Plantain and chicory could potentially complement the perennial ryegrass dominant dairy feedbase

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Abstract
A modelling study was undertaken to identify if pasture mixtures or monocultures containing plantain or chicory are likely to convey a dry matter (DM) production advantage over perennial ryegrass (Lolium perenne) at the dairy locations of Terang and Ellinbank in Victoria, and Smithton, Elliott, Cressy and Scottsdale in Tasmania. The growth of monocultures of perennial ryegrass (PRG), plantain (Plantago lanceolata; PLA), and chicory (Cichorium intybus; CHIC), along with mixtures of perennial ryegrass, white clover (Trifolium repens) and plantain (RC-PLA), and mixtures of perennial ryegrass, white clover and chicory (RC-CHIC) were simulated at the six locations for a 40 year period using the biophysical model DairyMod. The average annual yield of PLA ranged between 12.1 and 25.1 tDM/ha and was comparable to or greater than PRG (11.2 to 20.7 tDM/ha) for all locations. For the Victorian locations of Terang and Ellinbank, the average annual yield of CHIC (11.4 and 15.5 tDM/ha respectively) was comparable to PRG (14.5 and 14.4 tDM/ha respectively). At the Tasmanian locations the average annual yield of the CHIC ranged from 5.2 to 16.8 tDM/ha and was lower than PRG (11.2 to 20.7 tDM/ha). The RC-PLA average annual yield ranged from 12.6 to 24.9 tDM/ha and the RC-CHIC average annual yield ranged from 10.1 to 20.4 tDM/ha for all locations. These yields were greater than the average annual yields of PRG. However, for the Tasmanian locations the RC-CHIC had a greater variance in yield (CV's between 8.3 and 27.1%) than the PRG (CV's between 3.1 and 17.2%). The RC-CHIC had greater summer production but lower winter production than the PRG at all locations. At the Tasmanian locations the RC-PLA had greater autumn and winter production than the PRG. It is concluded that the species that best complements the dairy feedbase is chicory or plantain for the Victorian locations and plantain for the Tasmanian locations.

Key words
Alternative forage species, pasture mixtures, biophysical modelling

Introduction

Perennial ryegrass (*Lolium perenne*) pastures form the basis of dairy production in the southern regions of Australia. This species is productive, relatively easy to establish, has well established and understood guidelines for its grazing management, and is relatively responsive to inputs of fertiliser and irrigation water (Rawnsley *et al*. 2014). Perennial ryegrass pastures have a bimodal distribution in growth with maximum growth rates occurring in spring (occurring concurrently with a decline in nutritive value due to reproductive development), followed by a decline in summer production due to temperature and moisture stress. There is a secondary peak in production in autumn followed by a slowing in growth during winter due to low temperatures (Rawnsley *et al*. 2007). This inter-seasonal variation in pasture growth and nutritive value presents a challenge to dairy farmers in terms of managing forage supply and demand within their business.

The perennial forbs plantain (Plantago lanceolata) and chicory (Cichorium intybus) are noted for their superior dry matter (DM) production during summer and autumn, and superior nutritive value compared to perennial grasses. The improvement in DM yield of plantain and chicory is associated with deeper root systems (Neal *et al*. 2009) and tolerance to heat (Stewart 1996) compared to the grasses. The superior nutritive value is associated with lower fibre content (Woodward *et al*. 2008) and a balanced mineral composition (Pirhofer-Walzl *et al*. 2011), and leads to improved animal production (Pembleton *et al*. 2015). It is for these reasons that these species may complement the perennial ryegrass forage base and assist to increase the production and consumption of 'home grown' forage on dairy farms.

While field research in Victoria and Tasmania has identified that both plantain and chicory grown either as monocultures or as components of a mixture can increase forage DM production (Tharmaraj *et al*. 2008, K.G Pembleton unpublished data), there has been contrasting results as to which forb species is the most suitable for a given region. The aim of this study was to identify which regions are most suitable for plantain and which regions are most suitable for chicory. It achieved this aim by using biophysical modelling to evaluate the production of chicory and plantain as monocultures and in pasture mixtures across six locations that represent major dairy regions in Victoria and Tasmania.

Methods

Model description

The biophysical pasture model DairyMod (version 5.2.15) (Johnson *et al*. 2008) was used for this study. It integrates weather data, soil water dynamics, soil carbon and nitrogen dynamics with plant water uptake and transpiration, canopy photosynthesis, tissue nitrogen dynamics and pasture management (irrigation, fertiliser and grazing management) to simulate plant growth on a daily time step. DairyMod has been used to explore the growth of perennial ryegrass across a range of locations (Chapman *et al*. 2009), the impact of future climates on pasture production (Cullen *et al*. 2009) and the optimising of inputs (Rawnsley *et al*. 2009). Users provide weather data and a description of the soil hydraulic properties, organic carbon and nitrogen pools and inorganic nitrogen pools. Users also define nitrogen fertiliser, irrigation and grazing management rules and select the species that are present in the pasture. The model is released with species specific parameter sets for perennial ryegrass and white clover. Recent research has further defined parameter sets for the forb species plantain and chicory and has confirmed that the model appropriately represents their growth in mixed pastures (Pembleton *et al*. 2015, K.G. Pembleton unpublished data).

Simulations

The growth of monocultures of *perennial ryegrass* (PRG), *plantain* (PLA) and *chicory* (CHIC) along with a mixture of perennial ryegrass, white clover and plantain (RC-PLA), and a mixture of perennial ryegrass, white clover and chicory (RC-CHIC) were simulated over two locations in Victoria (Ellinbank and Terang) and four locations in Tasmania (Smithton, Elliott, Cressy and Scottsdale), using site specific soil and weather data. Details of the soil and climatic conditions at these locations are provided in Table 1.

Each simulation was run using weather data from the years of 1963 to 2013 inclusive. Weather data for each location was accessed from the SILO (Scientific Information for Land Owners) online climate data base (Jeffrey *et al*. 2001). In each simulation the pastures were grazed to a residual height of 1200kgDM/ha on a 6 week rotation with spring calving dairy cows. Nitrogen (N) fertiliser, in the form of urea, was applied after each grazing event between May and January inclusive; 40 kgN/ha was applied in each application. Pasture growth was simulated under dryland conditions at Ellinbank and Terang. At Smithton, Elliott, Cressy and Scottsdale pasture growth was simulated under both dryland and irrigated conditions. In the irrigated simulations 15mm of water was applied on a 20mm rainfall deficit between the months of November and February inclusive. To allow the soil conditions within the model to initialise, the data from the first 10 years of each simulation was discarded from any subsequent analysis.

Table 1. Summary of soil and climate details for each location used in the simulations. Plant available water content (PAWC) is calculated over upper 1m of the soil profile. Climatic information is calculated over the period of the simulations (1963 to 2013 inclusive).

Location	Lat/ Lon	Soil type	PA-WC (mm)	Mean annual rainfall (mm)	Mean monthly maximum/minimum temperature (°C)											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Terang Vic	-38.24/ 142.92	Chromosol	162	774	24.5/ 11.8	25.0/ 12.4	22.8/ 11.2	19.4/ 9.2	15.9 /7.6	13.3 /5.7	12.7 /5.1	13.7/ 5.6	15.4 /6.6	17.6 /7.6	19.9/ 9.0	22.1/ 10.3
Ellinbank Vic	-38.25/ 145.93	Ferrosol	200	1052	24.9/ 12.6	25.4/ 13.1	23.0/ 11.7	19.2/ 9.4	15.7 /7.4	13.2 /5.5	12.5 /4.7	13.7/ 5.4	15.6 /6.6	18.0 /8.0	20.3/ 9.6	22.6/ 11.1
Elliott Tas	-41.08/ 145.77	Ferrosol	200	1184	20.5/ 11.0	20.9/ 11.6	19.2/ 10.3	16.5/ 8.5	13.9 /6.8	11.9 /5.1	11.2 /4.4	11.8/ 4.7	13.1 /5.4	15.1 /6.5	17.1/ 8.2	18.7/ 9.4
Scottsdale Tas	-41.17/ 147.49	Ferrosol	200	987	22.6/ 10.8	22.8/ 11.3	21.1/ 9.9	17.6/ 7.8	14.7 /6.0	12.4 /4.2	11.8 /3.6	12.5/ 4.1	14.1 /5.0	16.3 /6.0	18.6/ 7.8	20.5/ 9.2
Cressy Tas	-41.68/ 147.08	Red tenosol	100	602	29.3/ 10.4	24.1/ 10.4	22.0/ 8.1	18.1/ 6.1	14.7 /3.8	12.0 /1.9	11.6 /1.8	12.6/ 2.3	14.7 /3.9	17.0 /5.4	19.7/ 7.1	22.2/ 8.8
Smithton Tas	-40.83/ 145.11	Hemic Organosols	200	1106	20.5/ 11.3	20.6/ 11/7	19.3/ 10.5	17.0/ 8.7	14.9 /7.1	13.1 /5.5	12.5 /5.0	13.0/ 5.4	14.2 /6.3	15.7 /7.2	17.3/ 8.6	18.9/ 10.0

Results

Annual forage yields of the PRG at the Victorian locations of Terang and Ellinbank were 14.4 and 14.5 tDM/ha respectively (Table 2). The PLA at Terang had a similar average annual forage yield to the PRG, while at Ellinbank the PLA on average outperformed the PRG by 3.9 tDM/ha. There was also considerably less inter-annual variation in yield (as indicated by the co-efficient of variation) for the PLA compared to the PRG at these two locations. At Terang the CHIC had a lower yield (11.4 tDM/ha) than the PRG, while at Ellinbank the CHIC yield was similar to PRG. At both locations the RC-PLA and RC-CHIC had at least a 2.8 tDM/ha yield advantage over the PRG, along with a reduction in inter-annual variability in yield. For the Tasmanian locations PLA had between a 0.9 to 4.4 tDM/ha yield advantage over the PRG under both dryland and irrigated conditions. The inter-annual variability in yield was similar for the PLA and PRG with coefficients of variation between 2.0 and 19.0%. Growth of the CHIC across the Tasmanian locations was less than the PRG. The RC-PLA had an equivalent or greater average annual yield compared to the PRG across the Tasmanian locations. The RC-CHIC when grown dryland had a lower yield than the PRG at Cressy and Scottsdale and when irrigated at Elliott. In all cases the RC-PLA had a greater yield than the RC-CHIC.

Table 2. Modelled annual forage yields (t/ha) of perennial ryegrass (PRG), plantain (PLA), chicory (CHIC), a mixture of perennial ryegrass, white clover and plantain (RC-PLA) and a mixture of perennial ryegrass white clover and chicory (RC-CHIC) under dryland and irrigated conditions across 6 locations in southern Australia. Values are the mean of the years between 1973 and 2013. The values in parenthesis are the coefficients of variation associated with each mean.

Location	Terang, Vic	Ellinbank, Vic	Smithton, Tas		Elliott, Tas		Cressy, Tas		Scottsdale, Tas	
Irrigation	Dry	Dry	Dry	Irr	Dry	Irr	Dry	Irr	Dry	Irr
PRG	14.5	14.4	16.0	19.7	17.0	20.0	11.2	19.8	17.1	20.7
	(25.7)	(25.4)	(10.5)	(3.1)	(9.2)	(4.1)	(17.2)	(8.9)	(9.6)	(5.7)
PLA	14.4	18.3	18.0	23.5	17.1	20.9	12.1	23.4	18.7	25.1
	(18.8)	(13.4)	(11.8)	(2.8)	(10.7)	(3.0)	(19.0)	(6.4)	(11.5)	(2.0)
CHIC	11.4	15.5	12.2	11.4	8.6	16.8	5.2	10.0	10.0	11.3
	(30.6)	(27.4)	(37.1)	(58.6)	(35.3)	(24.9)	(36.6)	(47.7)	(36.6)	(52.2)
RC-PLA	17.9	19.0	18.9	24.0	17.5	19.9	12.6	23.9	19.3	24.9
	(10.3)	(15.7)	(12.7)	(3.0)	(9.9)	(10.9)	(17.9)	(8.9)	(13.0)	(5.7)
RC-CHIC	17.2	18.4	16.8	20.4	17.3	19.6	10.1	18.5	16.4	20.4
	(12.1)	(11.3)	(15.5)	(11.3)	(14.7)	(8.3)	(27.1)	(14.1)	(15.3)	(9.9)

Table 3. Modelled monthly growth rates (kgDM/ha) of perennial ryegrass (PRG), plantain (PLA), chicory (CHIC) and a mixture of perennial ryegrass, white clover and plantain (RC-PLA) and perennial ryegrass white clover and chicory (RC-CHIC) under dryland conditions across 6 locations in southern Australia. Values are the mean of the years between 1973 to 2013. The values in parenthesis are the coefficients of variation associated with each mean.

Location	Species/ mixture	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Terang	PRG	39 (101)	28 (139)	26 (112)	35 (97)	33 (80)	31 (86)	33 (74)	50 (69)	60 (71)	52 (99)	42 (115)	47 (111)
Vic	PLA	34 (96)	29 (115)	18 (115)	23 (100)	25 (74)	28 (58)	34 (46)	50 (44)	59 (50)	65 (56)	63 (73)	43 (90)
	CHIC	44 (81)	33 (87)	29 (92)	37 (77)	23 (65)	6 (100)	2 (175)	4 (104)	16 (89)	42 (50)	69 (52)	69 (65)
	RC-PLA	35 (81)	20 (93)	20 (105)	28 (91)	36 (63)	38 (53)	48 (47)	57 (50)	72 (44)	85 (43)	88 (38)	61 (60)
	RC-CHIC	46 (63)	43 (60)	34 (51)	36 (57)	27 (54)	13 (104)	10 (118)	31 (75)	76 (38)	96 (43)	93 (35)	61 (57)
Ellinbank	PRG	37 (113)	20 (135)	24 (114)	35 (98)	38 (73)	32 (70)	32 (76)	49 (69)	56 (75)	54 (94)	46 (100)	52 (93)
Vic	PLA	25 (96)	15 (129)	15 (132)	26 (88)	37 (46)	45 (25)	56 (16)	76 (16)	88 (18)	93 (20)	71 (39)	51 (64)
	CHIC	72 (50)	62 (68)	46 (90)	43 (80)	25 (71)	6 (96)	2 (207)	3 (132)	12 (113)	46 (64)	90 (46)	103 (46)
	RC-PLA	29 (86)	20 (104)	21 (95)	41 (63)	52 (42)	50 (40)	46 (47)	57 (52)	82 (36)	94 (30)	78 (37)	57 (62)
	RC-CHIC	61 (46)	53 (55)	47 (63)	43 (54)	27 (54)	15 (96)	19 (110)	39 (74)	67 (42)	91 (42)	81 (44)	63 (50)
Elliott	PRG	55 (44)	40 (62)	32 (67)	28 (69)	29 (53)	24 (64)	26 (54)	42 (29)	56 (15)	72 (8)	79 (14)	75 (33)
Tas	PLA	49 (51)	35 (60)	28 (67)	33 (42)	32 (28)	32 (20)	35 (17)	46 (9)	60 (6)	75 (7)	72 (15)	64 (34)
	CHIC	46 (77)	43 (80)	38 (83)	30 (90)	12 (103)	2 (102)	1 (131)	1 (127)	4 (116)	14 (99)	38 (70)	56 (78)
	RC-PLA	53 (43)	44 (49)	36 (44)	35 (49)	34 (30)	26 (45)	32 (33)	40 (27)	59 (12)	74 (13)	74 (26)	68 (31)
	RC-CHIC	67 (40)	69 (45)	53 (50)	37 (58)	25 (49)	15 (73)	18 (78)	29 (49)	47 (43)	69 (69)	73 (30)	68 (31)
Scottsdale	PRG	46 (59)	36 (65)	26 (80)	32 (57)	32 (44)	28 (50)	30 (43)	44 (25)	60 (11)	78 (10)	80 (16)	68 (41)
Tas	PLA	42 (62)	32 (62)	28 (70)	35 (48)	37 (28)	39 (21)	42 (17)	57 (8)	72 (4)	88 (9)	78 (21)	64 (45)
	CHIC	56 (56)	50 (65)	34 (87)	30 (65)	14 (88)	4 (118)	2 (150)	4 (157)	11 (114)	21 (88)	47 (60)	56 (52)
	RC-PLA	45 (59)	32 (63)	31 (64)	36 (51)	41 (21)	37 (28)	42 (21)	59 (10)	77 (8)	89 (12)	81 (23)	63 (45)
	RC-CHIC	51 (43)	57 (46)	45 (54)	36 (36)	21 (59)	13 (79)	21 (75)	38 (48)	55 (41)	71 (25)	72 (30)	61 (39)
Cressy	PRG	19 (116)	11 (127)	11 (142)	21 (76)	21 (66)	26 (59)	31 (47)	45 (25)	59 (16)	59 (35)	36 (665)	29 (85)
Tas	PLA	16 (117)	8 (139)	9 (159)	17 (83)	26 (47)	28 (36)	40 (18)	57 (8)	66 (20)	61 (39)	37 (58)	30 (75)
	CHIC	29 (82)	19 (105)	15 (101)	12 (93)	7 (121)	2 (109)	1 (220)	1 (166)	6 (103)	15 (105)	26 (79)	38 (63)
	RC-PLA	20 (96)	12 (113)	14 (97)	20 (80)	26 (53)	30 (42)	36 (33)	55 (11)	69 (19)	63 (41)	39 (60)	31 (75)
	RC-CHIC	28 (73)	23 (99)	20 (79)	18 (59)	11 (83)	7 (72)	18 (86)	33 (59)	51 (45)	52 (47)	38 (60)	31 (74)
Smithton	PRG	51 (48)	28 (81)	24 (76)	32 (60)	27 (56)	26 (51)	26 (49)	44 (24)	56 (12)	73 (9)	75 (14)	64 (37)
Tas	PLA	46 (53)	28 (70)	28 (64)	35 (41)	35 (23)	33 (26)	38 (20)	53 (12)	67 (5)	81 (8)	80 (17)	65 (37)
	CHIC	51 (65)	45 (75)	35 (82)	34 (72)	22 (71)	9 (83)	7 (102)	11 (95)	25 (78)	36 (64)	63 (41)	63 (55)
	RC-PLA	48 (54)	31 (64)	28 (57)	39 (41)	36 (30)	34 (25)	40 (26)	56 (11)	69 (11)	86 (7)	84 (18)	68 (35)
	RC-CHIC	61 (39)	55 (52)	45 (41)	41 (48)	24 (53)	18 (53)	22 (65)	31 (58)	52 (30)	66 (30)	70 (29)	70 (36)

Under dryland conditions the CHIC was able to maintain greater growth rates into the summer months compared to the PRG (Table 2). However, the CHIC also had lower growth rates in winter and spring due to the expression of winter dormancy. This response also carried through into the RCCM. Compared to the PRG, the PLA and RCPM had greater late spring growth at the Victorian locations and greater autumn growth at the Tasmanian locations.

Discussion

This study suggests that using a RCPM in Tasmania and a RCPM or RCCM in Victoria can increase forage yields. For locations in Victoria these mixtures also reduce the inter-annual variability in yield. This modeling is confirmed by field observations of pasture mixtures that contain plantain and/or chicory exploiting temporal niches that develop within dairy pastures (Pembleton *et al*. 2015). While the PLA and CHIC were able to change the distribution of forage yield to produce forage when the PRG growth was low due to high temperatures and soil moisture deficits, they still had considerable variability in yield. This variability, coupled with the challenges that the PLA and CHIC present in terms of management and plant persistence (Pembleton et al. 2015), will limit their use on dairy farms. Furthermore, the growth of the CHIC during the winter months was constrained by the winter dormancy displayed by this species and hence they are unsuitable for regions with cold winters (i.e. Tasmania).

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