16.3	16.2	16.3
ME (MJ/kg DM)	12.7	12.2	12.4	10.6
EE	1.55	1.91	3.59	3.20
Ca	1.16	1.26	1.24	0.30
P	0.48	0.49	0.50	0.40
Ca: P	2.42	2.58	2.48	0.90
ADL	1.23	1.45	1.46	5.10
NFC	70.7	69.2	67.2	25.4
Starch	53.6	56.9	55.5	-
NDIN	-	-	-	5.60
ADIN	-	-	-	6.80

[1]C: Control concentrate with no supplemented rumen protected amino acids (RPAA); RPL: control concentrate supplemented with rumen protected Lysine providing 53.12 g LysiGEM™/cow/day; RPML: control concentrate supplemented with rumen protected Lysine and Methionine providing 53.12 g LysiGEM™/cow/day and 41.68 g MetaSmartDry®/cow/d

[2] DM – Dry matter; OM – Organic matter; CP – Crude protein; Neutral detergent fibre; ADF – Acid detergent fibre; IVOMD – *in vitro* Organic matter digestibility; GE – Gross energy; ME – Metabolisable energy (ME = GE × IVOMD × C (Concentrate = 0.81 and Pasture = 0.84); EE – Ether extract; Ca – Calcium; P – Phosphorous; Acid detergent lignin; NFC – Non-fibre carbohydrates (NFC = 100 – (CP + NDF + EE + ash); NDIN – Neutral detergent insoluble nitrogen; ADIN – Acid detergent insoluble nitrogen

Table 2. Mean ((g/100g) ± SD) essential amino acid composition of the concentrate fed and pasture grazed during the trial

	Concentrate treatments[1]			Pasture
	C	RPL	RPML	
Essential amino acids				
Lysine (Lys)	0.50 ± 0.18	0.65 ± 0.03	0.60 ± 0.07	0.75 ± 0.06
Methionine (Met)	0.26 ± 0.01	0.24 ± 0.07	0.26 ± 0.01	0.43 ± 0.03
Arginine (Arg)	1.04 ± 0.15	0.86 ± 0.05	0.85 ± 0.03	1.06 ± 0.04
Histidine (His)	0.35 ± 0.04	0.29 ± 0.05	0.28 ± 0.02	0.30 ± 0.02
Isoleucine (Ile)	0.72 ± 0.04	0.67 ± 0.03	0.67 ± 0.03	0.89 ± 0.04
Leucine (Leu)	1.50 ± 0.20	1.35 ± 0.07	1.28 ± 0.01	1.40 ± 0.04
Phenylalanine (Phe)	0.93 ± 0.22	0.74 ± 0.09	0.77 ± 0.03	1.27 ± 0.05
Threonine (Thr)	0.53 ± 0.06	0.46 ± 0.03	0.42 ± 0.01	0.74 ± 0.03
Valine (Val)	0.70 ± 0.14	0.64 ± 0.05	0.62 ± 0.03	0.99 ± 0.03
Total EAA	6.53	5.90	5.75	7.819

[1]C: Control concentrate with no supplemented rumen protected amino acids (RPAA); RPL: control concentrate supplemented with rumen protected Lysine providing 53.12 g LysiGEM™/cow/day; RPML: control concentrate supplemented with rumen protected Lysine and Methionine providing 53.12 g LysiGEM™/cow/day and 41.68 g MetaSmartDry®/cow/d

The performance results are presented in Table 3. Treatment had no significant effect on mean milk production, 4% fat corrected (FCM) or energy corrected milk (ECM). The mean milk protein percentage of the cows on the RPML treatment was significantly higher than the RPL treatment, although both the RPML and RPL did not differ significantly from the C treatment. There was no significant difference between treatments for milk fat, lactose and MUN. Milk nitrogen fraction did not differ ($p < 0.05$) across treatments. Cow BW and BCS for the C, RPL and RPML treatment before and after the study are presented in Table 3. Cows allocated to the C group did not differ in BW compared to the RPL and RPML, but the cows allocated to the RPL and RPLM did differ in BW ($p < 0.05$). However, the cows consuming the RPML treatment gained more body weight ($p < 0.05$) than the RPL treatment but not the C treatment. Body condition score (Table 3) was affected ($p < 0.05$) by treatment. Cows on the RPML treatment gained more ($p < 0.05$) body condition than those on the C treatment, but not the RPL treatment. The increase in BCS across all treatments was expected in cows past peak lactation. Mean starch concentration in the faeces of cows of each treatment is presented in Table 3. There was no significant difference in faecal starch concentration of the cows in the three experimental treatments.

Table 3. Mean production performance, milk composition, milk nitrogen fraction, cow body measures and faecal starch content for Jersey cows grazing ryegrass and fed supplemental RPML and/or RPL

Parameter	Experimental treatment[1]			SEM[2]
	C	RPL	RPML	
Production (kg/cow/d)				
Milk yield (kg/cow/d)	22.26	22.27	22.33	0.485
4% FCM (kg/cow/d)	24.7	24.6	24.9	0.539
ECM (kg/cow/d)	25.2	25.0	25.6	0.482
Milk composition (kg/cow/d) or as stated				
Fat (%)	4.77	4.73	4.79	0.114
Protein (%)	3.93[ab]	3.86[a]	4.03[b]	0.056
Lactose (%)	4.68	4.64	4.70	0.035
MUN (mg/dL)	8.60	8.74	9.01	0.241
Milk nitrogen fractions (% CP)				
Crude protein	3.81[cd]	3.62[c]	3.83[d]	0.090
NPN (% CP)	4.60	4.58	5.18	0.302
Casein (% CP)	81.8	81.9	81.5	0.768
Whey protein (% CP)	13.6	13.5	13.2	0.929
Cow body measurements				
BW (kg)				
Before	397.7[ab]	405.5[a]	385.3[b]	4.786
After	422.9[ab]	425.6[a]	415.7[b]	4.710
Change	+25.2[ab]	+20.1[a]	+30.4[b]	2.422
BCS (1-5 Scale)				
Before	2.09[ab]	2.20[a]	2.05[b]	0.036
After	2.39[a]	2.57[b]	2.48[ab]	0.042
Change	+0.31[a]	+0.37[ab]	+0.43[b]	0.034

[1]C: Control concentrate with no supplemented rumen protected amino acids (RPAA); RPL: control concentrate supplemented with rumen protected Lysine providing 53.12 g LysiGEM™/cow/day; RPML: control concentrate supplemented with rumen protected Lysine and Methionine providing 53.12 g LysiGEM™/cow/day and 41.68 g MetaSmartDry®/cow/d
[3]4% FCM – Fat corrected milk; ECM – Energy corrected milk; MUN – Milk urea nitrogen; SSC – somatic cell count; NPN – Non-protein nitrogen; NCN – Non-casein nitrogen; BW – Body weight; BCS – Body condition score; DM – Dry matter
[a,b]Row means with different superscripts differ ($P < 0.05$)
[c,d]Row means with different superscripts tend to differ ($P < 0.1$)

The blood plasma AA parameters are presented in Table 4. All plasma AA, except Phe, Thr, Trp and Tyr increased when RPL was fed, although not significantly. When RPML were fed, all plasma AA increased, but only Met and Gly increased significantly compared to the C group. The AA that tended ($p < 0.01$) to increase when RPML were fed include Lys, Thr and Gly. Aside from small numerical changes in most of the plasma AA, the Lys: Met ratio were impacted as a result of the treatment, with the C, RPL and RPML treatment being 3.31, 3.67 and 2.62, respectively. There was no significant treatment effect on urine volume and microbial protein flow.

Table 4. Mean physiological blood plasma amino acid concentration (mmol/L) of cows grazing ryegrass and fed a concentrate supplemented with rumen protected Met and/or Lys

Parameter	Experimental treatment[1]			SEM[2]
	C	RPL	RPML	
Plasma amino acids				
Essential amino acid (EAA)				
Lysine (Lys)	96.0[c]	106.4[cd]	108.5[d]	5.34
Methionine (Met)	28.8[a]	29.0[ab]	41.4[b]	1.75
Histidine (His)	62.34	64.22	70.65	4.6
Phenylalanine (Phe)	68	68	72	2.57
Leucine (Leu)	146	153	162	6.89
Isoleucine (Iso)	113.6	119.5	119.7	4.00
Threonine (Thr)	104.0[cd]	98.37[c]	114.8[d]	5.82
Tryptophan (Trp)	35.3	33.6	36.6	1.46
Arginine (Arg)	76.3	76.9	79.2	2.31
Valine (Val)	223.7	229.6	243.4	5.58
Non- essential amino acids (NEAA)				
Tyrosine (Tyr)	68.9	68.3	69.9	3.63
Glutamine (Gln)	196.9	217.9	200.4	11.45
Glutamic acid (Glu)	51.6	55.7	52.6	2.26
Alanine (Ala)	280.8	292.0	305.7	14.44
Serine (Ser)	132.3	132.9	137.9	3.61
Glycine (Gly)	404.9[a]	423.4[ab]	448.1[b]	15.19
Aspartic acid (Asp)	5.48	5.96	5.76	0.28
Proline (Pro)	111.9	120.1	122.0	6.3
Asparagine (Asn)	61.4	65.2	66.7	3.61
Cystine (Cys)	8.40[c]	9.05[cd]	9.45[d]	0.40

[1]C: Control concentrate with no supplemented rumen protected amino acids (RPAA); RPL: control concentrate supplemented with rumen protected Lysine providing 53.12 g LysiGEM™/cow/day; RPML: control concentrate supplemented with rumen protected Lysine and Methionine providing 53.12 g LysiGEM™/cow/day and 41.68 g MetaSmartDry®/cow/d
[2]Standard error mean
[a,b]Row means with different superscripts differ ($P < 0.05$)
[c,d]Row means with different superscripts tend to differ ($P < 0.1$)

Table 5. Mean microbial protein yield (CP: g/day) for cows grazing ryegrass and fed a concentrate supplemented with rumen protected Met and/or Lys

Parameter	Treatment[1]			SEM[2]
	C	RPL	RPML	
Urine analysis				
Specific gravity (g/cm^3)	1.0178	1.0181	1.0164	<0.01
Volume (L/day)	18.86	19.28	19.64	1.01
Allantoin concentrations (mg/L)	1327	1334.97	1227.85	77.65
Allantoin output (mmol/day)	149.27	149.38	147.2	2.177
Microbial crude protein (CP: g/day)	738.82	738.02	716.47	23.97

[1]C: Control concentrate with no supplemented rumen protected amino acids (RPAA); RPL: control concentrate supplemented with rumen protected Lysine providing 53.12 g LysiGEM™/cow/day; RPML: control concentrate supplemented with rumen protected Lysine and Methionine providing 53.12 g LysiGEM™/cow/day and 41.68 g MetaSmartDry®/cow/d

Data was statistically analysed to determine treatment × group effects separating lower and higher producers. Cows were blocked primarily according to milk yield (kg/cow/d), thus the top portion of blocks would represent the high producers and the bottom portion the low producers. Table 6 indicate that there were on average a 4.7 kg/cow/d difference ($p < 0.05$) between the high producers and low producers. Milk fat percentage tended to be higher in the lower producing group for the C and RPML treatment, but not the RPL group and also did not differ across treatments. Milk protein percentage was significantly higher for the lower producers compared to the higher producers. There was no significant difference for protein percentage between control and amino acid treatments. Table 7 presents the group comparison for the milk nitrogen fraction. There were no significant differences across treatments for both high producers and low producers, except in the lower producing group where casein was higher ($p < 0.05$) for C than RPL, but not RPML. Interestingly, microbial protein tended to increase for cows fed RPL as opposed to the RPML (Table 8). Cows in the lower producing group gained significantly more weight and tended to gain more body condition, this is expected for lower performing cows (Table 7). However, cows consuming RPML gained significantly more weight than the cows consuming RPL, but not the C treatment. Cows consuming RPML gained significantly more condition than cows consuming the C treatment.

Table 6. Mean milk yield (kg/d) for higher and lower producing cows grazing ryegrass and fed a concentrate supplemented with rumen protected Met and/or Lys

	Milk yield		Milk composition							
	Milk kg/cow/d		Fat (%)		Protein (%)		MUN (mg/dl)		Lactose (%)	
	A	B	A	B	A	B	A	B	A	B
C	25.0^{a}	19.5^{b}	4.55^{c}	4.98^{d}	3.71^{a}	4.16^{12b}	8.69	8.51	4.74	4.63
RPL	24.1^{a}	20.3^{b}	4.77	4.69	3.87	3.85^{2}	8.58	8.89	4.68	4.60
RPML	24.7^{a}	19.9^{b}	4.57^{c}	5.01^{d}	3.86^{a}	4.21^{1b}	9.12	8.91	4.79	4.6
Average	24.6^{a}	19.9^{b}	4.63^{c}	4.89^{c}	3.81^{a}	4.07^{b}	8.79	8.77	4.73	4.61
SEM^{4}	0.385	0.385	<0.01	<0.01	0.045	0.045	0.227	0.227	0.033	0.033

*C: Control concentrate with no supplemented rumen protected amino acids (RPAA); RPL: control concentrate supplemented with rumen protected Lysine providing 53.12 g LysiGEM™/cow/day; RPML: control concentrate supplemented with rumen protected Lysine and Methionine providing 53.12 g LysiGEM™/cow/day and 41.68 g MetaSmartDry®/cow/d
^{a,b}Row means with different superscripts differ ($P < 0.05$)
^{c,d}Row means with different superscripts tend to differ ($P < 0.1$)
^{1,2}Column means with the different superscript differ ($P < 0.05$)
^{3}Group: A – Highest producing blocks; B – Lowest producing blocks
^{4}Standard error mean
5MUN – Milk urea nitrogen

Table 7. Mean milk nitrogen fraction for higher and lower producing cows grazing ryegrass and fed a concentrate supplemented with rumen protected Met and/or Lys

	Milk nitrogen fraction							
	NPN (%)		NCN (%)		Casein		Whey	
	A	B	A	B	A	B	A	B
C	0.18	0.16	0.67	0.72	2.85^{a}	3.39^{b1}	0.47	0.56
RPL	0.18	0.15	0.66	0.65	2.93	2.99^{2}	0.48	0.50
RPML	0.21	0.19	0.73	0.68	2.96	3.28^{12}	0.52	0.49
Average	0.19	0.17	0.69	0.68	2.9	3.22	0.49	0.52
SEM^{4}	0.01	0.01	0.03	0.03	0.06	0.06	0.03	0.03

*C: Control concentrate with no supplemented rumen protected amino acids (RPAA); RPL: control concentrate supplemented with rumen protected Lysine providing 53.12 g LysiGEM™/cow/day; RPML: control concentrate supplemented with rumen protected Lysine and Methionine providing 53.12 g LysiGEM™/cow/day and 41.68 g MetaSmartDry®/cow/d
^{a,b}Row means with different superscripts differ ($P < 0.05$)
^{1,2}Column means with the different superscript differ ($P < 0.05$)
^{3}Group: A – Highest producing blocks; B – Lowest producing blocks
^{4}Standard error mean
^{5}NPN – Non-protein nitrogen; NCN – Non-casein nitrogen

Table 8. Mean microbial protein flows for higher and lower producing cows grazing ryegrass and fed a concentrate supplemented with rumen protected Met and/or Lys

	Parameter									
	Specific gravity (g/cm³)		Volume urine (L/day)		Allantoin concentrations (mg/L)		Allantoin output (mmol/day)		Microbial crude protein (CP: g/day)	
	A	B	A	B	A	B	A	B	A	B
C	1.017[cd]	1.087	20.0	17.8	1196.5[a]	1456.7	146	153	712.3[cd]	765.3
RPL	1.019[c]	1.017	18.4	20.1	1412.3[b]	1256.6	152.9	145.8	758.6[c]	717.4
RPML	1.016[d]	1.017	19.2	20.1	1211.5[ab]	1249.9	148.1	152.3	702.6[d]	730.6
Average	1.017	1.040	19.2	19.3	1273.8	1321.1	147.0	150.4	724.5	737.8
SEM[4]	<0.01	<0.01	0.94	1.73	62.93	137.6	2.32	3.67	22.4	47.6

*C: Control concentrate with no supplemented rumen protected amino acids (RPAA); RPL: control concentrate supplemented with rumen protected Lysine providing 53.12 g LysiGEM™/cow/day; RPML: control concentrate supplemented with rumen protected Lysine and Methionine providing 53.12 g LysiGEM™/cow/day and 41.68 g MetaSmartDry®/cow/d

[a,b]Row means with different superscripts differ ($P < 0.05$)

[c,d]Row means with different superscripts tend to differ ($P < 0.1$)

[1,2]Column means with the different superscript differ ($P < 0.05$)

[3]Group: A: Highest producing blocks; B: Lowest producing blocks

[4]Standard error mean

Table 9. Mean change in cow weight and body condition score for higher and lower producing cows grazing ryegrass and fed a concentrate supplemented with rumen protected Lys and/or Met.

	Body measurements			
	Body weight		Body condition	
	A	B	A	B
C	23.3	27.1[12]	0.238[c3]	0.380[d]
RPL	17.8	22.4[1]	0.350[34]	0.389
RPML	23.0[a]	37.7[b2]	0.388[4]	0.463
Average	21.4[a]	29.1[b]	0.325	0.409
SEM[4]	1.87	1.87	0.03	0.03

*C: Control concentrate with no supplemented rumen protected amino acids (RPAA); RPL: control concentrate supplemented with rumen protected Lysine providing 53.12 g LysiGEM™/cow/day; RPML: control concentrate supplemented with rumen protected Lysine and Methionine providing 53.12 g LysiGEM™/cow/day and 41.68 g MetaSmartDry®/cow/day

[a,b]Row means with different superscripts differ ($P < 0.05$)

[c,d]Row means with different superscripts tend to differ ($P < 0.1$)

[1,2]Column means with the different superscript differ ($P < 0.05$)

[3,4] Column means with the different subscript tend to differ ($P < 0.10$)

[3]Group: A: Highest producing blocks; B: Lowest producing blocks

[4]Standard error mean

Conclusion

The supplementation of methionine and lysine did result in higher blood plasma amino acid levels. Production performance of cows grazing ryegrass in spring was not affected by supplementation of rumen protected methionine and lysine.

References

Apelo, S.A., Knapp, J. & Hanigan, M., 2014. Invited review: Current representation and future trends of predicting amino acid utilization in the lactating dairy cow. J. Dairy Sci. 97, 4000-4017.

ARC, 2018. The Agricultural Research Council's Institute for Soil Climate and Water, Department of Agro-Climatology. Elsenburg. Van der Colf J. JankeVdC@elsenburg.com.

Bargo, F., Muller, L.D., Kolver, E.S & Delahoy, J.E., 2003. Invited Review: Production and digestion of supplemented dairy cows on pasture. J. Dairy Sci. 86, 1-42

Botha, P., 2002. Die gebruik van vogspanningmeters vir besproeiingskedulering by weidings. *Weidingskursus Inligtingsbundel* 2002. Siud Kaap landbou-ontwikkelinsentrum, Departement Landbou Wes-Kaap. Pp 141-149.

Clark, J.H., Klusmeyer, T.H., & Cameron, M.R., 1992. Microbial Protein Synthesis and Flows of Nitrogen Fractions to the Duodenum of Dairy Cows. J. Dairy Sci. 75, 2304-2323.

Doepel, L. & Lapierre, H., 2010. Changes in production and mammary metabolism of dairy cows in response to essential and nonessential amino acid infusions. J. Dairy Sci. 93, 3264-3274.

Erasmus, L.J., Botha, P. M. & Meissner. H. H., 1994. Effect of Protein Source on Ruminal Fermentation and Passage of Amino Acids to the Small Intestine of Lactating Cows. J. Dairy Sci. 77, 3655-3665.

Kolver, E.S., 2003. Nutritional limitations to increased production on pasture-based systems. Proc. Nutr. Soc. 62, 291- 300.

Lapierre, H., Pacheco, D., Berthiaume, B., Ouellet, D.R., Schwab, C.G., Dubreuil, P., Holtrop, G. & Lobley, G.E., 2006. What is the True Supply of Amino Acids for a Dairy Cow. J. Dairy Sci. 89:E1-E14.

Meeske, R., Rothauge, A., Van der Merwe, G. & Greyling, J.F., 2006. The effect of concentrate supplementation on the productivity of grazing Jersey cows on a pasture based system. S. Afr. J. Anim. Sci. 36, 105-110.

NRC, 2001. Nutrient Requirements of Dairy Cattle. 7th rev. ed. National Academy Press, Washington, D.C.

Robinson, P., 2010. Impacts of manipulating ration metabolizable lysine and methionine levels on the performance of lactating dairy cows: A systematic review of the literature. Livestock Science 127,115-126.

Robinson, P. H., Fredeen, A.H., Chalupa, W., Julien, W.E., Sato, H., Fujieda, T. & H. Suzuki, H., 1995. Ruminally protected lysine and methionine for lactating dairy cows fed a diet designed to meet requirements for microbial and postruminal protein. J. Dairy Sci. 78, 582-594.

Rulquin, H., 1993. Amino acid nutrition of dairy cows: productive effects and animal requirements. Recent Advances in Animal Nutrition.

Rulquin, H., Graulet, B., Delaby, L. & Robert, J.C., 2006. Effect of Different Forms of Methionine on Lactational Performance of Dairy Cows. J. Dairy Sci. 89, 4387-4394.

Samuels, M. L., Witmer, J.A. & Schaffner, A., 2010. Statistics for the life sciences. Pearson education.

Schwab, C., 1996. Amino acid nutrition of the dairy cow: Current status. In Proc. Cornell Nutrition Conference for Feed Manufacturers. USA.

Schwab, C. G. & Broderick, G.A., 2017. A 100-Year Review: Protein and amino acid nutrition in dairy cows. J. Dairy Sci.100, 10094-10112.

Soil Classification Woking Group, 1991. Soil classification. A taxonomic system for South Africa. Memoirs of natural agricultural resources of South Africa, No 15. Dept. of Agric. Dev., Pretoria.

Socha, M. T.,Schwab, C.G.,Putnam, D.E., Whitehouse, N.L., Garthwaite, B.D. & Ducharme, G.A., 2008. Extent of Methionine Limitation in Peak-, Early-, and Mid-Lactation Dairy Cows. J. Dairy Sci. 91, 1996-2010.

Tylutki, T., D. Fox, T.D., V. Durbal, V., Tedeschi, L., Russell, J., Van Amburgh, M., Overton, T., Chase, L. & A. Pell. 2008. Cornell Net Carbohydrate and Protein System: A model for precision feeding of dairy cattle. Anim. Feed Sci. Technol. 143, 174-202.

Van Vuuren, A., Krol-Kramer, F., Van der Lee, R.A & Corbijn, H., 1992. Protein digestion and intestinal amino acids in dairy cows fed fresh Lolium perenne with different nitrogen contents. J. dairy Sci. 75, 2215-2225.

Plantain forage herb, a New Zealand perspective

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Plantain - *Plantago lanceolata* - is typically thought of as a short-lived, winter dormant flatweed, naturally occurring in cultivated lands around the world. However, research conducted in New Zealand in the early 1980's by AgResearch and by Dr Alan Stewart of PGG Seeds (now Agricom), identified the species as having potential forage applications. Dr Stewart identified productive, upright growing, winter active plants within the species which were later selected for seasonal and total dry matter production, animal acceptability and persistence. This initial research resulted in the release of two cultivars suitable for grazing in the mid 1990's, Grasslands Lancelot from AgResearch and Ceres Tonic from PGG Seeds. Further research by PGG Seeds and Agricom throughout the 1990's continued on seed production, grazing management, nutritional measurements, animal systems trials and general agronomy. The culmination of this work has seen the once common weed develop into a widely adapted and increasingly popular grazing herb which is now sold in over 30 countries around the world.

Best described as mineral-rich, upright growing, perennial grazing herb, plantain has become a valuable pasture component. Rapid to establish and a vigorous growing plant, high annual dry matter production has been demonstrated in various locations, with the cultivar Ceres Tonic producing 20.6 t DM/ha/year in fertile, irrigated situations in South Africa (Ammann, Lombard, Zulu 2018) and 17 t DM/ha/year in fertile, unirrigated situations in New Zealand (Powell *et al.* 2007).

A course fibrous root system provides drought tolerance and drought recovery, often better than ryegrass, although not as good as deep tap-rooted plants such as Chicory or Lucerne. Plantain is very flexible in establishment method with all commonly used methods producing viable forage crops. Compatible with commonly used pasture grasses, legumes and other forage herbs, Plantain is widely used as both a component of permanent pasture or as a short-term mono-culture forage crop.

A good source of minerals, animals grazing plantain swards have been shown to have increased uptake of both copper and selenium (Moorhead *et al.* 2002). Animal performance is demonstrated to be high in several studies (Judson *et al.* 2009, Moorhead *et al.* 2002, Kenyon *et al.* 2010) and across different classes of livestock and on both per-head and per-hectare basis. Plantain and clover mixtures produced 720 kg/ha of carcass weight compared to 400 kg/ha for ryegrass clover pastures (Kemp *et al.* 2010), Minnee 2016 demonstrated that when compared to ryegrass pastures of moderate quality (9.6 MJ ME/kg DM) Plantain produced approximately 19% more Milk Solids. Judson et. al. (2009) showed increased lamb growth rates and reduced faecal egg counts from sheep grazing plantain swards.

Current research in New Zealand is based around a collaborative program involving pasture seed company Agricom, Callaghan Innovation and research entities Lincoln University, Plant and Food New Zealand, and Massey University. This program is focused on preventing nitrate leaching from urine patches through the use of plantain. Agricom cultivars demonstrating the ability to reduce nitrate leaching through 4 different mechanisms are known as environmentally functional plantains. These environmental plantains are proven to work on different mechanisms both within the animal and in the soil.

Firstly, these plantains cause an increase in urine volume produced by the animal, which means N excreted is in a more dilute form, resulting in a reduced N load in the urine patch (O'Connell *et al.* 2016).

Secondly, there is a reduction in the amount of dietary N excreted in the urine when compared to ryegrass. This also reduces the N load in the urine patch (Cheng *et al.* 2017).

Thirdly, in urine patches from animals grazing environmental plantains the conversion of ammonium to nitrate is delayed (Judson *et al.* 2018). The slower conversion allows plants a greater opportunity to uptake N, significantly reducing potential leaching.

The forth mechanism of action is a restriction in the nitrification rate in the soil when environmental plantain plants are present, likely through the effect of biological nitrification inhibitors (Carlton *et al.* 2018).

Further, potential reductions in nitrous oxide, a potent greenhouse gas are also being investigated (Simon *et al.* 2019).

So, what was a "blue-skies" concept 30 years ago has yielded significant gains for farmers worldwide in terms of on-farm productivity, through increased dry matter production, seasonality of growth, drought tolerance and forage quality.

However, current research demonstrating the environmental benefits of specific cultivars within the species has potential to bring greater benefits far beyond the farm gate. A highly effective and practical solution to N leaching is now possible through a plant once considered by many as a weed.

Reference list

Carlton AJ, Cameron KC, Di HJ, Edwards GR, Clough TJ. 2018. Nitrate leaching losses are lower from ryegrass/white clover forages containing plantain than from ryegrass/white clover forages under different irrigation. *New Zealand Journal of Agricultural Research*: 1-23.

Cheng, L; Judson, H.G, Bryant, R.H, Mowat, H.A, Guinot, L, Hague, H, Taylor, S Edwards, G.R 2017 The effect of feeding cut plantain and perennial ryegrass white / cover pasture on dairy heifer feed and water intake, apparent nutrient digestibility and nitrogen excretion in urine. *Animal Feed Science and Technology* 229: 43-46.

Judson, H.G.; McAnulty, R.; Sedcole R. 2009. Evaluation of 'Ceres Tonic' plantain (*Plantago lanceolata*) as a lactation feed for twin-bearing ewes. *Proceedings of the New Zealand Grassland Association 71*: 201-205.

Judson H, Fraser P, Peterson M, Kemp P, Edwards G. 2018. Specific genotypes of plantain (Plantago lanceolata) vary in their impact on sheep urine volume and nitrification in the urine patch. *Proceedings of the New Zealand Grasslands Association 80*: 125-128.

Kemp PD, Kenyon PR, Morris ST (2010) The use of legume and herb forage species to create high performance pastures for sheep and cattle grazing systems. Sociedade Brasileira de Zootecnia 39, 169-174.

Chicory and plantain variety evaluation results

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Introduction

Forage chicory (*Cichorium intybus*) and Plantain (*Plantago lanceolata*) collectively known as forage herbs, have recently become regular components of mainly dairy pastures either as pure stands or as part of mixed swards.

Chicory belongs to the Asteraceae (daisy) family with its origin mainly in Europe, central and western Asia and North Africa (Agfact 2000; Koch et al 1999). It has been cultivated for many centuries as a food and feed source, as a vegetable, the root as a coffee substitute, as a source of fructose and for medicinal purposes (Agfact 2000; Koch et al 1999; to Li and Kemp 2005; Moloney and Milne 1993). Chicory roots are also a source of inulin which is used as a low calorie sweetner (van Laere and van den Ende 2002).

Plantain or ribgrass according to Stewart (1996) has a long history of being used in Europe as a minor forage plant and has occurred naturally in many pastures. Plantain belongs to the family Plantaginaceae and other common names according to cabi.org are ribwort plantain, narrowleaf plantain, English plantain, lamb's tongue and in Afrikaans smalblaarplantago, smalweeblaar or oorpynwortels.

Both chicory and plantain varieties have been bred specifically for forage production and grazing. For chicory one emphasis of plant breeding has been lowering the sesquiterpene lactone content (Lee at al 2015a; Rumball et al 2003) which can taint milk. Additionally there has been a focus on improved cool season productivity (Lee at al 2015a).

For plantain the plant breeding has focussed on more erect leaves, larger or longer leaves, improved winter and summer growth (Stewart 1996). Plantain is outcrossing and wind pollinated. According to Sagar & Harper (1964) more than 50% of the seeds retain their viability after passing though cattle.

Currently the cultivars of chicory and plantain are not listed on the SA Variety list, which makes the local evaluation trials valuable in providing not only yield data but also descriptive parameters in terms of plant morphology and uniformity. Some cultivars are listed in Australia and New Zealand as varieties. In the current trial that would be the case for Choice and Puna II for chicory and Tonic for the plantain.

On many farms the forage herbs are planted in a mixture with grasses and often clover species are added as a minor component. Recent small plot research at the Outeniqua Research Farm has shown that the pure stands yield significantly higher than the mixtures. In terms of pasture systems and how forage herbs can best be used, these results indicate that there could be merit in rather planting a pure forage herb sward and a grass pasture separately where both are grazed alternatively during the same day to ensure sufficient fibre from the grass pasture to counter the low DM content and high carbohydrate content of the forage herbs. Alternatively the grass/herb/clover mixtures provide easier grazing management options. (See article on systems trials of J van der Colf).

Basic management principles

Establishment

- Spring or early autumn
- Soil temperature must be above 12°C, especially for chicory
- Shallow planting depth less than 10mm is essential
- No competition from the previous crop at

establishment i.e. the previous crop should be sprayed off beforehand.

Grazing cycles (Lee et al, 2015)

- First grazing when chicory has seven leaves and plantain six leaves fully extended.
- Thereafter maximum dry matter production can be achieved by harvesting at specified extended leaf heights of between 350 and 550mm for chicory and approximately 300 to 350mm for plantain although it can be left to 450mm to maximise carbohydrate reserves as reported by Lee et al, 2015.

Nitrogen requirements

- Chicory and plantain both need nitrogen fertilization for good growth (Li and Kemp 2005; Stewart 1996). Total N recovery in chicory was found to be 80% over the season (Li and Kemp 2005), which is probably assisted by the deep root system. N fertilization will vary depending on whether there is a legume in the mixture.

Persistence

- According to the management guidelines given in AgFact (2000), the plant density of a pure chicory stand should be 50 to 60 plants m^{-2} and if the density falls below 20 plants m^{-2} the pasture would need to be re-established.
- Chicory population tends to decline from the second year onwards with the extent of decline being cultivar dependent.
- Chicory plants form a rosette from the second year onwards. In some cases the centre stem then becomes exposed resulting in deterioration from the middle.
- Plantain retains its population into the second year under trial conditions. This could be different under grazing depending on the grazing management.

Pure stands or mixtures

- "pure stands" can refer to a mono-specific stand of one of the species or a pure broad-leaved stand consisting of a mixture of chicory, plantain and clover (often red clover).
- Mixtures mostly refer to a grass/herb mixture or grass/herb/clover mixture.
- Weed control is easier in a monospecific stand.
- "Pure stands" should be grazed in rotation with a grass pasture to ensure sufficient fibre intake.

Cultivar trial results

The cultivar evaluation trial was planted on 5 October 2016 at the Outeniqua Research Farm when the soil temperature was consistently above 12ºC. The trial consists of 10 chicory varieties and one plantain variety which was planted at two different sowing rates of 8 and 10 kg/ha. The chicory was planted at 8 kg/ha. The aim of the trial is to determine the genetic potential of the cultivars.

The first harvest was taken at the six to seven leaf stage. Thereafter the harvests were determined by plant height and canopy closure. This was generally at 250mm (winter) to 300mm for the plantain and 350mm to 450mm for the chicory depending on season and cultivar, with some inherently either shorter or taller growing.

The parameters determined are dry matter yield, plant height at harvest, flowering behaviour and population density.

The chicory cultivars are also characterized according to growth form:

1. Upright growth form
- Entire leaf margin or slightly dentate
- Spatulate leaf shape
- Cultivars: Choice, Commandor, Puna II, Spada, VAR501

2. Intermediate growth form
- Shorter growing than the upright varieties
- Broadly hastate leaf shape
- Dentate leaf margin
- Cultivars: LaNina, Sambo, SixPoint, Trigger

2. Root type or short growing type
- Compressed spatulate leaf Broadly hastate leaf shape
- Slightly dentate leaf margin
- Cultivar: Polanowicka

Winter dormany in some varieties of both chicory and plantain. (Trial established in October 2018)

Variety dormancy (plant height) during winter was as follows:

<u>First winter (2017 after spring establishment)</u>*:*
- Dormant/flat (prostrate) growing: *SixPoint, Polanowicka, Trigger*
- Dormant with variability in the population: *Sambo*
- Semi-dormant but retains upright growth form: *Choice*
- Intermediate dormancy – growth form remains upright but reduced plant height compared to summer: *Commandor, VAR 501, Spada, Puna II*
- Non-dormant but flowering: *LaNina*
- Non-dormant/ winter active: *Tonic*
- During the <u>second winter</u> plant height was very variable in most chicory cultivars, with the most uniform being SixPoint, Trigger and Polanowicka. There was no height variation in the plantain.

Table 1. Forage Herbs Fh 1, Outeniqua Research Farm

Planted: 5 October 2016 DM yield (t DM/ha) Trial is continuing *flowering

Cultivars	Species	Cut 1 21/11/16 t DM/ha	Cut 2 8/12/16 t DM/ha	Cut 3 5/1/17 t DM/ha	Cut 4 24/1/17 t DM/ha	Cut 5 9/2/17 t DM/ha	Cut 6 28/2/17 t DM/ha	Cut 7 24/3/17 t DM/ha	Cut 8 19/4/17 t DM/ha	Cut 9 10/5/17 t DM/ha	Cut 10 9/6/17 t DM/ha	Cut 11 27/7/17 t DM/ha	Cut 12 28/8/17 t DM/ha	Cut 13 20/09/17 t DM/ha
Tonic 8	P	1.02 [b]	1.27 [ab]	2.67	1.80 [ab]	1.41 [a]	1.70 [ab]	2.91 [a]	1.89 [a]	1.01 [ab]	1.30 [ab]	2.00 [a]	1.60 [ab]	1.73 [ab]
Tonic 10	P	1.46 [a]	1.34 [ab]	1.90	1.63 [abc]	1.14 [abc]	1.82 [a]	2.78 [ab]	1.89 [a]	1.12 [a]	1.37 [a]	1.98 [a]	1.45 [b]	1.74 [ab]
Choice	C	1.30 [ab]	1.30 [ab]	2.19	1.65 [abc]	1.00 [bc]	1.34 [b]	2.06 [c]	1.40 [b]	0.76 [cd]	0.98 [def]	0.66 [cde]	0.55 [de]	1.51 [b]
Commandor	C	1.40 [a]	1.17 [ab]	2.06	1.80 [ab]	1.10 [bc]	1.57 [ab]	2.33 [bc]	1.67 [ab]	0.87 [bc]	1.24 [abc]	0.93 [c]	0.94 [c]	1.81 [a]
LaNina	C	0.64 [c]	0.94 [b]	*2.48	*1.36 [c]	*1.03 [bc]	*1.62 [ab]	*2.22 [c]	1.44 [b]	0.82 [cd]	1.20 [abc]	*1.51 [b]	*1.87 [a]	**1.64 [ab]
Polanowicka	C	1.38 [ab]	1.04 [ab]	1.60	1.47 [bc]	0.97 [bc]	1.57 [ab]	2.17 [c]	1.44 [b]	0.71 [d]	0.84 [f]	0.06 [f]	0.08 [g]	0.39 [d]
Puna II	C	1.37 [ab]	1.15 [ab]	1.91	1.60 [bc]	1.05 [bc]	1.67 [ab]	2.18 [c]	1.61 [ab]	0.84 [cd]	1.18 [abcd]	0.97 [c]	0.87 [c]	1.86 [a]
Sambo	C	1.18 [ab]	1.05 [ab]	1.73	1.34 [c]	1.00 [bc]	1.33 [b]	2.10 [c]	1.41 [b]	0.80 [cd]	0.91 [ef]	0.46 [de]	0.53 [ef]	1.18 [c]
SixPoint	C	1.25 [ab]	1.25 [ab]	2.36	1.64 [abc]	0.96 [c]	1.46 [ab]	2.12 [c]	1.61 [ab]	0.82 [cd]	1.08 [cde]	0.31 [ef]	0.31 [efg]	1.18 [c]
Spada	C	1.35 [ab]	1.42 [a]	2.66	2.01 [a]	1.24 [ab]	1.78 [ab]	2.28 [c]	1.76 [a]	0.88 [bc]	1.18 [abcd]	0.79 [cd]	0.95 [c]	1.81 [a]
Trigger	C	1.41 [a]	1.21 [ab]	2.47	1.66 [abc]	1.18 [abc]	1.59 [ab]	2.18 [c]	1.58 [ab]	0.83 [cd]	1.06 [cde]	0.28 [ef]	0.24 [fg]	0.95 [c]
VAR 501	C	1.49 [a]	1.33 [ab]	2.28	1.65 [abc]	1.07 [bc]	1.46 [ab]	2.20 [c]	1.83 [a]	0.81 [cd]	1.15 [bcd]	0.84 [cd]	0.85 [cd]	1.77 [ab]
CV %		17.5	23.0	28.7	14.1	14.7	16.8	12.2	11.4	10.2	11.0	25.3	21.4	11.6
LSD (0.05)		0.38	0.47	NS	0.34	0.27	0.45	0.48	0.32	0.15	0.21	0.39	0.31	0.29

P = Plantain, C= Chicory . Yield values with the same letter do not differ from each other statistically

*plants were reproductive and contained flowering stems.

Table 1 cont. Forage Herbs Fh 1, Outeniqua Research Farm

Planted: 5 October 2016 DM yield (t DM/ha) Trial is continuing *flowering

Cultivars	Species	Cut 14 19/10/17 t DM/ha	Cut 15 8/11/17 t DM/ha	Cut 16 29/11/17 t DM/ha	Cut 17 19/12/17 t DM/ha	Cut 18 8/1/18 t DM/ha	Cut 19 1/2/18 t DM/ha	Cut 20 27/2/18 t DM/ha	Cut 21 26/3/18 t DM/ha	Cut 22 20/4/18 t DM/ha	Cut 23 23/5/18 t DM/ha	Cut 24 6/7/2018 t DM/ha	Cut 25 13/8/2018 t DM/ha
Tonic 8 kg/ha	P	2.24 ^{bcd}	*1.69^{bcd}	*1.99^{abcd}	*2.27 ^{a}	*2.17^{ab}	2.36 ^{a}	2.02 ^{ab}	1.69 ^{ab}	1.51 ^{a}	1.55 ^{a}	1.70^{a}	1.54^{a}
Tonic 10kg/ha	P	2.30 ^{abc}	*1.60 ^{cd}	*2.14 ^{a}	*2.08 ^{ab}	*2.24^{a}	2.17^{ab}	2.16 ^{a}	1.88 ^{a}	1.54 ^{a}	1.51 ^{ab}	1.88^{a}	1.59^{a}
Choice	C	2.07^{bcde}	*1.69^{bcd}	*1.71 ^{cd}	*1.80^{bcde}	*1.58^{de}	*1.62^{cde}	1.55 ^{def}	1.39 ^{de}	1.12 ^{bc}	1.21 ^{bcd}	0.92^{bc}	0.90^{bc}
Commandor	C	2.54 ^{a}	*2.07 ^{a}	*1.63 ^{d}	*1.60^{de}	*1.48^{e}	*1.38 ^{e}	1.39 ^{f}	1.50^{bcd}	1.15 ^{bc}	1.11 ^{cde}	0.86^{c}	1.05^{b}
LaNina	C	**1.95^{cde}	**1.48 ^{d}	**1.68 ^{cd}	**1.78^{bcde}	**1.98^{abc}	**1.53 ^{e}	**0.68 ^{g}	**1.16^{e}	**0.61 ^{d}	*0.73 ^{f}	*1.17^{b}	***1.36^{a}
Polanowicka	C	0.89 ^{f}	1.10 ^{f}	2.08 ^{ab}	2.06^{ab}	1.69^{cde}	2.14^{ab}	1.88 ^{abc}	1.51^{bcd}	0.93 ^{c}	0.83 ^{e}	0.38^{e}	0.10^{e}
Puna II	C	2.67 ^{a}	*2.00 ^{a}	*1.70 ^{cd}	*1.54 ^{e}	*1.45^{e}	*1.51 ^{e}	1.53 ^{def}	1.60^{bcd}	1.18 ^{bc}	1.08 ^{cde}	0.83^{c}	0.91^{bc}
Sambo	C	2.05^{cde}	*1.96 ^{ab}	*1.66 ^{cd}	*1.64^{cde}	*1.53^{de}	*1.75^{cde}	1.70 ^{cde}	1.47 ^{cd}	1.03 ^{c}	0.95 ^{de}	0.57^{de}	0.63^{d}
SixPoint	C	1.84 ^{de}	1.76^{abc}	*2.01^{abc}	1.88^{bcd}	1.73^{cde}	1.91^{bcd}	1.79 ^{bcd}	1.67^{abc}	1.15 ^{bc}	1.29 ^{abc}	0.98^{bc}	0.83^{bcd}
Spada	C	2.64 ^{a}	*1.90 ^{ab}	*1.78^{abcd}	*1.61^{cde}	*1.54^{de}	*1.54 ^{de}	1.48 ^{ef}	1.62^{bcd}	1.25 ^{b}	1.10 ^{cde}	0.83^{cd}	1.05^{b}
Trigger	C	1.83 ^{e}	1.88 ^{ab}	*2.14 ^{a}	1.89^{bc}	1.82^{bcd}	1.96 ^{bc}	1.75 ^{bcde}	1.71 ^{ab}	1.25 ^{b}	1.34 ^{abc}	0.97^{bc}	0.69^{cd}
VAR 501	C	2.47 ^{ab}	*2.05 ^{a}	*1.77^{bcd}	*1.57 ^{e}	*1.43^{e}	*1.51 ^{e}	1.28 ^{f}	1.46 ^{cd}	1.17 ^{bc}	1.10 ^{cde}	0.88^{c}	1.05^{b}
CV %		11.0	9.1	11.6	9.1	10.5	12.2	10.1	8.8	10.6	15.2	15.4	15.2
LSD (0.05)		0.40	0.27	0.36	0.28	0.30	0.37	0.27	0.23	0.21	0.30	0.26	0.25

P = Plantain, C= Chicory . Yield values with the same letter do not differ from each other statistically

*plants were reproductive and contained flowering stems.

Table 1 cont. Forage Herbs Fh 1, Outeniqua Research Farm

Planted: 5 October 2016 DM yield (t DM/ha) Trial is continuing *flowering

Cultivars	Species	Cut 26 26/9/18 t DM/ha	Cut 27 29/10/18 t DM/ha	Cut 28 22/11/18 t DM/ha	Cut 29 14/12/18 t DM/ha	Cut 30 7/11/18 t DM/ha	Cut 31 30/1/18 t DM/ha	Cut 32 20/2/19 t DM/ha	Cut 33 19/3/19 t DM/ha	Year 1 Sum2016-Spr2017# t DM/ha	Year 2 Sum2017-Spr2018# t DM/ha	Year 1+2 t DM/ha	Total Cuts 1-33 Oct2016 to Mar2019 t DM/ha
Tonic 8 kg/ha	P	*1.96^{ab}	***2.21^{abc}	*1.25^{cd}	**1.50^{abc}	*1.75^{ab}	*1.70^{a}	1.79^{ab}	2.05^{a}	26.55^{a}	23.90^{a}	50.45^{a}	59,05^{a}
Tonic 10kg/ha	P	*2.22^{a}	***2.23^{abc}	*1.13^{de}	**1.71^{ab}	*1.46^{b}	*1.63^{a}	1.62^{abcd}	1.93^{ab}	25.00^{ab}	24.39^{a}	49.39^{a}	57,79^{a}
Choice	C	1.14^{def}	*2.03^{abc}	*1.60^{ab}	*1.38^{bc}	*1.86^{ab}	*1.69^{a}	1.44^{d}	1.61^{cd}	20.19^{cd}	18.36^{b}	38.56^{cd}	46,61^{cd}
Commandor	C	1.44^{cd}	*2.48^{a}	***1.48^{abc}	**1.53^{abc}	**1.43^{b}	**1.15^{a}	1.41^{d}	1.50^{cd}	23.10^{b}	18.45^{bc}	41.55^{bc}	48,58^{bc}
LaNina	C	***1.72^{bc}	***2.37^{abc}	***1.11^{de}	***1.17^{c}	0	0	0	0	22.74^{bc}	17.66^{bcd}	40.40^{bc}	41,06^{ef}
Polanowicka	C	0.28^{h}	1.40^{d}	0.93^{e}	1.61^{abc}	1.51^{b}	1.56^{a}	1.52^{bcd}	1.69^{bcd}	15.86^{e}	15.62^{d}	31.48^{e}	39,43^{f}
Puna II	C	1.17^{def}	*2.42^{abc}	***1.65^{ab}	*1.58^{abc}	*1.81^{ab}	**1.31^{a}	*1.46^{d}	1.50^{cd}	22.66^{bc}	18.43^{bc}	41.09^{bc}	48,64^{bc}
Sambo	C	0.91^{efg}	2.02^{bc}	**1.38^{bcd}	*1.74^{ab}	*1.53^{b}	**1.70^{a}	*1.48^{cd}	1.57^{cd}	18.96^{d}	17.15^{cd}	36.10^{d}	43,90^{de}
SixPoint	C	0.82^{fg}	2.17^{abc}	1.60^{ab}	1.82^{ab}	1.80^{ab}	*1.68^{a}	1.76^{abc}	1.69^{bcd}	20.05^{cd}	19.47^{b}	39.53^{c}	48,09^{bc}
Spada	C	1.31^{cde}	*2.47^{ab}	**1.68^{a}	**1.74^{ab}	**1.72^{ab}	**1.49^{a}	*1.53^{bcd}	1.79^{abc}	24.33^{ab}	19.07^{bc}	43.39^{b}	51,77^{b}
Trigger	C	0.65^{gh}	1.99^{c}	1.57^{ab}	1.84^{a}	2.04^{a}	1.28^{a}	1.88^{a}	1.77^{abcd}	20.43^{cd}	19.28^{b}	39.71^{c}	48,46^{bc}
VAR 501	C	1.40^{cd}	*2.40^{abc}	**1.58^{ab}	**1.56^{abc}	**1.63^{ab}	**1.37^{a}	*1.47^{cd}	1.49^{d}	22.85^{b}	18.38^{bc}	41.22^{bc}	49,05^{bc}
CV %		21.7	12.1	12.4	16.6	16.1	26.6	11.2	10.0	6.2	6.5	4.7	4.78
LSD (0.05)		0.46	0.45	0.30	0.45	0.46	NS	0.30	0.29	2.34	2.10	3.28	3.93

#excludes the two establishment months in Spring 2016. Yield values with the same letter do not differ from each other statistically. *some plants were reproductive and contained flowering stems

Table 2. Forage Herbs Fh 1, Outeniqua Research Farm

Planted: 5 October 2016 DM yield (t DM/ha) Trial is continuing *flowering

Cultivars	Species	Spring 2016 (establish-ment) t DM/ha	Summer 2016/16 t DM/ha	Autumn 2017 t DM/ha	Winter 2017 t DM/ha	Spring 2017 t DM/ha	Summer 2017/18 t DM/ha	Autumn 2018 t DM/ha	Winter 2018 t DM/ha	Spring 2018 t DM/ha	Summer 2018/19 t DM/ha
Tonic 8 kg/ha	P	1.70^{a}	8.19^{a}	6.73^{a}	4.15^{a}	*7.65^{abc}	8.82^{a}	4.74^{ab}	4.85^{a}	*5.17^{a}	6.80^{a}
Tonic 10kg/ha	P	2.17^{a}	7.12^{ab}	6.75^{a}	4.02^{a}	*7.78^{ab}	8.63^{a}	4.93^{a}	5.21^{a}	*5.28^{a}	6.36^{a}
Choice	C	2.00^{a}	6.80^{ab}	4.90^{c}	1.64^{cd}	*6.98^{bc}	*6.56^{de}	3.72^{def}	3.11^{cd}	*4.81^{a}	6.33^{a}
Commandor	C	2.03^{a}	7.09^{ab}	5.73^{b}	2.40^{b}	*8.04^{a}	*5.85^{ef}	3.76^{def}	3.32^{c}	*5.36^{a}	5.40^{b}
LaNina	C	1.14^{b}	**6.95^{ab}	5.32^{bc}	*3.89^{a}	**6.74^{d}	**5.97^{def}	**2.50^{g}	*4.05^{b}	***4.92^{a}	***0.75^{c}
Polanowicka	C	1.93^{a}	6.09^{b}	4.91^{c}	0.50^{f}	4.47^{e}	7.77^{b}	3.28^{f}	1.42^{f}	3.09^{b}	6.12^{a}
Puna II	C	1.98^{a}	6.78^{ab}	5.46^{bc}	2.34^{b}	*8.23^{a}	*6.04^{def}	3.86^{cde}	3.04^{cd}	**5.33^{a}	6.03^{a}
Sambo	C	1.73^{a}	5.90^{b}	4.95^{c}	1.38^{de}	*6.85^{cd}	*6.63^{cd}	3.45^{ef}	2.39^{e}	*4.57^{a}	6.27^{a}
SixPoint	C	1.92^{a}	7.01^{ab}	5.30^{bc}	1.08d^{ef}	6.80^{d}	7.30^{bc}	4.11^{cd}	2.96^{cd}	4.92^{a}	6.89^{a}
Spada	C	2.10^{a}	8.36^{a}	5.75^{b}	2.24^{bc}	*8.12^{a}	*6.17^{def}	3.96^{cde}	3.23^{cd}	**5.55^{a}	6.37^{a}
Trigger	C	2.05^{a}	7.47^{ab}	5.33^{bc}	0.97^{ef}	6.80^{d}	7.41^{b}	4.33^{bc}	2.74^{de}	4.62^{a}	6.89^{a}
VAR 501	C	2.20^{a}	7.09^{ab}	5.66^{bc}	2.19^{bc}	*8.06^{a}	*5.78^{f}	3.73^{def}	3.32^{c}	**5.38^{a}	5.90^{a}
CV %		16.6	14.4	8.3	16.3	6.9	6.2	8.3	10.0	11.7	11.5
LSD (0.05)		0.54	1.73	0.78	0.62	0.84	0.73	0.54	0.56	0.98	1.14

P = Plantain, C= Chicory . Yield values with the same letter do not differ from each other statistically

*plants were reproductive and contained flowering stems.

Table 3. Forage Herbs Fh 1, Outeniqua Research Farm

Planted: 5 October 2016   Growth rates (kg DM/day)   Trial is continuing   *flowering

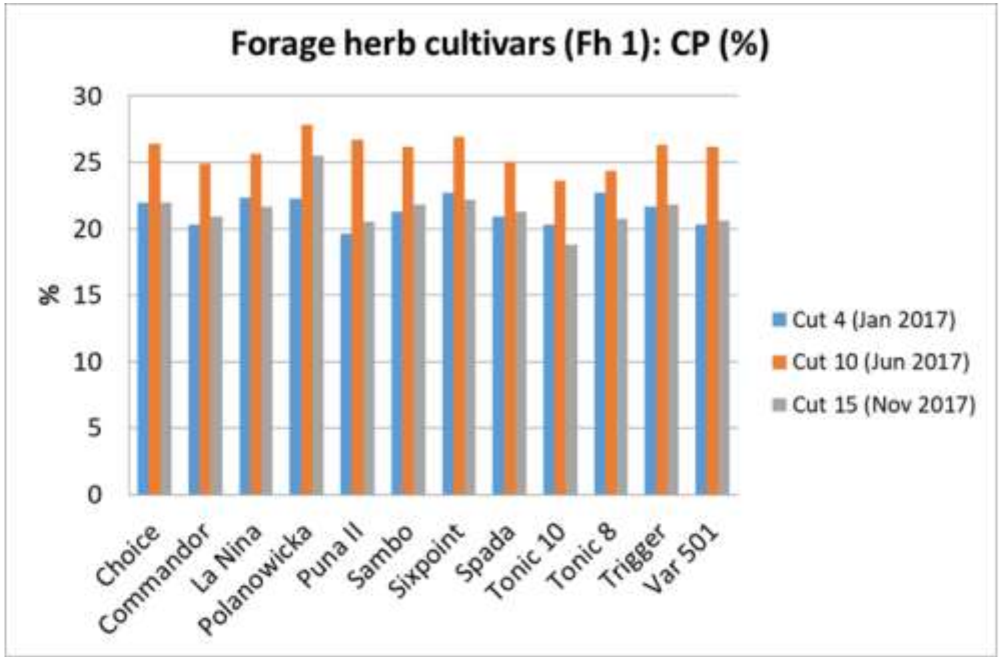
Cultivars	Species	Spring 2016 (establish-ment) t DM/ha	Summer 2016/16 t DM/ha	Autumn 2017 t DM/ha	Winter 2017 t DM/ha	Spring 2017 t DM/ha	Summer 2017/18 t DM/ha	Autumn 2018 t DM/ha	Winter 2018 t DM/ha	Spring 2018 t DM/ha	Summer 2018/19 t DM/ha
Tonic 8 kg/ha	P	26.4	89.0	73.1	43.3	85.0	98.0	54.3	52.8	56.8	75.6
Tonic 10kg/ha	P	32.9	72.1	73.4	41.7	86.5	95.9	56.7	56.6	58.1	70.6
Choice	C	28.1	73.9	53.2	16.4	77.6	72.9	41.8	33.7	52.9	70.4
Commandor	C	27.7	77.1	62.3	24.4	89.3	65.0	42.1	36.1	58.9	60.0
LaNina	C	16.9	75.5	57.8	40.6	74.9	5.9	29.2	44.1	54.0	8.3
Polanowicka	C	27.3	66.2	53.3	4.3	49.6	86.3	36.0	15.5	33.9	68.0
Puna II	C	25.6	73.6	59.3	23.8	91.5	67.1	43.1	33.1	58.6	66.9
Sambo	C	24.0	64.1	53.8	13.4	76.1	73.7	38.2	26.0	50.2	69.7
SixPoint	C	26.5	76.2	57.6	10.3	75.6	81.1	46.1	32.2	54.0	76.6
Spada	C	30.6	90.9	62.5	22.7	90.2	68.6	44.3	35.1	61.0	70.8
Trigger	C	28.7	81.2	57.9	9.1	75.6	82.4	48.4	29.8	50.8	76.5
VAR 501	C	32.8	77.0	61.5	22.2	89.6	64.2	41.8	36.1	59.1	65.7

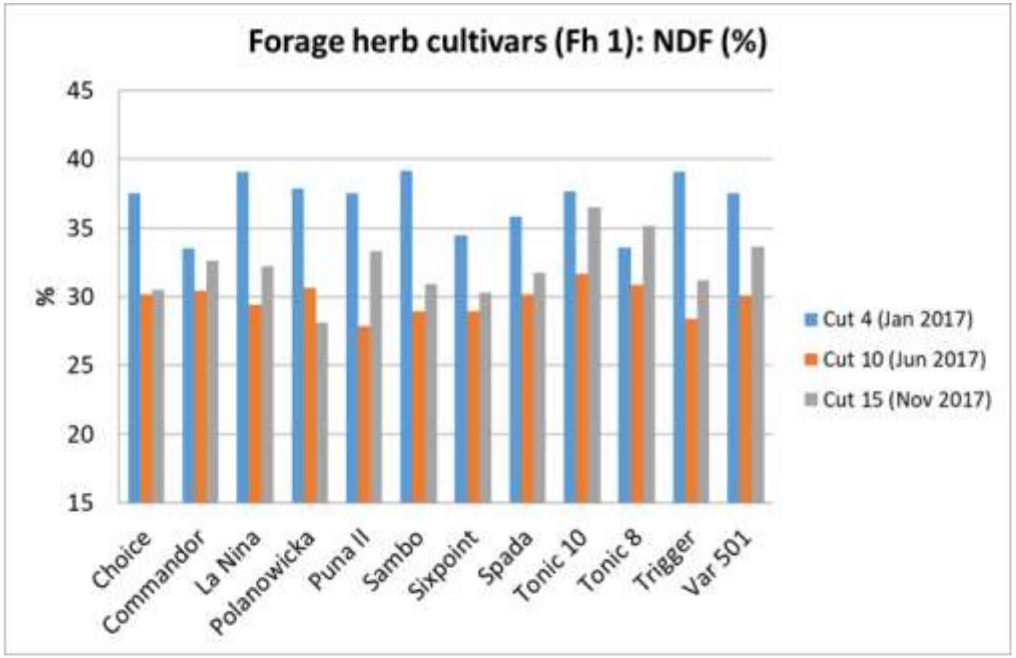
P = Plantain, C= Chicory . Yield values with the same letter do not differ from each other statistically

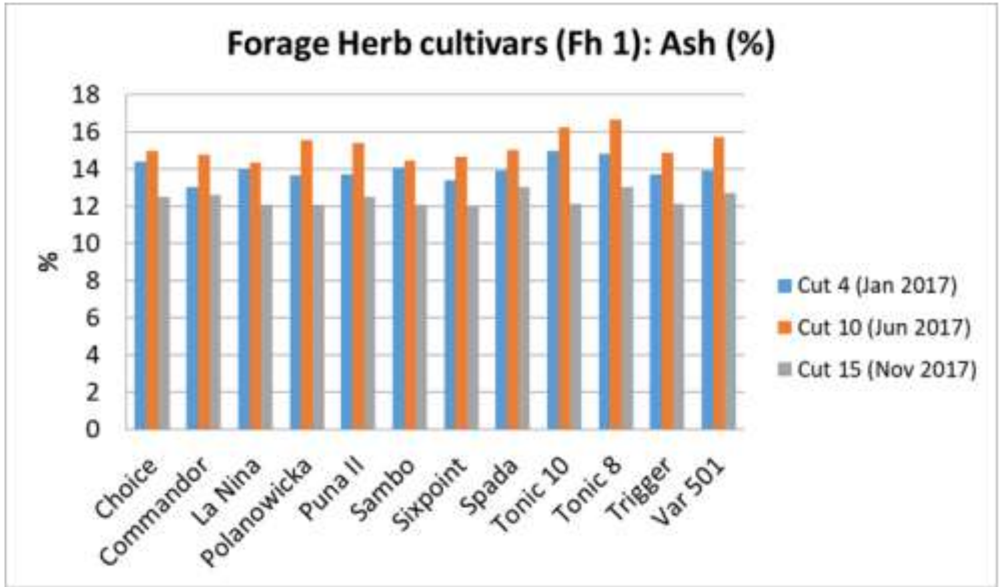
*plants were reproductive and contained flowering stems.

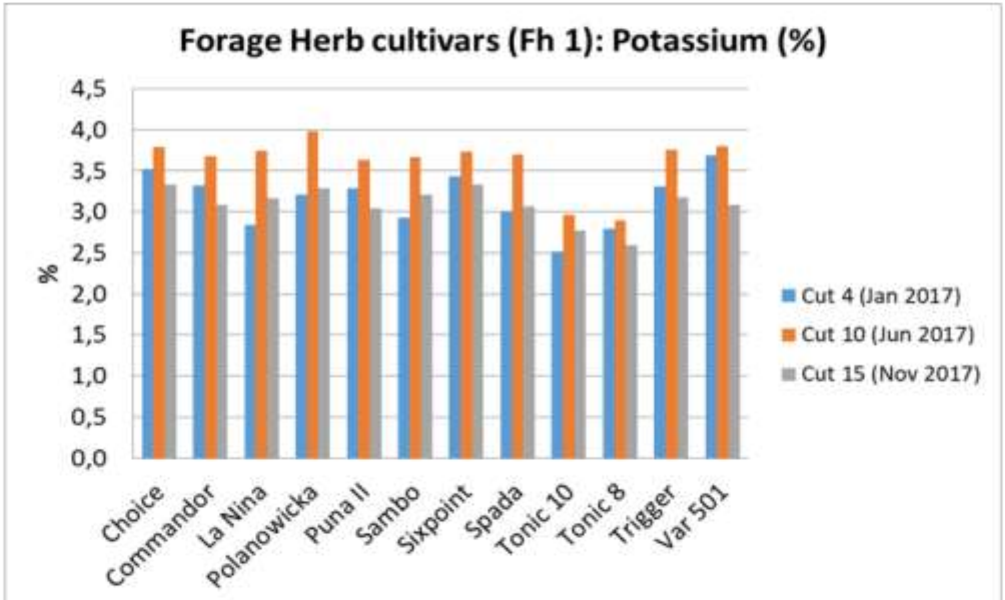
Table 2.Forage quality of Forage Herbs Fh 1, Outeniqua Research Farm

Planted: 5 October 2016









Discussion of yield results

In terms of total dry matter yield over the reported 30 month period, the plantain cv. Tonic was significantly superior ($p<0.05$)to all the chicory cultivars. This was also the case over the two-year period from summer 2016 to spring 2018. Tonic sown at 8 kg/ha yielding of 59.1 t DM/ha over 30 months or 50.5 tDM/ha over 24 months. The main advantage of the plantain over chicory was realized during the autumn and the winter months. The higher yield potential of the plantain can in part be attributed to the consistent population and uniform plant height.

In terms of seasonal yield for plantain, winter was the lowest, but significantly higher ($p<0.05$) than all the chicory cultivars. In all the seasons Tonic attained the highest yield ($p<0.05$) or at least similar to the best chicory cultivars in spring and summer.

Amongst the chicory cultivars Spada, Commandor, 501, Puna II, SixPoint and Trigger where the highest yielding (p,0.05) in total yield. The main yield advantage of SixPoint and Trigger was in the second summer and autumn while they were very dormant during the first winter. Spada Commandor, 501 and Puna II yielded consistently, with winter the most dormant period and a yield decrease manifesting in the second autumn as well as spring.

Conclusions

Tonic plantain has been outstanding in terms of yield consistency and persistence showing a very high yield capacity.

Chicory shows seasonal effects to a greater degree than plantain and has a reduced population density in the second year. In addition the flowering stems of the chicory can be unpalatable while the much smaller flowering stems of the plantain are readily grazed. The deeper taproot of the chicory is a definite advantage.

It is clear that the yield potential of the plantain and the best chicory cultivars can add a new level of productivity to pasture production. The main questions are how to best fit these species into pasture systems. Should it be in broad-leaved mixtures, or in grass/herb mixtures with clovers. Which clovers and which grass species would be most suitable. Some of the answers are related to combining plants with a similar plant structure that will best ensure light utilization in the canopy that will not result in light competition and rather result in complementarity amongst the various components. Another consideration is the use of herbicides, if required to control weed problems, which may favour a monospecific herb stand or a mixed broad-leaved stand planted separately of a grass pasture and utilized alternately.

Forage herbs can provide a good alternative pasture with the advantages of deeper root systems, higher water and nitrogen use efficiency and high forage quality.

Farm system study: Development of dairy systems based on forage herb pastures in the southern Cape

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A focus on sustainability

Much focus in recent years within the field of agricultural research has been on how to improve the sustainability of production systems. According to Pretty (2008), strategies to improve sustainability should focus on the need to develop technologies and practices that do not have adverse effects on environmental goods and services, are accessible to and effective for farmers, and at the same time lead to improvements in food productivity.

Within grassland and pasture based systems, particular criteria for systems to remain sustainable include the maintenance of efficiency, productivity and profitability, primarily driven by lowering of input costs and developing systems that display resistance or resilience to stresses such as drought, defoliation and weed invasion (Sanderson et al. 2007).

From an animal viewpoint, improved productivity and environmental sustainability in pasture based animal production systems is most likely to be achieved through an improved efficiency in the conversion rate of pasture to milk (Chapman et al. 2012) or more simply a high feed conversion ratio (Galloway et al. 2018). In terms of environmental sustainability, the best approach is most likely to be achieved by either minimising environmental impact at a given rate of production or by increasing production at a particular degree of environmental impact (Galloway et al. 2018).

Problem identification and aim

High stocking rates, poor persistence of pastures, an increase in weed ingression in no-till pastures and increasing input costs associated with irrigation and fertilisation, are putting a strain on the ability of pasture based dairy producers to maintain acceptable forage quality and pasture yields within their systems in the southern Cape. This in turn, threatens the continued sustainability of these systems. Research should thus focus on strategies that can improve the resilience and efficiency of pasture systems.

One potential strategy to address some of the above points, could be the selection of species that are high yielding, possess a high forage quality and are more stress tolerant than the current pasture species being used *viz.* kikuyu (*Pennisetum clandestinum*), ryegrass (*Lolium* spp.) and clover (*Trifolium* spp.).

The inclusion of forage herbs, such as Plantain, into pastures, has been reported to hold various potential advantages for pasture based producers including (Moorhead and Piggot 2009, Cave et al. 2013, Totty et al. 2013, Woodward et al. 2013, Lee et al. 2015, Cheng et al. 2015, Box et al. 2016; Minee et al. 2017):

- an improvement or maintenance of milk

yield compared to ryegrass during adverse climatic conditions,

- higher kg milk solids production per animal,
- lowered rates of N leaching,
- improved dry matter intake in animals,
- higher forage quality compared to perennial ryegrass-clover pastures,
- higher summer/autumn production than temperate grasses,
- a lower decline in plant population over years compared to ryegrass
- improved resilience to periods of drought.

In terms of an alternative grass component within dairy systems, Tall Fescue has been noted to be a potential species that can be included due to its improved drought tolerance, the resultant ability to more effectively utilise soil water and rainfall due to their deep root systems (Van Eekeren et al. 2010) and improved persistance over years (Lowe and Bowdler 1995, Nie et al. 2004).

However, before systems can be adapted for the inclusion of these alternative pasture species, the following needs to be evaluated and determined relative to current systems:

- The milk yield, pasture yield and forage quality should either be similar or higher than the accepted norm for current pasture systems.
- The effect that alternative species and mixtures will have on the seasonal distribution of dry matter production and the resultant impact on feed budgets, particularly as it relates to the need to buy in feed, needs to be determined.
- The potential of alternative species and pastures to be persistent and maintain yield over years needs to be evaluated.
- The rate of deterioration in pasture composition, indirectly associated with persistence, but also related to the rate of weed ingression, over years needs to be characterised.
- The efficiency with which resources can be utilised by the pasture species and systems, particularly as it relates to water utilisation, nitrogen utilisation and feed conversion ratio should be quantified.
- The appropriate rate of inclusion of alternative pasture species and systems on a farm scale to ensure adequate returns needs to be determined. This includes an evaluation of whether monocultures, mixtures or both should be included in systems.

This aligns with the recommendation that an integrated approach to sustainability is required, where multiple and interacting factors need to be managed including fertiliser and bought feed use efficiency, as well as the maximum utilisation of available land (Galloway et al. 2018). In addition, the study will aim to function on the basis of "adaptation analysis" as described by Keating et al. (2010), which takes an approach of broadly participatory and multi-disciplinary research, rather than focusing on a predefined discipline in isolation. The aim of this study will thus be to determine the whole system production potential and efficiency of three pasture systems based on the current system (Kikuyu-ryegrass), monocultures of alternative species (Tall fescue and plantain) and a pasture mixture that includes alternative species (Tall fescue, plantain and red clover). In essence the project will aim to develop a toolbox, which can be utilised to select, combine, place and monitor plant species in a managed landscape on farm scale to assist in improving productivity (Sanderson et al. 2007).

Site description

The study will be carried out on the Outeniqua Research Farm (altitude 210 m, 33°58'38" S and 22° 25'16"E) in the Western Cape Province of South Africa. The mean annual rainfall (30 year average) in this area is 725 mm, with mean minimum and maximum temperatures ranging between 7-15°C and 18-25°C respectively (ARC 2010).

Treatments, site selection and layout

The project will evaluate three pasture systems based on different pasture species and types. The first system, which will be referred to as "Unimproved" (UI), will be based on kikuyu-ryegrass pasture, and is aimed at representing a typical long term no-till pasture in the region. The second system, or "Monoculture" (MC), will consist of two separate areas, one planted to a monoculture of plantain (*Plantago lanceolata;* approximately 20% of area) and the other to Tall Fescue (*Festuca arundinacea;*

Table 1. Species, varieties and seeding rates for pastures during the study

System	Abbreviation	Species	Scientific name	Variety*	Seeding rate (kg ha^{-1})
Unimproved	UI	Kikuyu	*Pennisetum clandestinum*	Existing sward	-
		Perennial ryegrass	*Lolium perenne*	24Seven	25
Monoculture	MC	Tall Fescue	*Festuca arundinacea*	Easton	25
		Plantain	*Plantago lanceolata*	Tonic	8
Diverse pasture mixture	DPM	Tall fescue	*Festuca arundinacea*	Easton	20
		Plantain	*Plantago lanceolata*	Tonic	3
		Red clover	*Trifolium pratense*	Oregon red	3

approximately 80% of area). The third system will be based on a diverse pasture mixture (DPM) consisting of Tall Fescue, plantain and red clover.

The trial will be conducted in the form of a full farmlet study over a three year period. The premise behind a farmlet study is to apply systems to a large enough area and in such a manner that it resembles a practical farming unit (Murrison and Scott 2013). This presents a particular challenge when planning and implementing such a study, as the possibility of replication is largely constrained by the availability of both physical and financial resources. As such, the planned project will be based on the principles described by Scott et al. (2013a) for allocating areas to an un-replicated farmlet study, with sub-sampling implemented to over-come problems of estimating experimental error (Grima and Machodo 2013).

According to Scott et al. (2013a) a potential method to allocate areas to farmlets is via the empirical method, to ensure that as few systematic differences between farmlets exist. This is particularly important in terms of aspects that cannot be manipulated such as slope and soil type. The area identified for the project has a negligible gradient in slope and as such, the primary criteria utilised to identify the research site(s) was soil type based on a soil survey map of Outeniqua Research Farm (Measured Agriculture, Greyton). Each farmlet is approximately 5 ha in size, with 60% allocated to a Katspruit soil type and the remaining to a Witfontein soil type.

1. Unimproved system:

Ryegrass

Kikuyu

2. Monoculture system

Plantain monoculture

Tall Fescue monoculture

3. Diverse pasture mixture system

Plantain; Tall Fescue and Red clover

To facilitate sub-sampling on each system, grazing strips (average size of 0.18 ha) within the respective paddocks will be utilised as measurement units. A varying degree of sampling intensity will be applied to strips based on the parameters being measured. For highly intensive measurements (for example botanical composition determination or weekly pasture measurement), paddocks will be divided into approximate half hectare (0.50 ha) "blocks", each consisting of three pasture strips, with the centre strip functioning as a monitor strip for sampling purposes. For less intensive sampling (for example daily pasture allocation), sampling will occur on a grazing strip basis. Strips will further be divided into 3 subplots referred to as "Front", "Middle" and "Back". This is based on the observation of gradients in pasture yield and botanical composition from the front to the back of paddocks. It is hoped that this will allow for inferences to be made between changes in soil parameters and pasture characteristics along this gradient.

Pasture establishment

The plantain pasture was established in October 2018. Two applications of a non-selective contact herbicide (200 g/L Glufosinate ammonium applied at 6L ha^{-1}) were used to spray off the existing pasture approximately a month before establishment. The remaining residue was then mulched to ground level (1.6 meter Nobili with 24 blades) and the plantain planted utilising a modified Aitchison no-till seeder with press wheels.

The other pastures were established during March 2018. The area earmarked for the establishment of Tall Fescue and the diverse pasture mixture was sprayed off with a non-selective contact herbicide (200 g/L Glufosinate ammonium applied at 6L ha^{-1}) during February 2018. Approximately 2 weeks after herbicide application, the remaining residue was mulched to ground level to facilitate breakdown and allow weed germination. A week prior to establishment, a follow up application of a non-selective contact herbicide (200g/L Paraquat ion at 4L ha^{-1}) was undertaken, with remaining residue mulched to ground level just prior to establishment. The mono-culture Tall Fescue was established using a standard planting method with a modified Aitchison no-till seeder with press wheels. In order to facilitate the shallow planting depth required for the small seeded plantain and clover, this mixture site was "cross-planted". This entailed planting the Tall Fescue parallel to the length of grazing strips (i.e. from front to back), followed by the plantain/red clover mixture perpendicular to this (right to left). The perennial ryegrass on the kikuyu-ryegrass site was established by grazing the area down to a height of 50 mm, mulching the remaining stubble to ground level and planting the perennial ryegrass with a modified Aitchison no-till seeder with press wheels.

The kikuyu-ryegrass pasture will be over-sown on an annual basis as is common practice in the region, motivated by the poor persistence and resultant decline in yield of ryegrass that occurs from year 1 to year 2, even in pure swards under cutting (van der Colf et al. 2016).

Trial animals

The selection of animals will aim to construct a "mini-herd" for each system, with the purpose of being representative of a typical herd structure within a pasture based system with a non-seasonal calving distribution. The criteria to achieve this goal will be broadly based on achieving an even distribution of lactation number, maintaining days in milk (DIM) at approximately 150 and providing a constant flow of animals into and out of the system. Milk yield and milk composition form the previous lactation will be used to block animals. The number of animals allocated to each of the three systems will be:

- 20 animals in milk (stocking rate of approximately 4 cows ha^{-1})
- 5 dry animals (25% of herd)

This equates to a total of 25 animals per treatment and 75 animals for the entire study. As animals in the "milk herd" are dried off, they will be replaced by animals from the systems' "dry herd" as they calve. This may result in periods when the pasture area for each system is stocked below or above the 20 animals/system.

Soil measurements and management

Pre-trial sampling

In preparation for the project, intensive soil sampling was undertaken on the earmarked sites for the MC and DPM systems during June 2018. Sampling was based on the principle of grid sampling, where an area is divided into a number of smaller grids to determine the spatial distribution and variation in soil characteristics at a site. The 24 grazing strips were each divided into 3 subplots *viz.* front, middle and back. Approximately 30 sub-samples were taken per plot using a beater type soil sample to make up a representative composite sample for analysis. Separate samples were taken for the 0 -100, 100 – 200 and 200 – 300 mm soil depths. Samples were then sent for analysis for Ca, Mg, Na, K, P, Zn, Mn, B, S, C, ammonium-N, titratable acid and cation exchange ability.

The motivation behind this intensive sampling is three-fold:

1. To determine variation in soil chemical properties between strips and paddocks, which could in turn be implemented as co-variates in future statistical analysis
2. To develop a fertilisation programme and recommendations for trial sites that will ensure that pasture production is optimised
3. To monitor how soil nutrient gradients within strips affects pasture yield and composition d) To determine how soil nutrient status changes with depth in the soil profile.

Annual soil sampling

The intensive soil sampling conducted in June 2018 will be utilised to determine how samples could potentially be pooled across strips for an annual sampling of the entire system trial area from year 2 onwards. Once these areas have been earmarked, samples will again be taken at the three depths, from front to back, as in June 2018.

Penetration resistance

Penetration resistance will be determined using a GPS enabled Penterologger (Eijkelkamp Agrisearch Equiptment, Giesbeek, Netherlands) on a sub-plot basis.

Fertilisation

Corrective fertilisation application for the entire project site will be based on annual soil sample analysis results for the 0-100 mm soil depth and the recommend soil nutrient levels indicated in Table 2.

Table 2. The recommended nutrient levels for grass-clover pastures

Soil nutrient	Recommendation
pH (KCl)	5.5
Phosphorus (P) (citric acid)	40 mg/kg
Potassium (K)	100 mg/kg
Calcium (Ca)	400 mg/kg
Magnesium (Mg)	70 mg/kg
Ca:Mg ratio	4:1
Sulphur (S)	11 mg/kg
Copper (Cu)	1.0 mg/kg,
Zinc (Zn)	1.0 mg/kg
Manganese (Mn)	25 mg/kg
Boron (B)	1.0 mg/kg

Literature on the recommended nitrogen fertilisation rate for plantain and diverse pasture mixtures containing plantain is limited. In current small plot cutting trials on Outeniqua with pure forage herb and grass/herb swards, nitrogen is applied at a rate of 40 kg ha-1 after each cut. To date (two years after establishment), no nitrogen deficiencies have been apparent. Taking into account the nutrient cycling that occurs in pastures under grazing, an application rate of 30 kg N ha-1 after each grazing should be sufficient. This also aligns with the general application rate to pastures in the region and application rates of approximately 200 kg N ha-1 annum-1 reported in previous studies on plantain based pastures (Woodward et al. 2013, Beukes et al. 2014, Lee et al. 2015).

Pasture parameters

Pasture yield (kg DM ha-1)

Dry matter production of the pasture treatments will be estimated using the rising plate meter (Stockdale 1984, Fulkerson 1997). In order to develop calibration equations that relate rising plate meter (RPM)

Table 3. Components into which botanical composition samples will be fractioned

System	Sown components	Volunteer/weed grasses	Broadleaf weeds	Volunteer legumes
UI	Kikuyu Ryegrass	*Paspalum urvillei** *Eragrostis plana** *Sporobolus africanus** *Bromus catharticus** *Poa pratensis** Other*	All	All
DPM	Tall Fescue Plantain Red clover	Same as above* (UI) Ryegrass	All	White clover Trefoil
MC	Plantain site	Same as above* (UI) Ryegrass	All	White clover Trefoil
	Fescue site	Same as above* (UI) Ryegrass	All	All

readings to pasture yield, calibration cuts will be taken on monitor strips before grazing or cutting silage throughout the study. At each cut the height of the pasture will be measured with the RPM at a specific point, a ring of the same size as the RPM plate (0.098m2) placed over the RPM and all DM within the ring borders cut (t'Mannetjie 2000) to a height of 50 mm. Three samples will be cut at a height estimated by the operator as low, medium and high, respectively, within each of the sub-plots in a monitor strip. Linear and curvilinear relationships between herbage mass and pasture height will be determined and best fit equations used to calculate available herbage mass from pre-grazing height readings.

Pasture height of each grazing strip will be estimated by taking approximately 35 RPM measurements per sub-plot in a zigzag pattern before and after grazing. Measured pasture height and the developed calibration equations will then used to estimate the average DM available per hectare, grazing strip and sub-plot. "Before grazing" readings will be taken between one and three days before an area is grazed or cut. Post-grazing readings will be taken a maximum of two days after animals are removed from a grazing strip. Estimated dry matter intake will be determined from pre- and post-grazing yields. The estimated pre-grazing yield will also be used for pasture allocation purposes (see section on "Pasture allocation and conservation").

Botanical composition (%)

Botanical composition will be estimated by placing three 0.098 m2 rings randomly within a sub-plot on monitor strips before grazing/cutting and cutting samples to a height of 50 mm above ground during each grazing cycle. The three samples will be pooled, thoroughly mixed; a grab sample of approximately 500 g taken and then separated into the relevant fractions for each pasture type as described in Table 3.

Forage quality

Samples for quality analyses will be collected at the same time as the calibration clippings i.e. before grazing on subplots of monitor strips. A total of three samples (of 0.098 m2 each) will be cut at a height of 50 mm per subplot at each sampling date. Samples will be dried at 70ºC for 72 hours to a constant mass and weighed to determine the DM content (%). The samples will be pooled within a strip and milled (SWC Hammer mill, 1mm sieve). Samples will be analysed by Near Infrared Spectroscopy (NIR) for a total of 36 forage quality parameters (Dairyland Laboratories, USA).

Animal parameters

Cows will be milked twice daily at, 07:00 and 15:00, utilising a 20 Point Waikato/Afikim swing over milking machine with electronic meters. The machine is fully automated with weigh-all electronic milk meters that will allow daily milk production of each individual cow to be measured.

Milk composition will be determined on an approximately monthly basis from a 24 mL composite morning and afternoon milk sample of 16 mL and 8 mL, respectively. Samples will be analysed for butterfat (BF), lactose and milk urea nitrogen (MUN) content (Milkoscan FT 6000 analyzer; Foss Electric, Denmark) by Merieux Nutriscience Pty (Ltd) (Stellenryk Building, Constantia Square Office Park, 526 16th Street, Randjespark, Midrand, 1685). In addition, daily milk composition in terms of milk protein, lactose and fat will be available as determined by the Afimilk milking system.

Pasture and grazing management

Pasture allocation

Each system will be managed as a self-sustaining, closed system, with pasture allocated to each group following the morning and afternoon milking according to available pasture biomass (kg DM ha^{-1}) to facilitate high intensity rotational grazing. Pasture biomass available above 50 mm will be determined per sub-plot approximately one to three days before cows are planned to enter a pasture strip employing the RPM (35 readings per sub-plot) and RPM calibrations determined during the study for each sward type. Pasture will be allocated at a rate of 10 kg DM cow^{-1} day^{-1} (approximately 2% of body weight), with a fresh piece of pasture provided at a rate of 5 kg DM cow^{-1} after each milking. On the MC system, animals will be allocated plantain according to the proportional availability of the pasture within a period, with the rest of the intake allocated to Tall Fescue. Once a strip has been fully grazed, it will be fenced off utilising temporary electric fencing to prevent animals from grazing residual re-growth. Cows will receive 2 kg of dairy concentrate at each milking, equating to a total of 4kg cow^{-1} day^{-1}.

Weekly farm walks and fodder flow management

In order to facilitate ease of management of fodder flow within the respective systems, pasture will be measured on a weekly basis for the entire study site. For this purpose, grazing strips will be allocated to 0.5 ha monitoring blocks on which average leaf number and pasture height will be determined using a RPM. Data will be entered into the Fourth Quadrant software package, which automatically calculates pasture yield (according to manually entered calibrations), leaf appearance rate and average predicted rotation length. Based on leaf appearance rates calculated by the software, dry matter yield on a farmlet scale and the estimated pasture requirement for animals, it will be determined whether pasture availability on the pasture platform is in excess of animal requirements (surplus) or lower than requirements (shortfall). The following strategies will be followed in these circumstances:

- Shortfall in year 1: Animals will be supplemented with bought in feed in the form of lucerne hay.
- Shortfall in year 2 and 3: Grass silage from system fed to cow groups in isolation.
- Surplus: Area will be cut to make wrapped grass silage. Plantain will not be cut for silage, with allocation rate (% of intake) adjusted upwards as yield increases.

Areas to be cut for silage will be harvested for the determination of pasture parameters as per normal procedures described above. Bales will be marked with a batch number according to pasture type and date. Grab samples will be taken from each bale, pooled within a batch and analysed with NIR as for forage quality samples.

Fruitlook data

Fruitlook (https://www.fruitlook.co.za/) is an open web portal that uses satellite imaging to provide data on the biomass production, leaf area index, vegetation index, evaporation deficit, actual evapotranspiration, biomass water use efficiency, nitrogen in the upper leaf layer and nitrogen in the whole plant. The 0.5 ha monitor blocks employed for weekly farm walks will be drawn into the Fruitlook application and weekly data pulled from the system. Alongside yield, weather and irrigation data collected on site, this will provide the opportunity to determine how Fruitlook can be implemented in a practical and logical manner for pasture management by producers.

Determination of a sustainability complex and efficiency parameters

The parameters that will be utilised to estimate a sustainability index are laid out in Table 4 (modified from Scott et al. 2013b).

As per Scott et al. (2013b), data will undergo normalisation as follows:

- For desirable traits, such as pasture or milk yield, the values will be divided by the maximum value achieved across the three systems.
- For undesirable traits, such as weed content or costs, the minimum value over the three farmlets will be divided by the value for each farmlet.

Table 4. Parameters that will be included in the construction of a sustainability index

Soil layer:	Pasture layer:	Animal production:	Farmlet productivity and	Cost analysis
• Soil P • Soil S • Soil K • Soil C • Soil penetration resistance • Soil texture classes	• Sown component • Weedy grass component • Broadleaf weed component • LAI before grazing/NDVI before grazing • Cover before grazing • Species distribution • Forage quality parameters	• Actual stocking rate (cow days) • Milk yield/cow • Milk yield/lactation • Milk solids • Reproduction • Replacement rate?	• Nutrient production ha^{-1} (for example nitrogen) • Nutrient use efficiency (kg pasture/nutrients applied) • Water utilisation efficiency (kg pasture/mm water applied) • Milk yield/ha • Milk solids/ha • Stocking rate (actual based on cow days) • Silage production (Fodder flow) • Feed use/kg milk produced • Feed conversion ratio (milk yield kg $intake^{-1}$ of pasture and supplemental feed) • Fertiliser kg^{-1} FCM	• Irrigation cost • Fertilisation cost • Pasture maintenance cost (herbicide, renovation costs, mowing) • Supplemental forage cost (silage making and bought in feed) • Gross margin ha^{-1}

The resultant values will be used to construct a non-weighted index for each system. The opportunity will, however, exist to construct an index where the various parameters can be weighted according to their relative importance in determining sustainability.

Conclusion

Sustainable agriculture within pasture based dairy systems should focus on increasing profitability, efficiency and limiting the negative impact on natural resources such as soil and water. The integration of high yielding and more resilient pasture species is the most likely pasture based approach whereby to achieve these goals. However, before these species can be integrated into pasture systems, the impact on a whole farm system needs to be determined. The planned study will provide the opportunity to fully quantify and describe these systems in terms of both economic and biological processes, and in turn develop an extensive management toolbox on which management decisions can be based.

References

Ammann SB, Lombard D, Zulu L. 2018a. Chicory and plantain production results 2018. Outeniqua Research Farm Information Day 2018 Booklet. Western Cape Department of Agriculture. 18-24.

Ammann SB, Lombard D, Zulu L. 2018a. Elite cultivar evaluation: Lolium and Tall Fescue. Outeniqua Research Farm Information Day 2018 Booklet. Western Cape Department of Agriculture. 25-33.

ARC. 1984. Agriculture Research Council. The Nutrient Requirements of Ruminant Livestock. The Lavenham Press, LTD., Lavenham, Suffolk, UK. P59.

Beukes PC, Gregorini P, Romera AJ, Woodward SL, Khaemba EN, Chapman DF, Nobilly F, Bryant RH, Edwards GR, Clark DA. 2014. The potential of diverse pastures to reduce nitrogen leaching of New Zealand dairy farms. Animal Production Science 54: 1971-1979.

Box LA, Edwards GR, Bryant RH. 2016. Milk production and urinary nitrogen excretion of dairy cows grazing perennial ryegrass-white clover and pure plantain pastures. Proceedings of the New Zealand Society of Animal Production 76: 18-21.

Cave LM, Kemp PD, Kenyon PR, Morris ST. Plantain (Plantago lanceolata) and chicory (Cichorium intybus) under moisture stress in glasshouse. Proceedings of the 22nd International Grassland Congress. pp.139-140.

Chapman D, Clark D, Beukes P, Edwards G, Dalley D, Pinxterhuis I, Romera A, Shepherd M, Cameron K, Woodward S, Glassey C, Roach C, Lynch B. 2012. Strategies for increasing dairy system productivity while controlling environmental footprint: a common system research approach in two regions of New Zealand. Proceedings of the 5th Australasian Dairy Science Symposium, 417 – 421.

Cheng L, McCormick, Hussein AN, Fraslin C, Moonsan Y, Logan C, Grabot J, Edwards GR. 2015. Urinary nitrogen excretion, grazing and urination behaviour of dairy heifers grazing pasture, chicory and plantain in autumn. Proceedings of the New Zealand Society of Animal Production 75: 70-73.

Fulkerson WJ. 1997. Use of the rising plate meter to allocate pasture. Research to Farm. NSW Agriculture, Wollongbar Agricultural Institute, May 1997.

Galloway C, Conradie B, Prozesky H, Esler K. 2018. Are private and social goals aligned in pasture based dairy production? Journal of Cleaner Production 175: 402-408.

Keating AB, Carberry PS, Bindraban PS, Asseng S, Meinke H and Dixon J. 2010. Eco-efficient Agriculture: Concepts, Challenges, and Opportunities. Crop Science 50:109-119.

Lee JM, Hemmingson NR, Minee EMK, Clark CEF. 2015. Management strategies for chicory (Chicorium intybus) and plantain (Plantago lanceolata): impact on dry matter yield, nutritive characteristics and plant density. Crop and Pasture Science 66:168 – 183.

Lowe KF, Bowdler TM. 1995. Growth, persistence, and rust sensitivity of irrigated, perennial temperate grasses in Quennsland subtropics. Australian Journal of Experimental Agriculture, 35,571-8

Mineé EMK, Waghorn GC, Lee JM, Clark CEF. 2017. Including Chicory and plantain in perennial ryegrass/ white clover-based diet of dairy cattle in late lactation: Feed intake, milk production and rumen digestion. Animal Feed Science and Technology 227: 52-61.

Moorhead AJE, Piggot GJ. 2009. The performance of pasture mixes containing "Ceres Tonic" plantain in Northland.. Proceedings of the New Zealand Grassland Association 71: 195-199.

Murrison R, Scott JM. 2013. Statistical methodologies for drawing causal inference from an unreplicated farmlet experiment conducted by the Cicerone project. Animal Production Science 53:643-648.

Nie Z, Miller S, Moore G, Hackney B, Boschma S, Reed KFM, Mitchell M, Albertsen TO, Clark S, Craig AD, Kearney G, Li GD, Dear BS. 2008. Field evaluation of perennial grasses and herbs in southern Australia 2. Persistence, root characteristics and summer activity. Australian Journal of Experimental Agriculture, 48:424-435.

Pretty J. 2008. Agricultural sustainability: concepts, principles and evidence. Philospophical Transactions of The Royal Society. 363: 447-465.

Sanderson MA, Goslee SC, Soder KJ, Sikinner RH, Tracy BF, Deak A. 2007. Plant species diversity, ecosystem function, and pasture management- A perspective. Canadian Journal of Plant Science 87:479-487.

Scott JM, Munro M, Rollings N, Browne W, Vickery PJ, Macgregor C, Donald GE, Sutherland H. 2013a. Planning for whole farm systems research at a credible scale: subdividing land into farmlets with equivelant initial conditions. Animal Production Science 53: 618-627.

Scott JM, Behrendt K, Colvin A, Scott F, Shakhane LM, Guppy C, Hoad J, Gaden CA, Edwards C, Hinch GN, Cacho OJ, Donald GE, Cottle D, Coventry T, Williams G, Mackay DF. 2013b. Integrated overview of result from a farmlet experiment which compared the effects of pasture inputs and grazing management on profitability and sustainability. Animal Production Science 53: 841-855.

Stockdale CR. 1984. Evaluation of techniques for estimating the yield of irrigated pastures intensively grazed by dairy cows. II. The rising plate meter. Australian Journal of Experimental Agriculture and Animal Husbandry 24: 305-311.

`t Mannetjie L. 2000. Measuring biomass of grassland vegetation. In: Field and Laboratory methods for grassland and animal measurement. Eds: `t Mannetjie L, Jones RM. CAB International. Wallingford, UK.

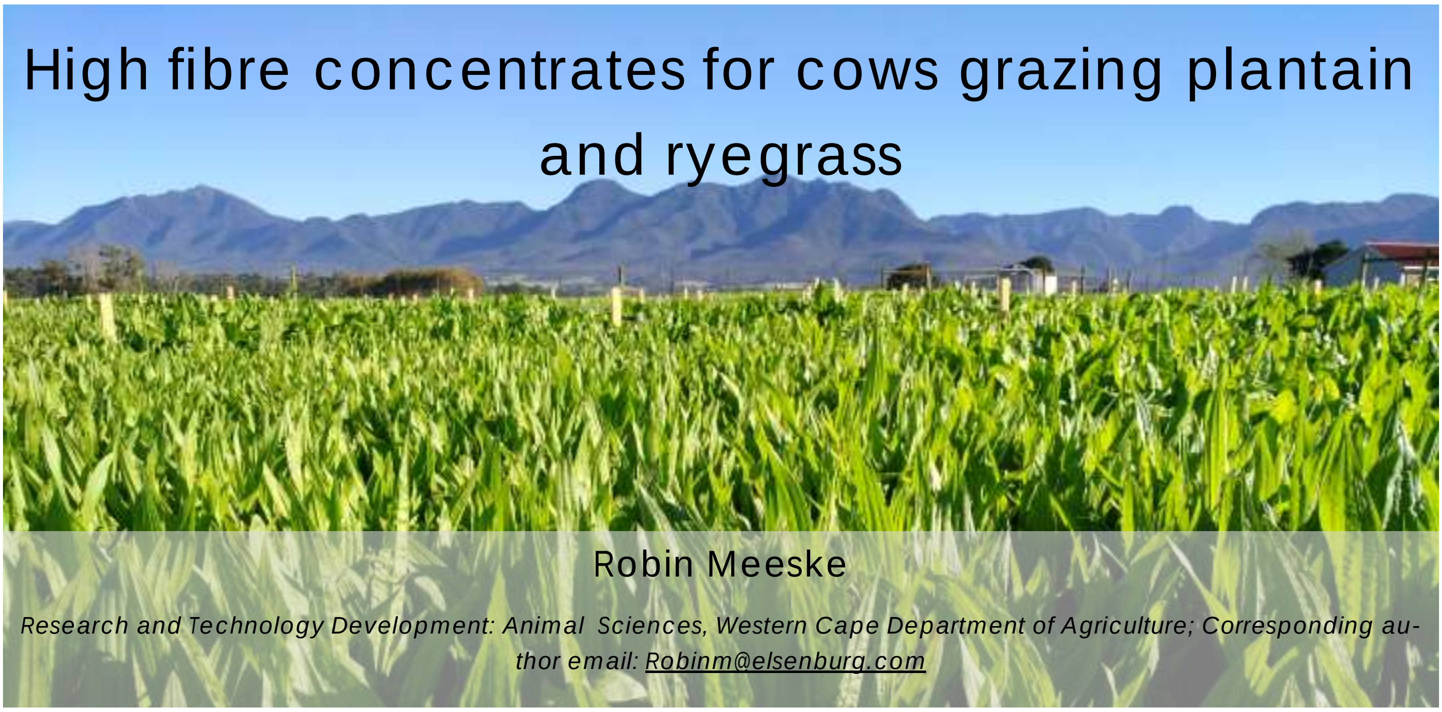
Totty VK, Greenwood SL, Bryant RH, Edwards GR. 2013. Nitrogen partitioning and milk production of dairy cows grazing simple and diverse pastures. Journal of Dairy Science 96:141-149.

van der Colf J, Ammann SB, Zulu LB, Lombard MM. 2016. Pasture dry matter yield of perennial ryegrass and ryegrass hybrids in the southern Cape. Outeniqua Research Farm Day 2016 Booklet. 21-27.

Van Eekeren N, Bos M, De Wit J, Kiedel H, Bloem J. 2010. Effect of individual grass species and grass species mixtures on soil quality as related to root biomass and grass yield. Applied Soil Ecology 45: 2715-283.

Woodward SL, Waugh CD, Roch CG, Fynn D, Phillips J. 2013. Are diverse species mixtures better pastures for dairy farming. Proceedings of the New Zealand Grassland Association.

High fibre concentrates for cows grazing plantain and ryegrass



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Kikuyu/ryegrass pasture under irrigation has been the main source of forage used by dairy farmers to produce milk in the Southern Cape for the last two decades. Forage herbs like plantain and chicory are becoming more popular and are planted as pure stands or as part of a pasture mix. Plantain has a high production potential and high feeding value but is low in effective fibre. This will result in less rumination and lower rumen pH levels. Dairy concentrates normally contain 50-80% maize and are supplemented at 5-8kg/cow/day. The starch in maize is rapidly fermented in the rumen and results in a reduction in rumen pH. When rumen pH gets below 5.8, fibre digestion may be compromised. Previous research at Outeniqua research farm has shown that supplementing high fibre concentrates to cows grazing kikuyu/ryegrass pasture in spring resulted in sustained milk production and higher milk fat content when compared with conventional maize based concentrates. Most research on plantain has been done in New Zealand where no or very little concentrate is fed to dairy cows. Very limited research is available on effective concentrate supplementation to cows that consume plantain as 50% of their forage intake. The nutritional composition of ryegrass/clover and plantain is shown in Table 1. It is clear that plantain has a lower dry matter and fibre content than ryegrass/clover pasture while protein and metabolisable energy content may be similar.

Cows need 30% NDF in their total diet of which two thirds should be from roughage. The effective fibre content of pasture differs depending on the specific fibre components. Hemicellulose is highly digestible while cellulose may be highly digestible to very indigestible. When incorporating plantain in the diet of grazing dairy cows new focus is needed on the composition of dairy concentrates as well as on the level of concentrate feeding. The Table 2 shows three concentrates that will be fed at 6kg/cow/day

Table 1. The composition of ryegrass/clover and plantain and milk production of cows grazing ryegrass/clover or plantain (Box et.al., 2016)

Parameter	Ryegrass/clover	Plantain
Dry matter %	17.1	9.8
Metabolisable energy (MJ/kg)	11.2	11.4
Crude protein %	23.3	22.3
Neutral detergent fibre (NDF) %	42.9	29.9
Acid detergent fibre (ADF) %	28.2	22.4
Water soluble carbohydrates %	7.6	10.9
Milk production (L)	14.3	16.4

Table 2. Ingredients and nutrient composition of concentrates differing in maize and by-product content fed to cows grazing plantain and kikuyu/ryegrass pasture during spring.

Ingredient	Low Fibre	Medium Fibre	High Fibre
Maize	80	50	20
Hominy chop	0	17.5	35
Wheat bran	4.27	9.52	14.77
Soybean hulls	0	9	18
Soybean oilcake	7.7	6.25	4.8
Molasses	4	4	4
Feed lime	2.5	2.45	2.4
MCP	0.4	0.2	0
Salt	0.5	0.5	0.5
MgO	0.3	0.25	0.2
Premix	0.33	0.33	0.33
Nutrient % of DM			
Dry matter (%)	87.6	87.4	87.2
Crude protein (%)	12.3	12.3	12.3
ME (MJ/kg)	12.5	12.0	11.5
NDF (%)	10.5	19.3	28
Hemicellulose %)	6.0	9.4	12.7
Starch (%)	62	45.7	29.4
Ca (%)	0.98	1.01	1.04
P (%)	0.40	0.42	0.45
Mg (%)	0.39	0.40	0.41

to cows grazing pure plantain during the day and kikuyu/ryegrass during the night. The study will be done at Outeniqua Research farm during September and October 2019. The high fibre concentrate contains only 20% maize grain and 68% by-products (hominy chop, wheat bran and soybean hulls).

The NDF content of the high fibre concentrate is 28% compared to only 10.5% of the low fibre concentrate. The starch content of the high fibre concentrate is only 29% compared to 62% on the low fibre concentrate. We do expect that cows on the high fibre concentrate will produce more fat corrected milk and have an increase of 0.5% in milk fat %. Previous studies (Lingnau, 2011 and Vd Vyver, 2018) have clearly shown sustained milk production with an increase milk fat and milk protein when feeding high fibre by-products to cows grazing kikuyu/ryegrass during spring. When pasture contains plantain and therefore less effective fibre the potential of highly digestible by-products should be utilised.

Conclusions

Concentrates containing high levels of by-products should complement pasture containing plantain well. Feeding high starch (high maize) concentrates to cows grazing pasture with low levels of effective fibre could result in reduced milk fat % and even reduced milk production.

References

Box, L.A., Edwards, G.R. & Bryant, R.H., 2016. Milk production and urinary nitrogen excretion of dairy cows grazing perennial ryegrass-white clover and pure plantain pastures. NSentinel4, Nitrogen management system with the power of 4. The Supporting Science vol 1/2017, pp 28-31. (www.nsentinel4.co.nz)

Van der Vyver, A., 2019. Partial substitution of maize with soybean hulls in a concentrate for grazing dairy cows. MSc. Agric. Stellenbosch University. Supervisor: R. Meeske, Co-supervisor: C.W. Cruywagen.

Lingnau, W.A.L., 2011. Substitution of maize with high fibre by-products in concentrates supplemented to dairy cows grazing kikuyu/ryegrass pasture during spring. MSc. Agric. Stellenbosch University. Supervisor: C.W. Cruywagen, Co-supervisor: R. Meeske.