Dry matter yield and botanical composition of the ‘MaxClover’ grazing experiment at Lincoln University, Canterbury, New Zealand

2002/03 to 2010/11

PHOTO DIARY

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How this photo diary is structured

This photo diary shows what happened to the yield and botanical composition of six grazed dryland pastures through a combination of graphs, photos and a brief commentary.

General information

The MaxClover Grazing experiment was established at Lincoln University, Canterbury in Feb 2002.

There were six paddocks of each of the six pasture types. This gave 36 individual plots of 0.05 ha each.

Measurements of yield and botanical composition began in Sept 2002 and continued until June 2011.

No Nitrogen fertiliser or irrigation was applied to any pasture over the nine years. Other nutrients (S, P) and lime were applied in response to annual soil tests.

Annual soil test results can be found on the 'MaxClover' page at www.lincoln.ac.nz/dryland

No irrigation was applied. Annual rainfall ranged from 490 to 770 mm and the mean is about 630 mm/yr in this environment.

Rainfall is variable and unpredictable, particularly from September to March when potential evapotranspiration exceeds rainfall leading to the development of soil moisture deficits.

The ‘MaxClover’ Grazing experiment in paddock H19 at Lincoln University

Grazing management

Lucerne was always rotationally grazed.

Grass-based pastures underwent a period of set stocking, short (2-paddock) or intermediate (3-paddock) rotationally grazing in early spring before being rotationally grazed in a six paddock rotation until insufficient feed supply led to destocking of the pastures (drought or low winter temperatures).

Pastures were generally destocked in winter when there was insufficient feed. This simulated a commercial farm system when sheep would be removed to graze winter forage crops or a smaller area of the farm set aside for winter grazing.

For pastures with annual clovers (sub or balansa) stock were removed to allow re-seeding. The timing differed as pastures were closed sequentially as the rotation progressed.

When necessary, ewes were used to hard graze annual clover pastures in early autumn to open the sward in preparation for the germination of annual clover seedlings after autumn rains.

Yield and composition of six dryland pastures over nine growth seasons

- The pastures were sown in autumn 2002. They were:
  - CF/Sub – 4 kg/ha ‘Vision’ cocksfoot + 10 kg/ha ‘Denmark’ subterranean clover
  - CF/Bal – 4 kg/ha ‘Vision’ cocksfoot + 6 kg/ha ‘Bolta’ balansa clover
  - CF/Wc – 4 kg/ha ‘Vision’ cocksfoot + 3 kg/ha ‘Demand’ white clover
  - CF/Cc – 4 kg/ha ‘Vision’ cocksfoot + 8 kg/ha ‘Endura’ Caucasian clover
  - RG/Wc – 10 kg/ha ‘Aries’ HD AR1 perennial ryegrass + 3 kg/ha ‘Demand’ white clover
  - Luc – 8 kg/ha ‘Kaituna’ lucerne monoculture

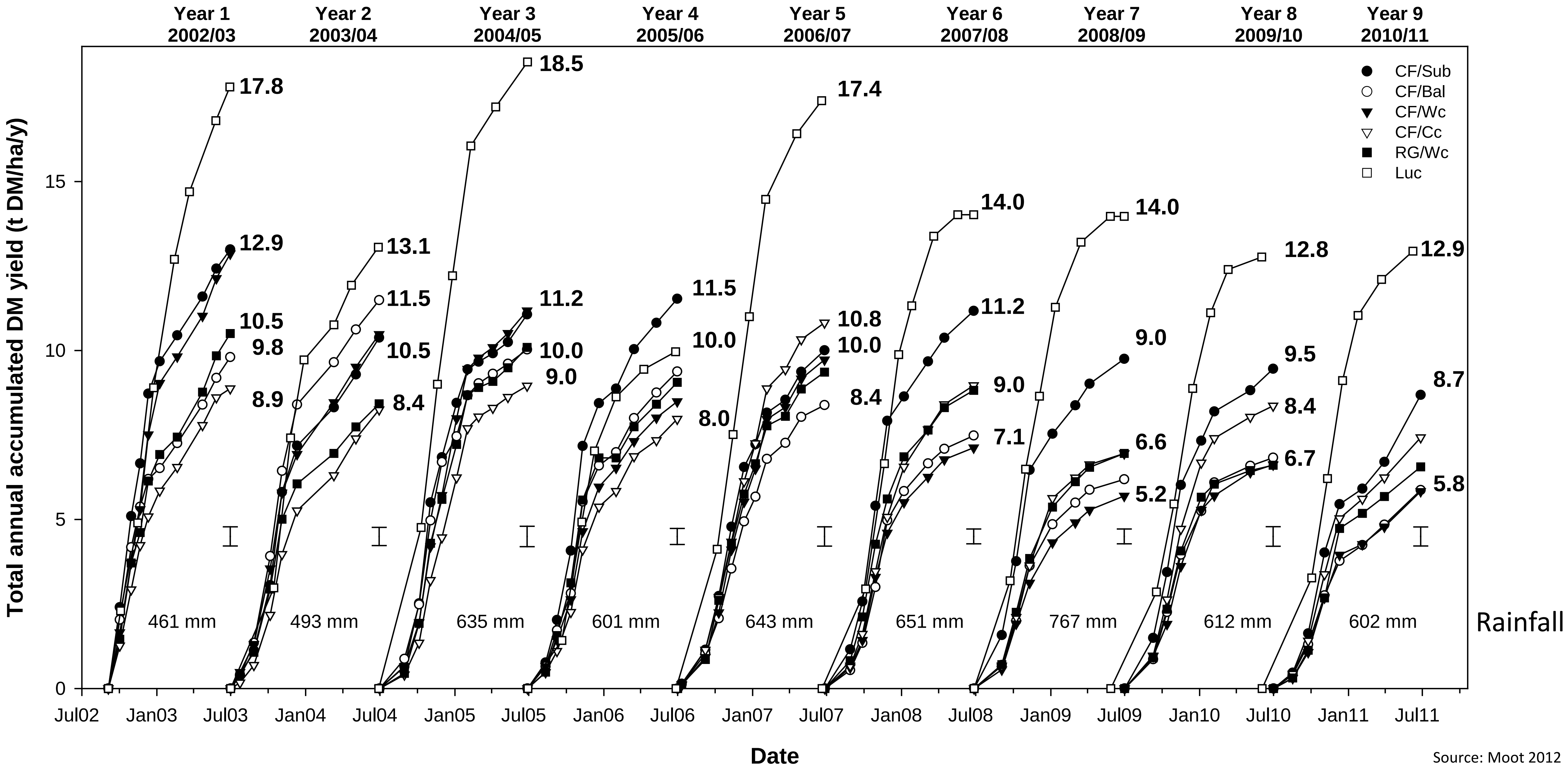
- All clovers and the lucerne were inoculated with the correct peat based inoculants in the 24 hrs prior to sowing.

- A list of scientific publications is on the last slide **(to June 2014)**

Yield and composition of six dryland pastures over nine growth seasons

- Lucerne produced more DM than all grass based pastures in most years.
- Its tap-root enabled access to water from lower soil layers but it also used water more efficiently than the grass based pastures - especially in spring.
- CF/Sub clover was the highest yielding grass based pastures in Years 6-9.
- Yields of all pastures declined over time.

Figure 1. Total annual accumulated dry matter production

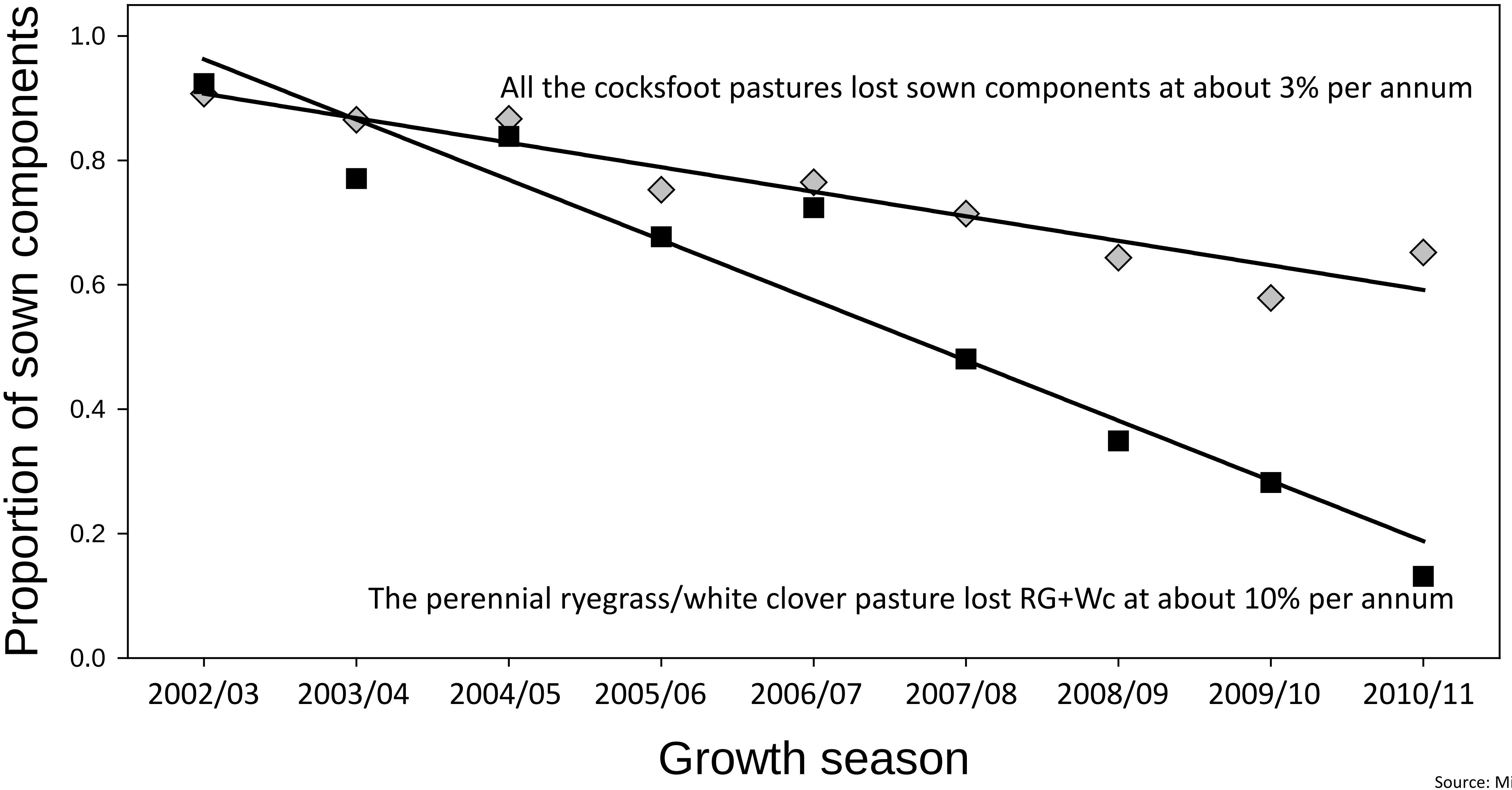


Source: Moot 2012

Summary of yields in Figure 1

- RG/Wc yield declined from 10.5 to 6.6 t/ha in Year 9.
- Lucerne yield was over 17 t/ha in 3 years and 12.9 t/ha in Year 9.
- CF/Sub yield declined from 12 t/ha to 8.7 t/ha in Year 9.
- CF/Wc, CF/Cc, CF/Bal yields were lower than CF/Sub in most years.

Figure 2. Change in the proportion of originally sown pasture components (grass + clover) over time



Source: Mills *et al.*, 2014a

Summary of Figure 2

- After 9 years about 10% of the RG/Wc pasture was from originally sown species compared with about 60% in the cocksfoot based pastures. Lucerne (not shown) was about 85% pure due to winter weed control.
- In Years 1-3 the RG/Wc pastures maintained a high proportion of ryegrass and white clover. Most experiments only run for 3 years – this long-term experiment shows how this pasture deteriorated from Year 4 to Year 9.
- By Year 5-6 only about half the yield in RG/Wc pastures is from the sown species. Ideally pasture renewal would be recommended at this point.
- By Year 9 only about 10% of the 6.6 t DM/ha that was produced was from RG or Wc.
- For cocksfoot sown pasture species decreased by about 3% per year. This meant after 9 years about 60% of the total yield produced by the four cocksfoot based pastures was from the originally sown pasture species.
- Cocksfoot was persistent but pasture vigour had declined. These pastures did not require renovation but had the potential for increased production by overdrilling in autumn with 10 kg/ha sub plus 1 kg/ha white clover to increase clover content and nitrogen fertility which would stimulate production from the existing cocksfoot component.

Perennial ryegrass/white clover pastures

White clover in flower – Lees Valley, Canterbury.
Photo: Dr K.M. Pollock

- This section details the changes in yield and composition of the grazed perennial ryegrass/white clover pastures.
- Photos are included to show the condition of the pastures over time.

Perennial ryegrass/white clover pastures

Introduction…

- Perennial ryegrass and white clover pastures have formed the basis of New Zealand's successful grass fed pastoral agriculture systems since white clover breeding began in the 1920’s. There is substantial investment in breeding new white clover and perennial ryegrass cultivars relative to other permanent pasture species.
- It‘s ability to produce high yields of quality feed led to its recommendation as the primary pasture for pastoral areas throughout New Zealand.
- The mix is easily managed and performs well in suitable environments.
- However, it fails to thrive and persist in dryland drought prone areas.
- White clover loses its taproot at about 18 months after sowing and relies on a fibrous adventitious root system.

Production by RG/Wc pastures over 9 years

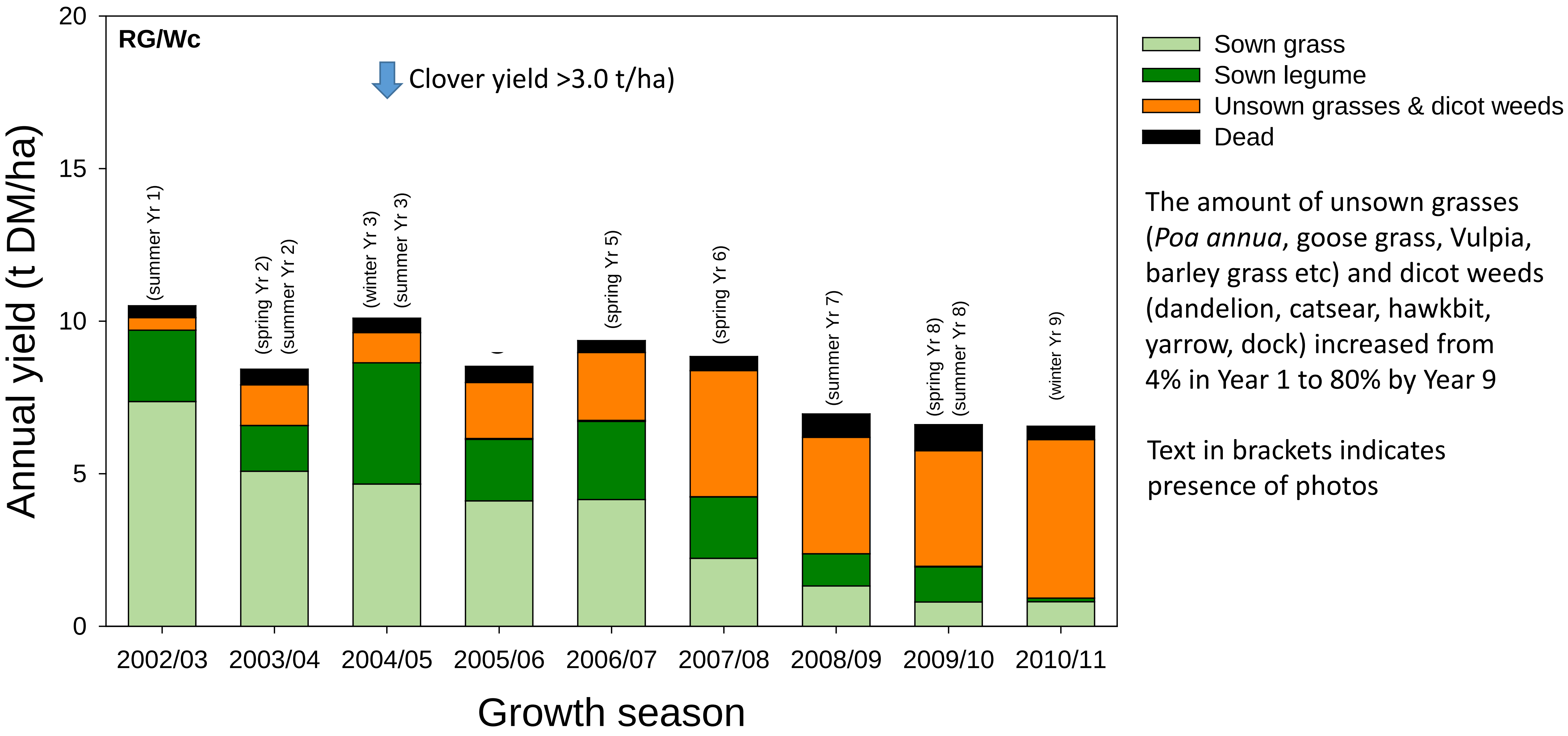
- Annual yield was highest in Year 1 (10.5 t DM/ha) and lowest in Year 9 (6.6 t DM/ha).

- Low yield and white clover content in Year 2 was due to drought conditions. December rainfall was only 1 mm compared to the long-term mean of about 50 mm/month.

- In Year 3 white clover yield was almost 4 t/ha (blue arrow). This was the highest white clover yield from the RG/Wc pasture over the nine years and the only year clover yield was >3.0 t/ha. December rainfall was 132 mm compared with the average of 50 mm/month.

- By Year 9 only about 10% of all the yield produced was from the originally sown RG and Wc.

Figure 3. RG/Wc – Annual Botanical composition



The amount of unsown grasses (*Poa annua*, goose grass, Vulpia, barley grass etc) and dicot weeds (dandelion, catsear, hawkbit, yarrow, dock) increased from 4% in Year 1 to 80% by Year 9

Text in brackets indicates presence of photos

Summary of Figure 3

- The combination of the timing and duration of periodic water stress and rooting depth of the pasture resulted in a recommended time to renewal of **5 years** for RG/Wc pastures based on the invasion of unsown species.

- In most cases experiments which measure pasture performance are only funded for a period of 3 years. However, farmers expect their perennial pastures to produce and persist for 10 years or longer to be cost effective. This long-term experiment shows that in periodically water stressed dryland environments recommendations based on 3 years of data (which show satisfactory yield and composition) would not meet farmer requirements for a productive and persistent pasture.

- The loss of both ryegrass and white clover meant there was no opportunity to salvage the pasture by overdrilling.

Yr 1 Summer
(Feb 2003)
RG/Wc

The pasture is about 1 year old and drill rows are still obvious.
The pasture was exposed to drought conditions with summer rainfall (80 mm) only about half of what would fall in an average year.

Yr 2 Spring
(Aug 2003)
RG/Wc

The RG/Wc pasture is about 18 months old in this photo and drill rows are less obvious but still visible.
The pasture has recovered from summer drought conditions shown in the previous photo.

Yr 2 Spring
(Aug 2003)
RG/Wc

Yr 2 Spring
(Aug 2003)
CF/Bal

This photo was taken on the same day as the previous photo and shows a side-by-side comparison of the early spring yields in Plot 4 (RG/Wc on the left) and Plot 3 (CF/Bal on the right). (Note: The CF/Bal pasture was the highest yielding grass based pasture in Year 2).

Yr 2 Summer
(Jan 2004)
RG/Wc

This is Plot 4 in mid summer. Year 2 had the lowest summer rainfall of all nine years (66 mm) with only 1.2 mm falling in December 2003.

The quadrat in the photo has an area 0.1 m^2. The dry summer meant white clover failed to perform.

At this stage the white clover was about 2 years old and had likely lost its seminal taproot.

Yr 3 Winter
(Jul 2004)
RG/Wc

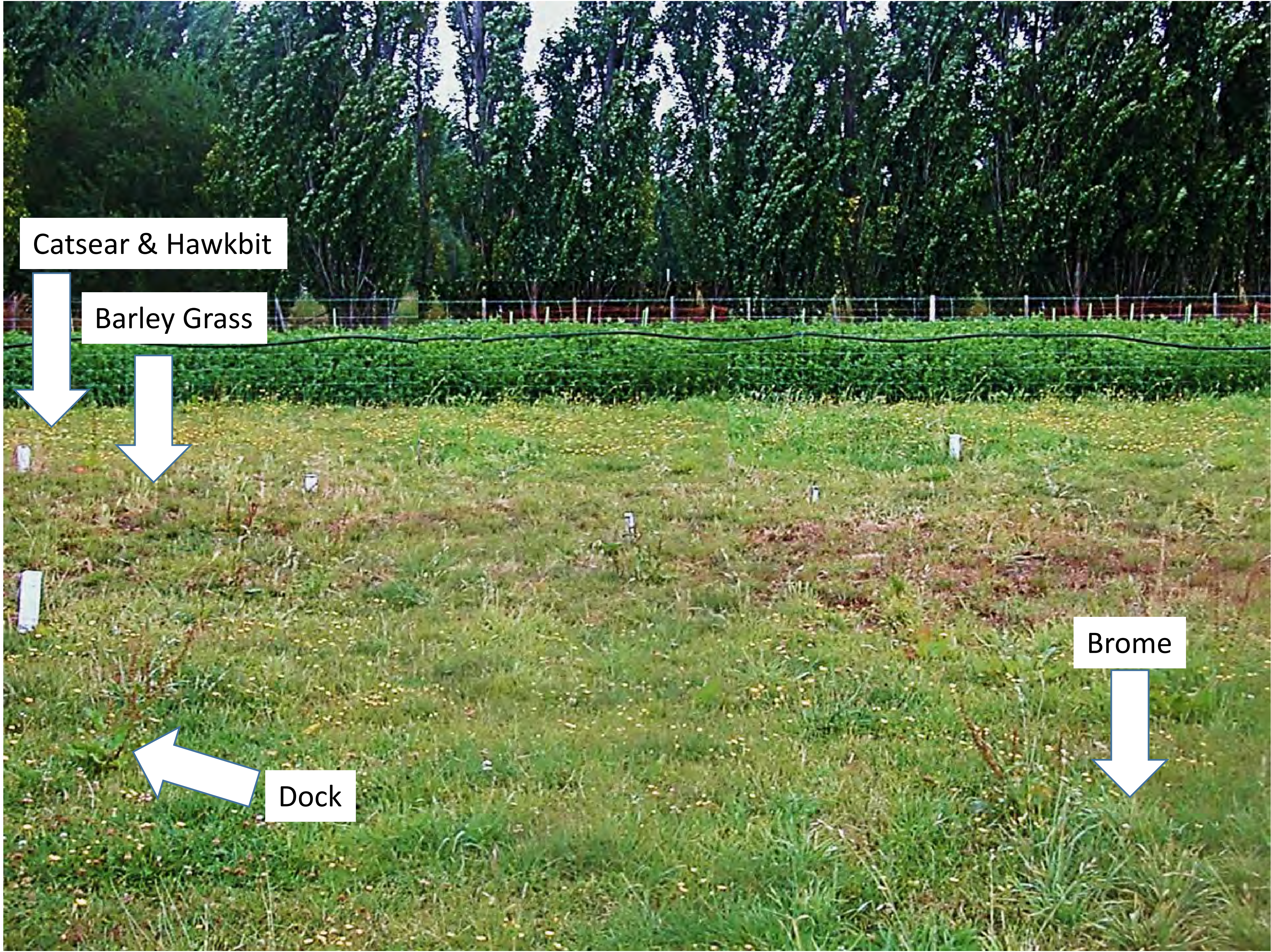
Although the pasture has recovered from summer drought conditions drill rows remain visible and arrows show invasion of some dicot weeds into areas within and between drill rows.

Yr 3 Summer
(Feb 2005)
RG/Wc

This shows a comparison of RG/Wc in Plot 13 in foreground with the pre-graze lucerne in Plot 19 Luc in background.

At this point perennial weed species have already started to invade the RG/Wc pasture even though annual rainfall was about average and summer rainfall almost 29% about average (180 mm).

The wet summer benefitted the white clover which has its main production period in the warmer summer months.



Yr 5 Spring
(Aug 2006)
RG/Wc

The shiny perennial ryegrass leaves can still be seen in the background but clumpy unsown brome grasses in the foreground are now clearly visible in early spring.

Little white clover can be seen at this time of year.

Yr 5 Spring
(Sept 2006)
RG/Wc

By mid September the yield of the ryegrass and white clover has increased compared with the photo in August on the previous slide.

The pasture shows evidence of nitrogen deficiency with clumpy higher yielding areas on old urine patches.

Yr 5 Spring
(Nov 2006)
RG/Wc

Two months later the perennial ryegrass has gone reproductive with seedheads visible or reproductive stems elongating.

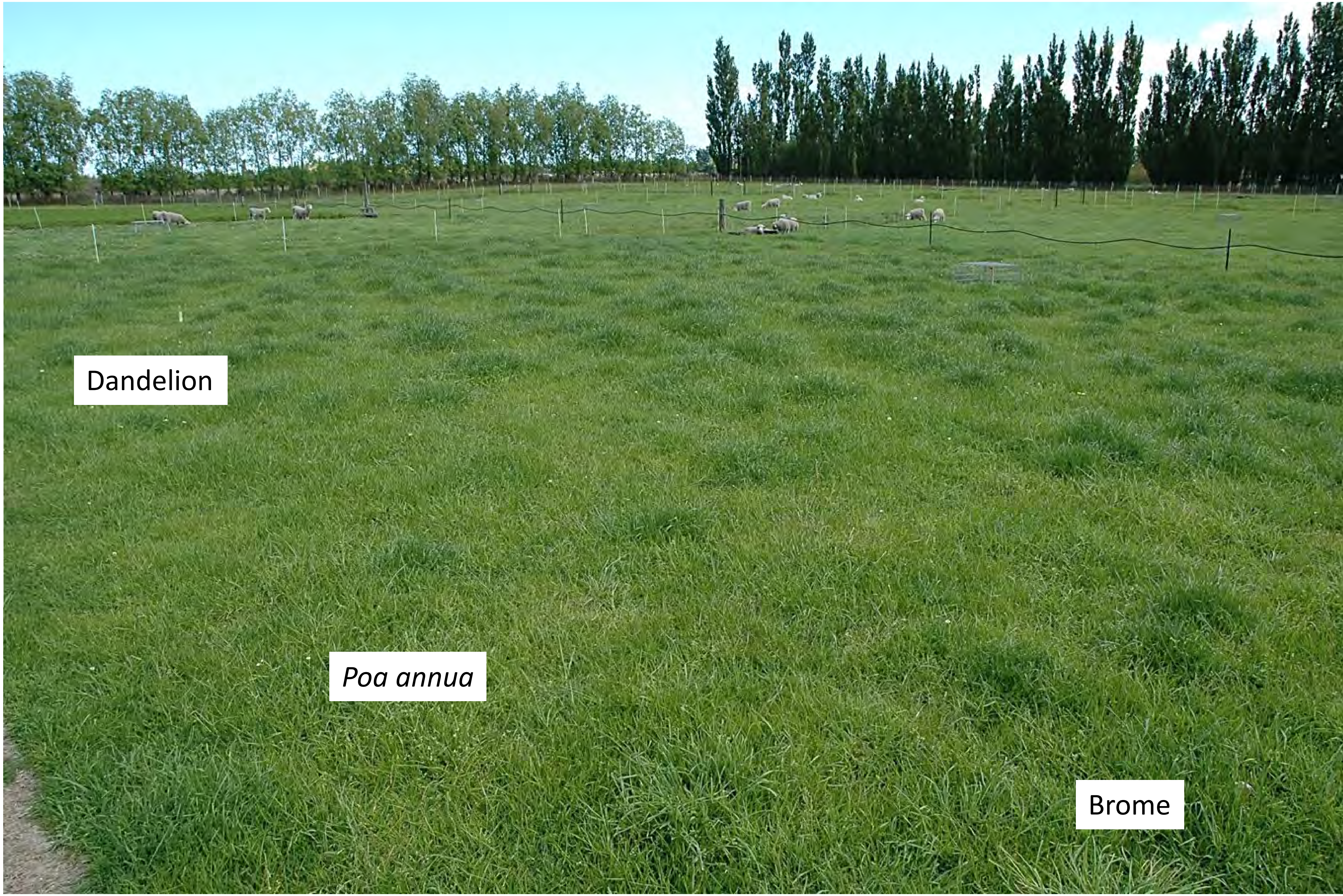
The pasture is pale green and looks visibly N deficient with a build up of dead material in the base.

Yr 6 Spring (Nov 2007) RG/Wc

Obvious N deficiency symptoms in areas between the numerous urine patches are visible.

Yellow dandelion flower sporadically visible in midground with patches of clumpy brome and reproductive *Poa annua* in foreground.

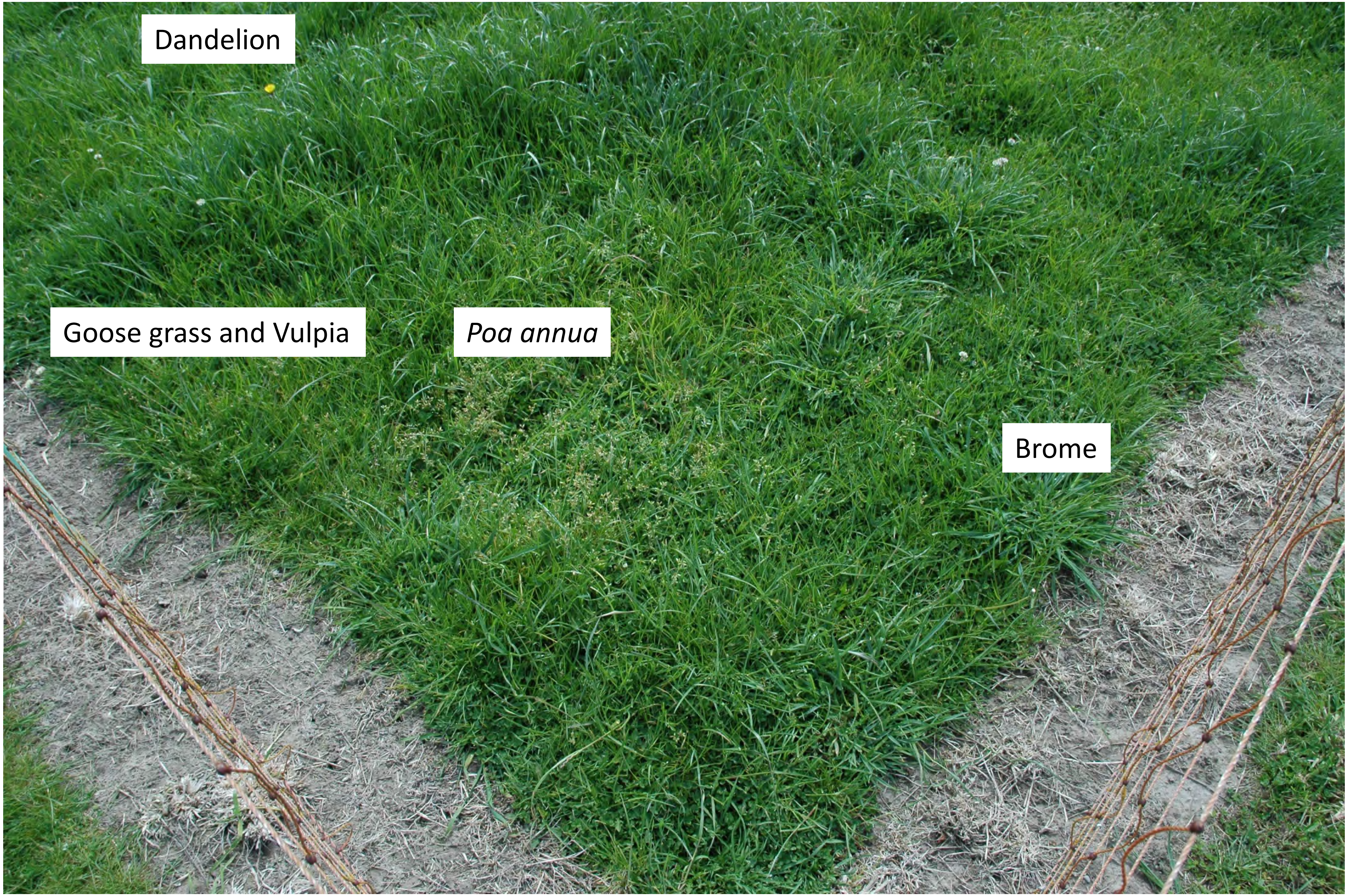
Commercially, an early spring application of 50 kg N/ha could have alleviated N deficiency and increased yield. (No N was applied here.)



Yr 6 Spring
(Nov 2007)
RG/Wc

This is a close-up of the previous photo taken in Plot 4.

The shiny perennial ryegrass leaves are at the top of the image all other (non shiny) grass leaves are invaders.



Yr 7 Summer (Dec 2008) RG/Wc

RG/Wc pasture in Plot 11. This year was the wettest of the nine years (780 mm compared to the long term average of 630) and the dying barley grass seedheads show the extent of the invasion into the RG/Wc pastures by Year 7.

This material has also been rejected by grazing sheep as seen from the lower grazed area in the foreground.

Yr 7 Summer
(Jan 2009)
RG/Wc

This was taken in Plot 21 about 1 month later than the previous photo.

Summer rainfall was about 30% above average and green material is visible beneath the dead reproductive stems.

Few of these appear to be from perennial ryegrass. Yellow flowers of the perennial flatweed catsear (arrows) can be seen throughout the pasture.

Yr 8 Spring
(Sept 2009)
RG/Wc

By spring of Year 8 the perennial rhizomatous weed yarrow is present.

This is now problematic for pasture renewal because, if cultivated, chunks of the yarrow root can form individual new plants and contaminate newly sown crops or pastures.

In this case the extent of the invasion and the type of weeds present mean the renewal phase may need to be extended to ensure adequate weed control before a new pasture can be established.

Ryegrass is not visible.

Yr 8 Summer (Dec 2009) RG/Wc

Summer rainfall was about 30% below average and the sheep grazing in the background continue to avoid the less palatable dying seedheads of the invading grasses.

There is no evidence of perennial ryegrass seedheads in this image.

Much of the green material is goose grass, *Vulpia* and *Poa annua.*

Yr 9 Winter (Jun 2011) RG/Wc

This is what a RG/Wc clover pasture looks like at the end of nine years in a grazed experiment in a periodically water stressed environment.

There is no evidence of any perennial ryegrass and few white clover leaves.

The majority of the unsown grasses will remain palatable to grazing stock – until they become reproductive or die.

However, stock grazing these pastures (or wind dispersal) could hasten the deterioration of other pastures on a farm by transferring the seeds of these species into other pastures on farm during the course of a rotation.

Cocksfoot/Subterranean clover pastures

This section describes the production and persistence of the CF/Sub pastures from Year 1 (2002/03) to Year 9 (2010/11) through a combination of measured data and photos.

Sub clover…

An annual clover, sub germinates from seed in autumn before growing slowly through winter. Its main production period is Sept-Oct before it flowers, sets seed then buries it and dies. This mechanism is known as **drought avoidance**. The plant survives by avoiding the drought period and regenerating from buried seed in open areas of the pasture following autumn rains.

When the plant dies **nitrogen** is released into the soil as the plant material breaks down and this becomes available to the cocksfoot. Nitrogen is also directly transferred to the other pasture components in urine returns from grazing stock. Sub clover fixes about 25 kg N per ton of clover DM produced – the higher the clover yield the more N enters the system to alleviate N deficiency symptoms in the grass.

To maintain sub clover in the pasture an early close up at 3-4 year intervals will allow the maximum amount of seed to set and replenish the seed bank.

'Antas' sub clover leaf – Mt Benger, North Canterbury
Photo: RJ Lucas

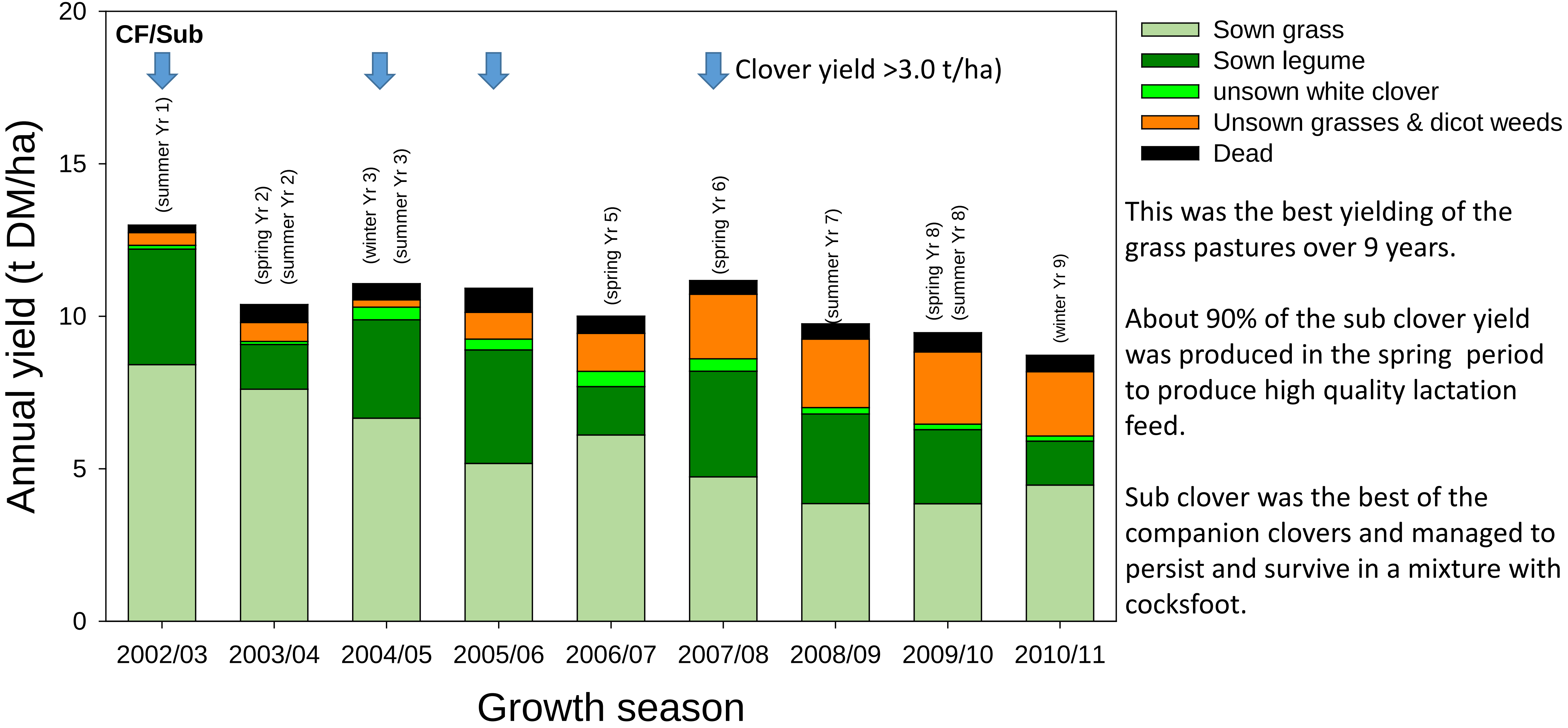
Cocksfoot/Subterranean clover pastures

Total yields ranged from 13.0 t/ha (Year 1) to 8.7 t/ha (Year 9).

By Year 9, 67% of the total yield was from the originally sown species.

In four of the nine years the sub clover yield was >3.0 t/ha (blue arrows).

Figure 4. CF/Sub – Annual Botanical composition



This was the best yielding of the grass pastures over 9 years.

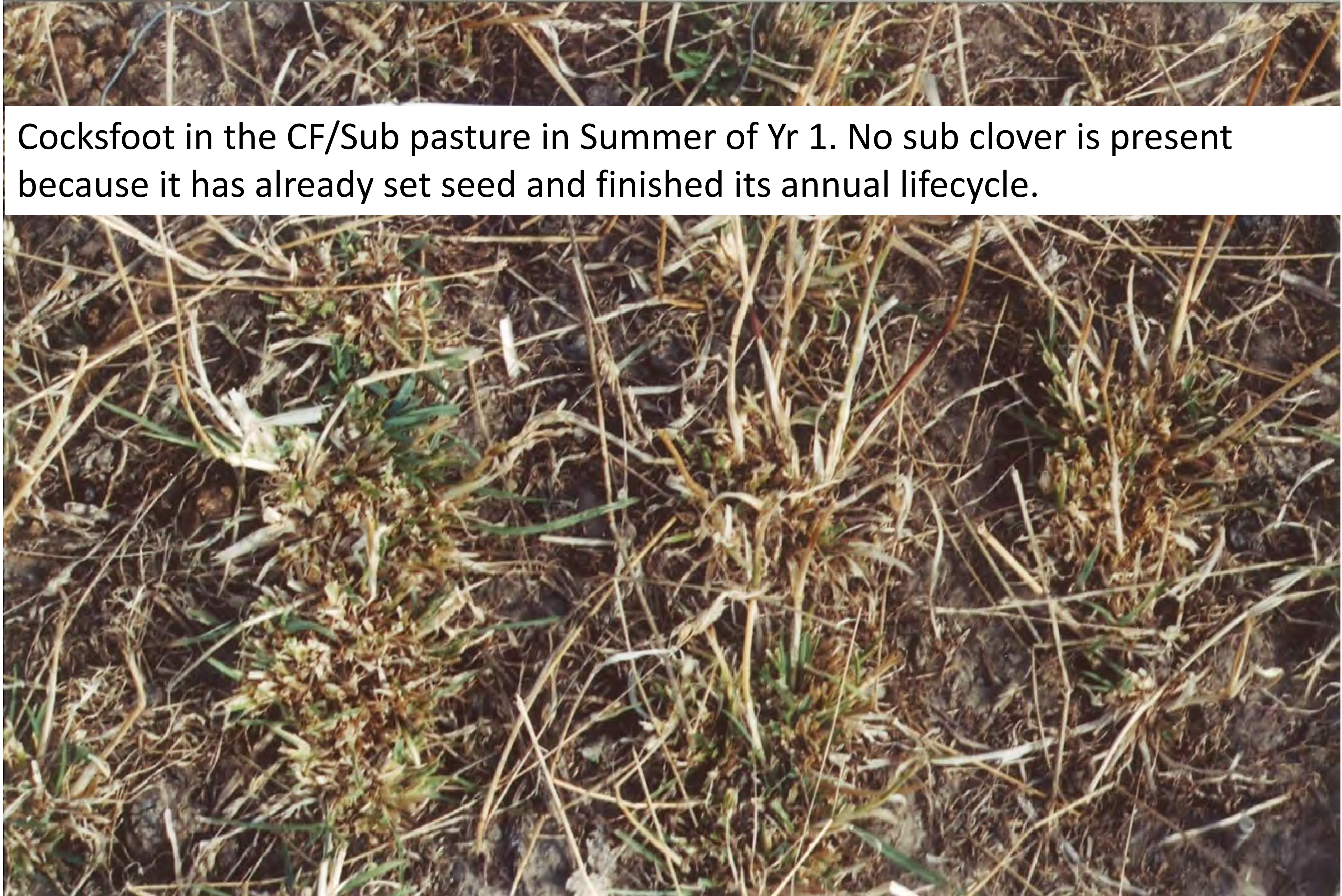
About 90% of the sub clover yield was produced in the spring period to produce high quality lactation feed.

Sub clover was the best of the companion clovers and managed to persist and survive in a mixture with cocksfoot.

Summary of Figure 4

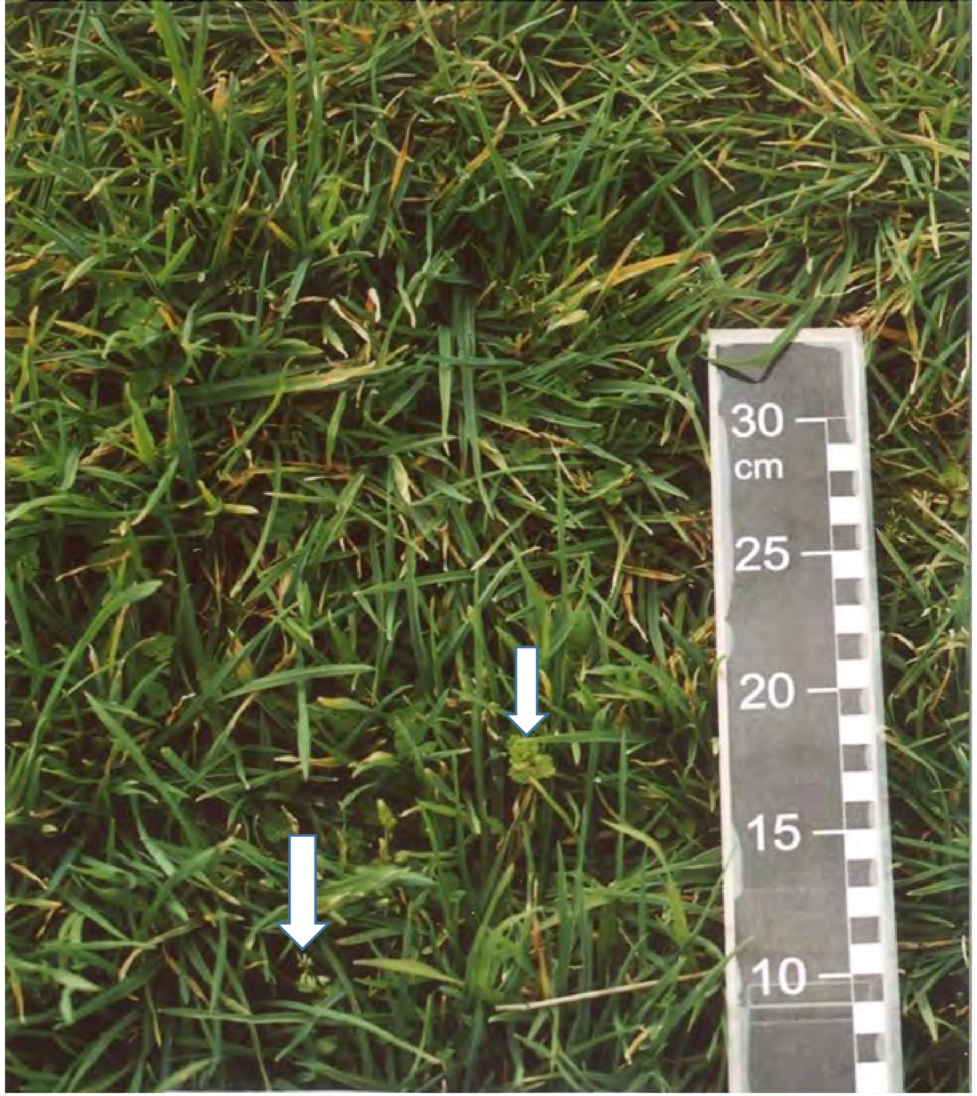
- The CF/Sub pasture was the most productive and persistent of the grass-based pastures monitored over nine years.
- As with all pastures the total yield declined over time. However, the persistence of the cocksfoot and sub clover meant there was no need to renew the pastures at the end of the experiment.
- These pastures could be overdrilled with 10 kg/ha sub clover plus 1 kg/ha white clover into a hard grazed pasture in autumn. This would stimulate total pasture production by increasing clover content and subsequent N transfer to the cocksfoot component. We recommend 5 kg/ha each of a mid and late flowering sub clover in this environment to allow for year-to-year variation in rainfall. White clover can contribute when summer rainfall allows.
- Previous research a Ashley Dene has shown overdrilling into grass dominant dryland pastures with sub clover can increase DM production by 40% annually and costs are reduced because full renovation is not necessary.

Yr 1 Summer
(Feb 2003)
CF/Sub

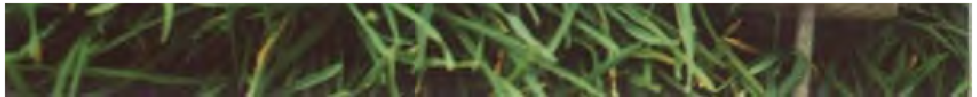


Cocksfoot in the CF/Sub pasture in Summer of Yr 1. No sub clover is present because it has already set seed and finished its annual lifecycle.

Yr 2 Spring
(Aug 2003)
CF/Sub



In contrast to the 18 month old RG/Wc pasture there drill rows are not visible in the CF/Sub pasture in early spring of Yr 2. Little sub clover is visible - this is normal for the first natural reseeding after a sub clover pasture is established because the plant produces a lot of hardseed.
A little of the annual weeds speedwell and *Poa annua* has infiltrated (by the arrows)



Yr 2 Summer
(Jan 2004)
CF/Sub

In the driest summer, a bit of cocksfoot remains green in the CF/Sub pasture compared with the RG/Wc pasture where only a bit of white clover remained green at this time of year. The quadrat is 0.1 m^2.

Yr 3 Winter
(Jul 2004)
CF/Sub

Note the presence of young sub clover plants in winter (following the 2nd natural reseeding – seed produced in the first year has softened enough to germinate following autumn rains).

Sub clover has expanded from the drill rows and has begun to exploit the areas between drill rows.

Total sub clover yield from these plants was >3.2 t DM/ha in Year 3.

Yr 3 Summer
(Feb 2005)
CF/Sub

CF/Sub in Summer 2005.

Note the lack of sub clover (its lifecycle has ended) and although the stems of the cocksfoot seedheads remain the underlying pasture has been decked by grazing sheep and the majority of seedheads at the tip of the stems have been eaten.

Yr 5 Spring
(Aug 2006)
CF/Sub

Little sub clover appears visible in early spring. Sub clover yielded 1.5 t/ha which was less than half of the previous two springs (3.2 and 3.7 t sub clover/ha).

To maintain sub clover an early close up at 3-4 year intervals will replenish the seedbank.

Close paddocks with low plant populations (evaluate in winter) and graze the sub clover pastures with higher populations of sub clover. Put paddocks on an early close up rotation based on what you see.

Yr 5 Spring
(Sept 2006)
CF/Sub

1 month later –
this CF/Sub pasture is cocksfoot dominant which is not ideal high quality lactation feed for priority stock.

Yr 5 Spring (Nov 2006) CF/Sub

2 months later.

Cocksfoot has started producing seedheads and is visibly N deficient and clumpy.

Nitrogen deficient cocksfoot has lower grazing preference than cocksfoot with adequate N levels (e.g. circled urine patches). Maintaining high clover content allows nitrogen transfer to the grass either through urine returns or from the breakdown of dying annual clover plant.

It is now Year 5 and few if any weeds are visible.

Yr 6 Spring
(Nov 2007)
CF/Sub

In Year 6 sub clover will contribute 3.2 t clover/DM to the annual yield – good for a species which is only alive for about 9 months of the year.

This pasture produced 2.8 t total DM/ha between 27 Sept and 29 Oct.

In this rotation almost 50% of the feed on offer was high quality sub clover.

Yr 6 Spring
(Nov 2007)
CF/Sub

A close up of the pasture in the previous photo.

Yr 7 Summer
(Jan 2009)
CF/Sub

CF/Sub pasture in Plot 24 (Rep 4).

Note the presence of bare ground following the end of the sub clover life cycle and the invasion of dicot flatweeds in the foreground (arrows).

Yr 8 Spring (Sept 2009) CF/Sub

CF/Sub pasture in Plot 5.

In Yr 8 the 2.4 t/ha of yield contributed by sub clover was more than double the clover yield produced from any other grass based pasture.

For the spring period (to 16 Nov 2009) about 40% of the DM yield on offer was sub clover.

Yr 8 Summer (Dec 2009) CF/Sub

Bare ground is visible following the end of the sub clover lifecycle.

A few barley grass seedheads are visible but it remains a minor component **of** the pasture compared with the level of invasion observed in the RG/Wc pastures of the same age.

It is important to **hard graze prior to autumn rainfall** to open these bare ground patches for small germinating clover seedlings. Rank, leafy grass pastures will shade out small establishing clover plants and they will not survive.

Yr 9 Winter
(Jun 2011)
CF/Sub

This is a CF/Sub clover pasture nine years after establishment.

Cocksfoot remains a major component of the pasture and sub clover can be seen in the base of the sward.

In six of the nine years sub clover contributed 26-32% of all DM produce on an annual basis.

Overdrilling with sub clover in autumn will rejuvenate the pastures and increase total annual production.

Cocksfoot/Balansa clover pastures

This section describes the production and persistence of the CF/Bal pastures.

Balansa clover…

Balansa clover is an autumn germinating annual clover which, like sub clover, survives periods of drought by drought avoidance. However, balansa clover is a top flowering annual which means grazing management during the reproductive phase is critical to ensuring seed is set and replenishes the seedbank. Ideally, an early close-up is required at 3-4 year intervals.

Lincoln University has been investigating balansa for about 15 years but have yet to achieve long-term success with it as a productive and persistent component of a permanent pasture.

Balansa clover monoculture in flower at Lincoln
Photo: A.Mills

Cocksfoot/Balansa clover pastures

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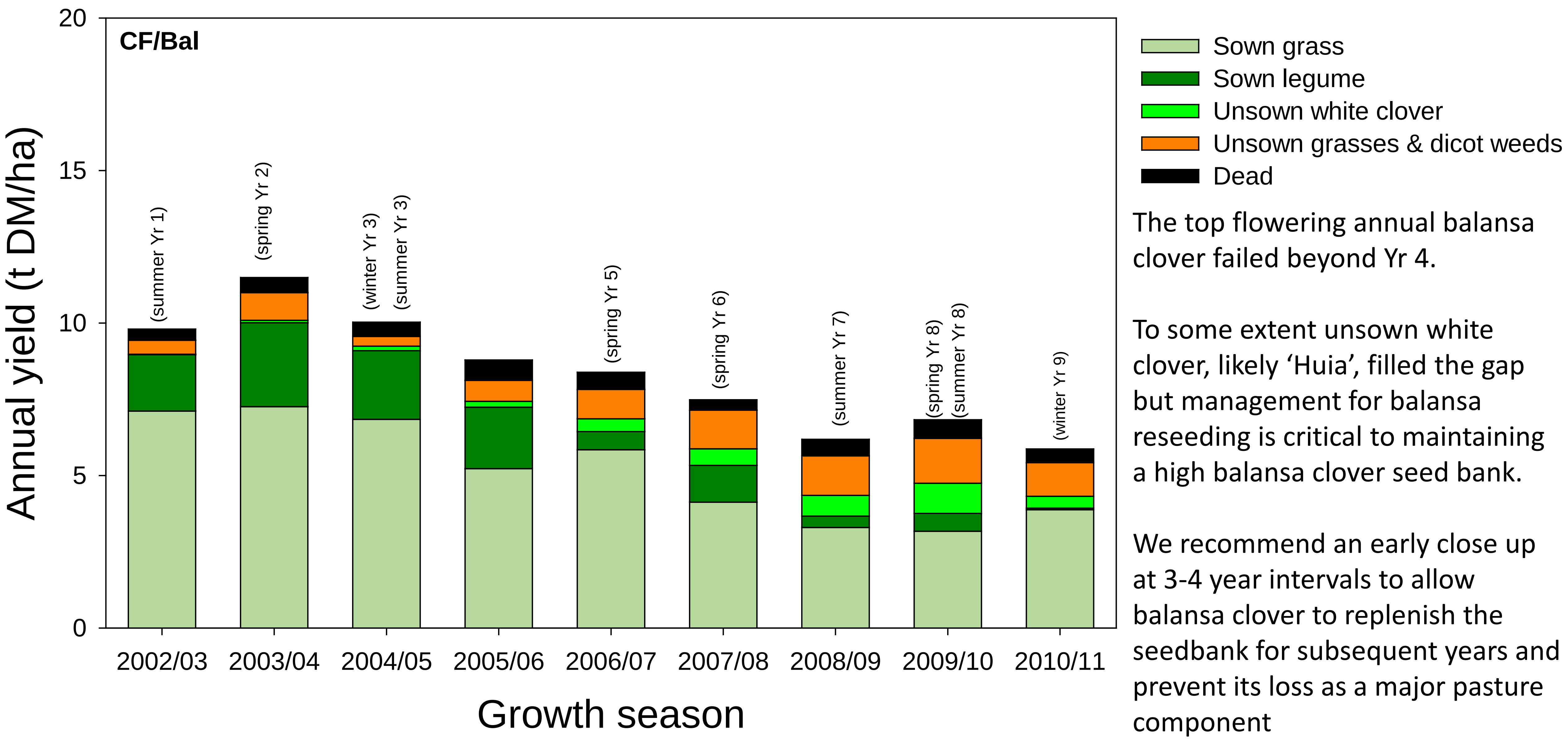
Total yields ranged from 11.5 t/ha (Year 2) to 5.9 t/ha (Year 9).

Balansa clover yields were 1.9 -2.7 t/ha in the first four years but then declined with only 54 kg/ha produced in Year 9.

Volunteer (unsown) white clover contributions increased to compensate for the loss of balansa after Year 4 but it was insufficient to prevent the loss of pasture vigour.

Figure 5. CF/Bal – Annual Botanical composition



The top flowering annual balansa clover failed beyond Yr 4.

To some extent unsown white clover, likely 'Huia', filled the gap but management for balansa reseeding is critical to maintaining a high balansa clover seed bank.

We recommend an early close up at 3-4 year intervals to allow balansa clover to replenish the seedbank for subsequent years and prevent its loss as a major pasture component

Summary of Figure 5

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- CF/Bal pastures were less successful than the CF/Sub mix in most years mainly due to loss of balansa clover beyond Year 4 and reduced the vigour of the pasture in Years 5-9.

- Balansa clover requires an early close up at 3-4 year intervals to ensure it can re-seed and replenish the depleted seedbank. This did not happen here and it could have increased the production and persistence of this mix over time.

- Ideally, due to the loss of the balansa this pasture should over been overdrilled with clover in autumn of Year 4 to rejuvenate the pasture and stimulate total pasture production in subsequent years.

- The persistence of the cocksfoot offered opportunity to extend the life of the pasture without going through a full pasture renewal phase. Overdrilling with 10 kg/ha sub clover plus 1 kg/ha white clover into a hard grazed pasture in autumn would extend stand life and alleviate N deficiency in the cocksfoot.

Yr 1 Summer
(Feb 2003)
CF/Bal

CF/Bal pasture in summer of Yr 1. Note the high amount of dead material remaining due to closeup for reseeding and creating a seedbank for future years. Arrows show some balansa clover seeds which have fallen on the soil surface (in contrast to sub clover which buries its seed in the soil)

Yr 2 Spring
(Aug 2003)
CF/Bal

Balansa regenerated well from the first natural reseeding and contributed 2.8 t of DM, or 24% of all the DM produced by the CF/Bal pasture in Yr 2.

For the spring period there was 32% balansa clover on offer in the CF/Bal pasture compared with about 20% sown clover in the CF/Sub and RG/Wc pastures.

Yr 2 Spring
(Aug 2003)
CF/Bal

Close up of the pasture in the previous photo. The balansa clover seedlings have germinated following autumn rain and filled in the drill rows.

Yr 3 Winter
(Jul 2004)
CF/Bal

22% of all DM produced in Yr 3 was from balansa clover (2.3 t DM/ha) but this was less than the 3.9 t/ha white clover yielded in the RG/Wc pasture or the 3.2 t/ha of sub clover produced by the CF/Sub pasture.

Note the lack of weed species.

Yr 3 Summer
(Feb 2005)
CF/Bal

CF/Bal in Plot 3 (Rep 1).

Note the reproductive stems of the cocksfoot remain ungrazed and the lack of balansa clover (as it’s lifecycle has ended).

Also note the green, vegetative pre-grazing yield of the lucerne in the background (Plot 17).

Yr 5 Spring (Aug 2006) CF/Bal

In Year 5 balansa clover only contributed 7% of the total annual DM yield in the CF/Bal pasture.

For the spring period only 0.4 t balansa clover was produced meaning lactation feed was 8.5% balansa clover.

The cocksfoot remains the major pasture component at Yr 5.

A bit of the spring annual weed speedwell can be seen in flower (arrow).

Yr 5 Spring (Sept 2006) CF/Bal

I month later.

The balansa clover is easier to see but the low population means spring feed on offer remains cocksfoot dominant.

50 kg N/ha could have been applied to stimulate pasture production given low clover content.

More dead material can be seen and there is evidence of leaf disease on the cocksfoot (arrow).

A chickweed plant is visible (arrow) but there is little evidence of other invading species.

Yr 5 Spring
(Nov 2006)
CF/Bal

2 months later.

Balansa clover has entered the reproductive phase and its priority now is to set seed.

However, the low initial population means few flowers are visible (foreground and by arrow) and with the depletion of the seed bank balansa clover content will decline as a pasture component over the next 4 years.

Yr 6 Spring (Nov 2007) CF/Bal

Balansa clover yield was about 1.2 t/ha – about double that produced in Year 5 but less than the 3.5 t/ha the sub clover produced in Yr 6.

Flowers indicate patchy distribution throughout the pasture.

Urine patches (e.g. circled areas) are obvious and indicate nitrogen deficiency symptoms in the cocksfoot.

No obvious presence of invading weed species at this time.

Yr 6 Spring
(Nov 2007)
CF/Bal

Close up of the pasture in the previous photo.

About 1/3 of the total clover yield in Yr 6 was from volunteer white clover (most likely ‘Huia’).

Note the clumpy and patchy clover distribution (arrows).

Yr 7 Summer
(Jan 2009)
CF/Bal

CF/Bal pasture in Plot 23 (Rep 4).

Urine patches are visible in the cocksfoot (e.g. circles).

Although balansa has completed its lifecycle and is not present it yielded only 0.4 t/ha in Yr 7 – but volunteer white clover filled the gap and contributed 0.8 t DM/ha.

The yellow flowers of catsear and hawkbit flatweeds can be seen in the foreground (arrow).

Yr 8 Spring (Sept 2009) CF/Bal

CF/Bal in Plot 8.

Cocksfoot and balansa and (unsown) white clover dominate in early spring.

In Year 8 balansa clover yielded 0.6 t DM/ha or 9% of total annual DM yield from the CF/Bal pasture. In contrast sub clover in the CF/Sub pasture yielded 2.4 t/ha and white clover was about 1.1 t/ha (CF/Wc and RG/Wc pastures).

The volunteer white clover yield in the CF/Bal pasture was also about 1 t DM/ha in Yr 8.

Yr 8 Summer
(Dec 2009)
CF/Bal

Dark green urine patches visible (e.g. circles) in cocksfoot clumps indicate severe N deficiency symptoms.

Some yellow hawkbit flowers in foreground (arrow) and senescing balansa clover flowers.

Flowers which remain white are likely to be the unsown white clover plants which contributed about two thirds of total clover yield in Yr 8.

Yr 9 Winter
(Jun 2011)
CF/Bal

In the final year (2010/11) cocksfoot accounted for 66% of the total yield of 6.5 t DM/ha.

Balansa clover yielded only 53 kg DM/ha and volunteer white clover contributed about 0.4 t DM/ha.

This pasture does not require a complete renewal as cocksfoot is still at an adequate level.

We would recommend a hard graze in autumn and 10 kg/ha of sub clover + 1 kg/ha of white clover was overdrilled to reinvigorate the pasture and increase nitrogen transfer from the clover to the N deficient cocksfoot.

Cocksfoot/White clover pastures

Yield data and photos are used to document the performance of the cocksfoot/white clover pastures in this section.

Cocksfoot…

Dryland pasture mixes often contain cocksfoot and white clover. The cocksfoot is persistent under dryland conditions but is “aggressive” towards companion legumes. More specifically, cocksfoot outcompetes other species in mixtures when the species have the same peak growth periods and are in direct competition for water, light and nutrients at the same time.

One of the reasons RG/Wc mixes are so successful (in the right environment) is because their peak growth periods are offset (RG in spring and again in autumn and Wc peaks in summer).

Both CF and Wc are summer active – the only way the mix can succeed is if there is no limitation of water, light or nutrients. As soon as a resource becomes limiting and competition begins one species will lose. The root system of white clover (after it loses is taproot) has less surface area than cocksfoot. Because the CF has more root surface area it can explore and capture more resources within the root zone than white clover.

Cocksfoot at ‘MaxClover’

Cocksfoot/White clover pastures

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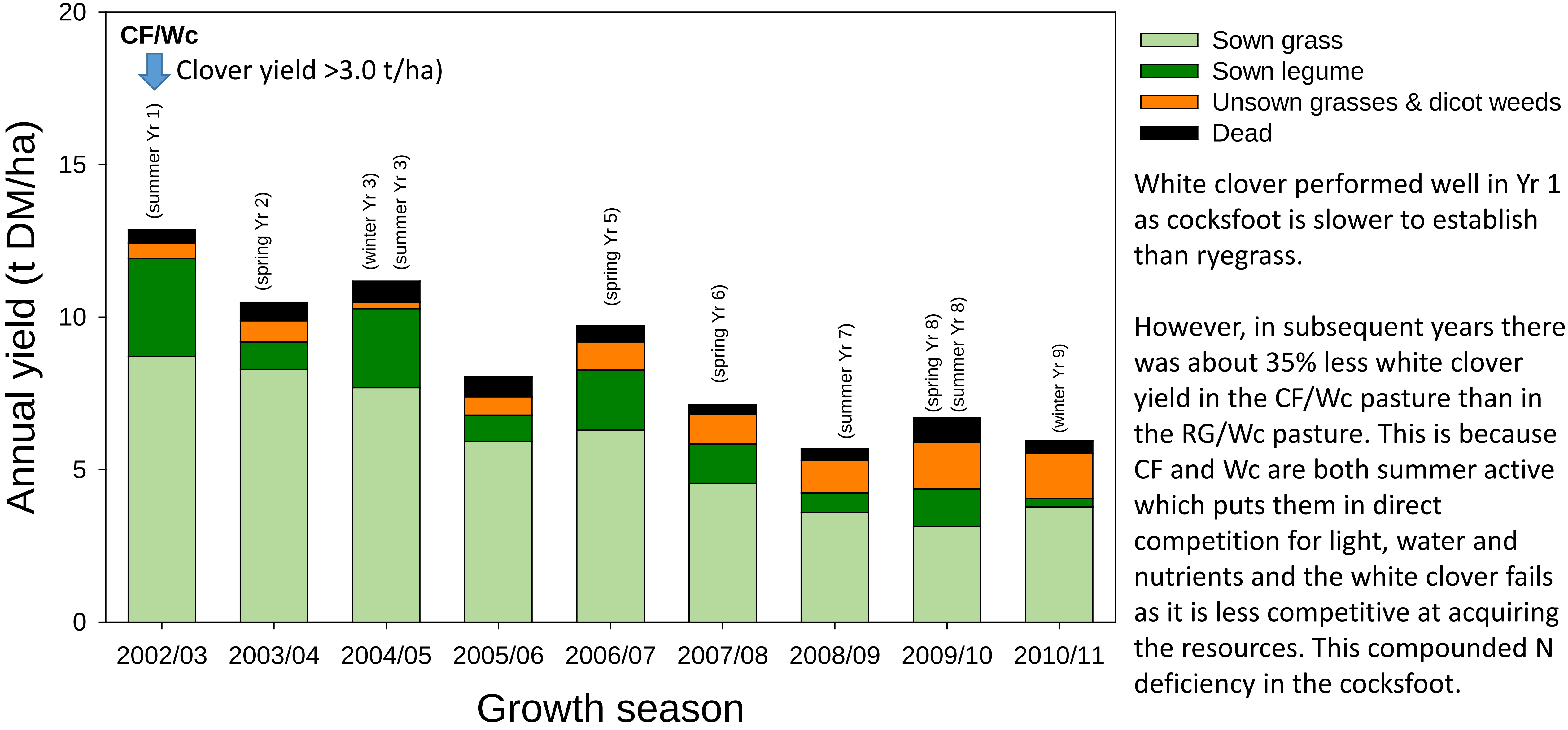
Yields ranged from 10.5 t/ha (Year 1) to 5.6 t/ha (Years 7 and 9)

Cocksfoot is slow to establish which benefited white clover in Year 1 . This was the only year clover yield exceeded 3 t/ha. White clover performed well in Year 3 which had a wet summer (2.5 t white clover/ha) but generally failed to perform in subsequent years and produced yields between 0.3 and 1.1 t/ha in five of the nine years.

Weed invasion was limited and 68% of the total yield produced was from originally sown pasture species (mainly cocksfoot) in Year 9.

Dryland white clover in flower – Lees Valley, Canterbury
Photo: V. Fasi

Figure 6. CF/Wc – Annual Botanical composition



White clover performed well in Yr 1 as cocksfoot is slower to establish than ryegrass.

However, in subsequent years there was about 35% less white clover yield in the CF/Wc pasture than in the RG/Wc pasture. This is because CF and Wc are both summer active which puts them in direct competition for light, water and nutrients and the white clover fails as it is less competitive at acquiring the resources. This compounded N deficiency in the cocksfoot.

Summary of Figure 6

- Pasture vigour declined over time and reflected the loss of N fertility due to a decrease in the clover content of the pasture.

- After Year 1 there was about 34% less white clover in the cocksfoot pasture than there was in the perennial ryegrass pasture.

- Both cocksfoot and white clover are both summer active species. This means they are in direct competition for water and nutrients at the same time and in a drought prone summer dry environment one species will lose. After white clover loses its taproot (beyond about 18 months) it relies on an adventitious root system. Cocksfoot has a greater root mass and surface area and can explore a greater volume of soil to capture water and nutrients. The white clover is supressed and preferentially grazed as the cocksfoot becomes N deficient. This puts more grazing pressure on the white clover remaining in the pasture.

Yr 1 Summer
(Feb 2003)
CF/Wc

CF/Wc pasture in summer of Yr 1. Total annual yield was 12.9 t DM/ha of which 3.2 t/ha was white clover. Total yield was similar to the 13.0 t/ha produced by the CF/Sub pasture and more than the 10.5 t/ha produced by the RG/Wc pasture which had 2.3 t/ha of white clover yield.

Yr 2 Spring
(Aug 2003)
CF/Wc

Following alleviation of summer drought conditions the CF/Wc pasture recovered and drill rows were not evident in early spring of Yr 2.

Yr 2 Summer (Jan 2004) CF/Wc

CF/Wc pasture in Plot 1 (Rep 1).

Annual yield was 10.5 t/ha and although 87% of the yield produced was from the sown pasture components the white clover yielded only 0.9 t/ha for the year.

This photo shows that the effects of direct competition have begun to compromise white clover production. Note the amount of green cocksfoot leaf compared to the small water stressed trifoliate leaves of the white clover.

Yr 3 Winter (Jul 2004) CF/Wc

The CF/Wc pasture is just over 2 years old (established Feb 2002).

Although the summer drought has broken drill rows can still be seen and white clover has failed to fully exploit the available gaps.

White clover losses its seminal taproot at 18-24 months. From this point the plant will be reliant on a weaker adventitious root system.

Cocksfoot also has an fibrous root system but more root mass/surfaces mean it can explore and capture resources from a greater volume of soil in the root zone.

Yr 5 Spring (Aug 2006) CF/Wc

Total yield was 9.7 t DM/ha for Yr 5 and white clover yielded 2.0 t/ha.

A wet spring and summer meant the competition for water between the CF and Wc components.

There is little evidence of unsown species however, we cannot tell if the white clover was the cultivar originally sown or if it was volunteer white clover from the seedbank (which if later established may have had a seminal taproot to increase competitive ability).

Yr 5 Spring
(Sept 2006)
CF/Wc

1 month later.

Low spring clover content and some yellowing/nitrogen deficiency symptoms in the cocksfoot.

No obvious signs of weed invasion.

Yr 5 Spring
(Nov 2006)
CF/Wc

2 months later.

Clear evidence of N deficiency outside the urine patches after grazing.

Later spring clover content remains low and there appears to be *Poa annua* invading less colonised areas of the pasture (arrow).

Yr 6 Spring
(Nov 2007)
CF/Wc

N deficient cocksfoot pasture in late spring with low clover content.

This pasture will yield 7.1 t DM/ha which is 37% less than in Yr 5.

The white clover yield will total 1.3 t/ha and is insufficient to alleviate N deficiency through N transfer to the cocksfoot so the productivity of the cocksfoot component will continue to decline over time.

Yr 6 Spring
(Nov 2007)
CF/Wc

Same pasture from the corner of Plot 1.

Little evidence of weed species or white clover.

Grazing stock have lower preference for N deficient cocksfoot. This compounds the degradation of the N fertility status of the pasture. This occurs because sheep, which prefer a diet 70% legume/30% grass, and will preferentially graze the remaining white clover.

The increased grazing pressure will cause further decline in the proportion of white clover in the sward.

Yr 7 Summer (Jan 2009) CF/Wc

Total yield in Yr 7 was 5.7 t DM/ha of which only 0.6 t/ha was from white clover.

Unsown weed species accounted for about 20% of all DM produced.

Total production for the year was 25% less than in the previous year.

Note invasion of catsear and hawkbit into the pasture.

Yr 8 Spring
(Sept 2009)
CF/Wc

CF/Wc pasture in Plot 18 (Rep 3) in spring of Yr 8.

Feed on offer is cocksfoot dominant and pale green colour indicates N deficiency symptoms.

Evidence of *Poa annua*, mouse eared chickweed and speedwell.

Yr 8 Summer (Dec 2009) CF/Wc

Reproductive cocksfoot and white clover in summer of Yr 8.

It is possible that white clover (‘Demand’ or ‘Huia’) benefited from seedling recruitment from seed produced in summer months. These seedlings would have a taproot for the first 1-2 years.

Distinct yellowing in cocksfoot outside the urine patches and reduced biomass clear in the N deficient areas.

Total yield in Year 8 was 6.7 t DM/ha of which 66% was from originally sown pasture components.

Yr 9 Winter
(Jun 2011)
CF/Wc

In the final year (2010/11) cocksfoot accounted for 65% of the total yield of 5.6 t DM/ha produced compared to 8.7 t DM/ha from the CF/Sub pasture.

White clover yield was only 0.3 t DM/ha.

As described for the CF/Bal pasture previously this pasture does not require renewal but the lack of clover has compromised production and vigour of the pasture. A hard graze in autumn would open the sward and allow 10 kg/ha sub and 1 kg/ha white clover to be overdrilled.

Cocksfoot/Caucasian clover pastures

Yield data and photos are used to document the performance of the cocksfoot/Caucasian clover pastures in this section.

Caucasian clover…

Caucasian clover is a perennial, summer active species. This species was selected as a companion legume for cocksfoot because it has a taproot which may have allowed it to avoid competition for water with the cocksfoot during summer months by extracting water from deeper in the soil - beyond the reach of the cocksfoot root system.

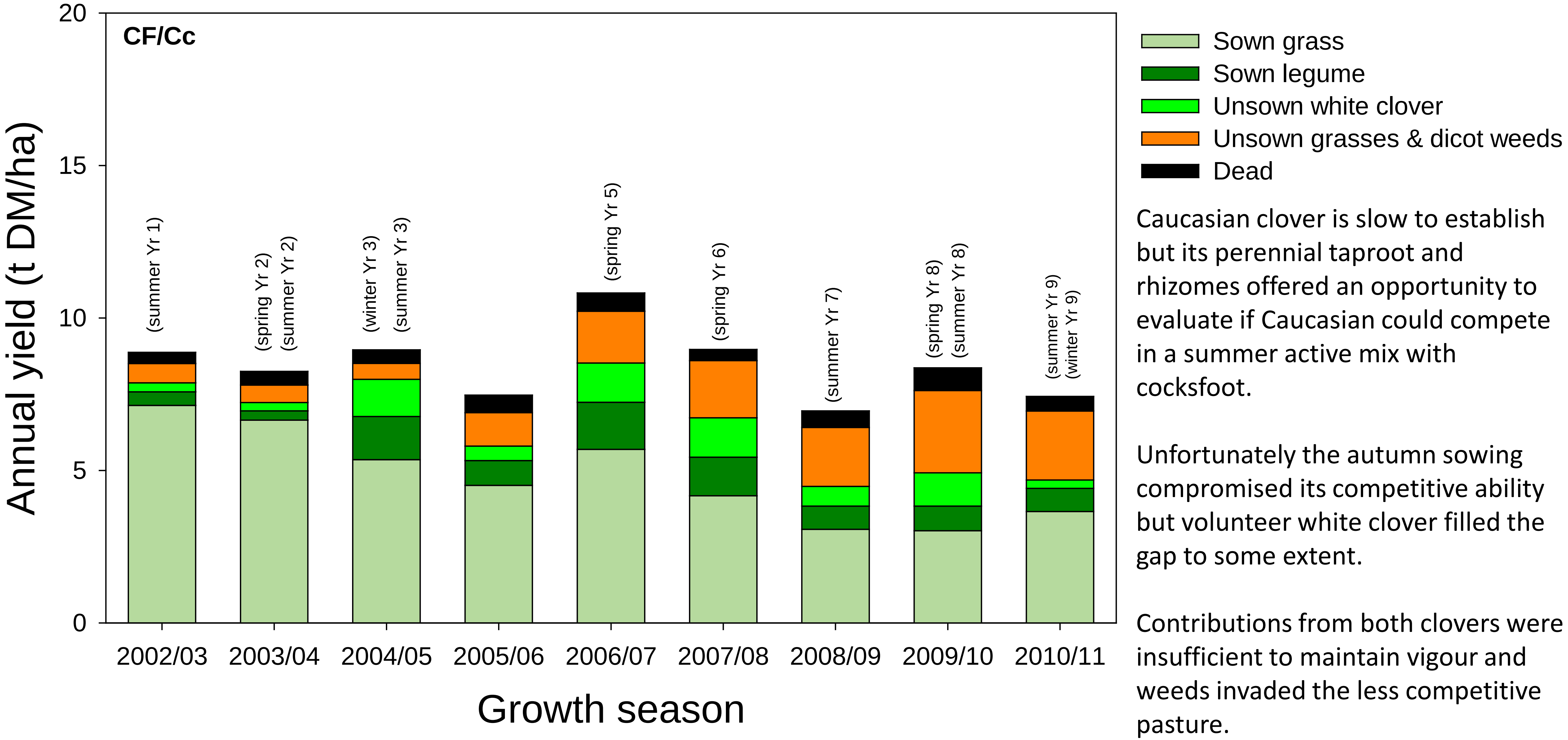
Caucasian clover can also spread through a pasture vegetative. New daughter plants form from nodes on below ground rhizomes which are protected from grazing damage.

This clover is best established from a spring sowing with a cover crop. This is because it is slow to establish and competition in early growth will compromise future production. The initial priority of establishing Caucasian clover is to form its root system. This occurs at the expense of above ground DM yield. The grass should be overdrilled in autumn after the Caucasian has been allowed time to establish.

Here, the autumn sowing of cocksfoot with Caucasian clover compromised long term production. The plants which established persisted however the initial population was too low to alleviate N deficiency symptoms in the cocksfoot.

Caucasian clover monoculture
Photo: Dr KM Pollock

CF/Cc – Annual Botanical composition

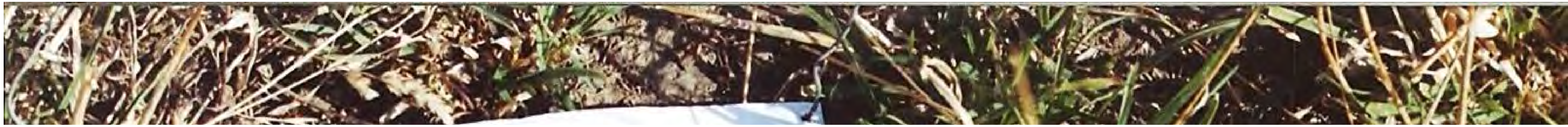


Caucasian clover is slow to establish but its perennial taproot and rhizomes offered an opportunity to evaluate if Caucasian could compete in a summer active mix with cocksfoot.

Unfortunately the autumn sowing compromised its competitive ability but volunteer white clover filled the gap to some extent.

Contributions from both clovers were insufficient to maintain vigour and weeds invaded the less competitive pasture.

Yr 1 Summer
(Feb 2003)
CF/Cc



A CF/Cc pasture in Plot 6 (Rep 1) about 12 months after sowing under summer drought conditions. Note no evidence of unsown species and arrow indicates only minimal Caucasian clover. Only 0.5 t DM/ha, or 5%, of the 8.9 t/ha of total yield was from Caucasian clover in Year 1.

Yr 2 Spring
(Aug 2003)
CF/Cc

Minimal clover content at the start of Yr 2 and Caucasian clover will only yield 0.3 t clover/ha over the course of the 2003/04 growth season. The majority of clover leaves present in this photo are unsown volunteer white clover which doubled the total clover yield.

Yr 2 Summer
(Jan 2004)
CF/Cc

Drill rows are open but no evidence of unsown weed species colonising gaps in sward.

Of the 8.2 t DM/ha produced for the year 85% will be from the sown species and most of this from the cocksfoot component.

Yield is similar to the 8.4 t/ha from the RG/Wc pasture but about 2-3 t/ha less than the other grass pastures and about 60% less than the 13.1 t/ha produced from the lucerne monoculture.

Yr 3 Winter (Jul 2004) CF/Cc

A few Caucasian clover leaves can be seen between cocksfoot plants but more obvious is the invasion of *Poa annua* and some annual dicot weeds into the gaps (arrows).

Total yield in Year 3 was 9.0 t/ha and with a wet summer Caucasian clover yield was 1.4 t/ha with and additional 1.2 t/ha from volunteer white clover.

Total yield is about 1-2 t/ha less than the other grass pastures and less than half the 18.5 t/ha the lucerne monoculture yielded.

Yr 5 Spring
(Aug 2006)
CF/Cc

Cocksfoot dominant spring feed with no obvious weed presence in early spring.

Clover content is low but some isolated small Caucasian and white clover leaves can be seen (arrows).

14% of the 10.8 t/ha yield came from Caucasian clover over the 2006/07 growth season.

Yr 5 Spring
(Sept 2006)
CF/Cc

As soil and air temperatures Caucasian clover, like lucerne, remobilises reserves from its root system and clover content in pre grazing mass increases.

Note also the more rounded leaflets of the volunteer white clover present in the pasture (arrow).

Yr 6 Spring
(Nov 2007)
CF/Cc

2 months later.

N deficient cocksfoot pasture between urine patches.

No obvious signs of weed invasion. No obvious Caucasian or volunteer white clover.

Total annual yield was 9.0 t/ha which was 1.5-2.0 t/ha more than the CF/Bal or CF/Wc pastures.

14% was from Caucasian clover and a further 14% from unsown volunteer white clover.

Yr 7 Summer
(Jan 2009)
CF/Cc

CF/Cc pasture in Plot 20 (Rep 4) showing widespread invasion be dicot flatweeds and some barley grass seedheads (arrows).

29% of the 6.5 t/ha total yield was from unsown grasses and dicot weeds in Yr 7.

Yr 8 Spring
(Sept 2009)
CF/Cc

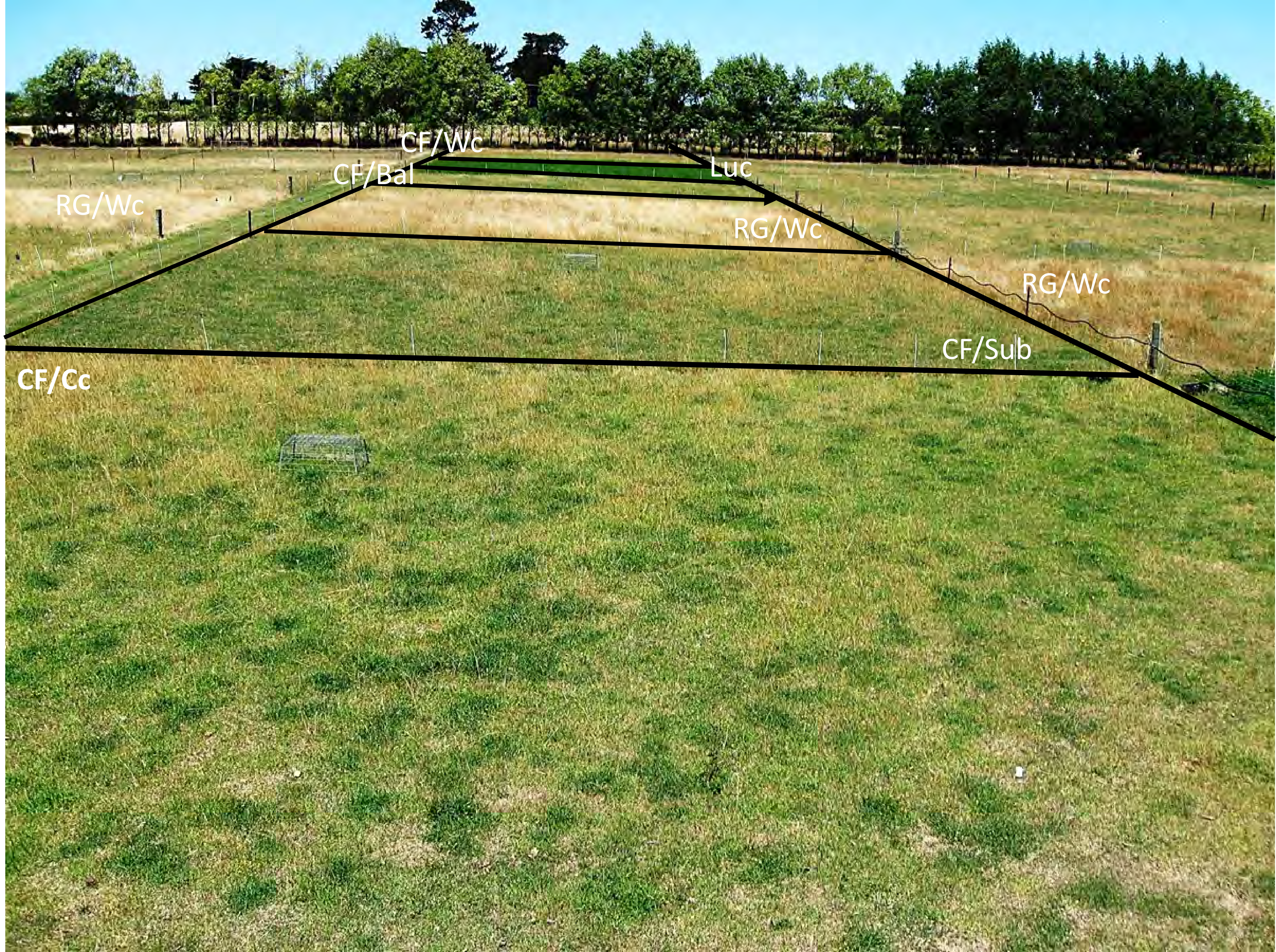
CF/Cc pasture in Plot 10 (Rep 2) showing presence of Caucasian and white clovers, *Poa annua*, mouse eared chickweed and invasion of perennial rhizomatous weed yarrow into the sward.

Of the 8.3 t DM/ha 33% was from unsown weed species and 10% from Caucasian clover.

Yr 8 Summer
(Dec 2009)
CF/Cc

Post graze reproductive CF/Cc pasture in summer.

Yr 9 Summer
(Jan 2011)
CF/Cc



Foreground shows N deficient reproductive cocksfoot pasture in Plot 6 (Rep 1) in summer of the last season (2010/11).

Sown species accounted for 60% of all DM produced with 0.8 t/ha or 10% of the total yield from the Caucasian clover.

Dicot weeds and unsown grasses contributed a further 30%.

After nine years Caucasian clover content was low but reasonably stable after plateauing at about Yr 3.

Autumn establishment was not suitable for Caucasian clover given its slow establishment. In hindsight the Caucasian clover should have been spring sown with a cover crop then overdrilled with the cocksfoot in autumn.

For this pasture we would recommend a hard graze followed by overdrilling with sub and white clovers to supplement the existing Caucasian clover which could contribute in wet summers. Annual weed species would fail to establish in a sward with improved vigour and when in direct competition with actively growing sub clover in spring.

Lucerne monocultures

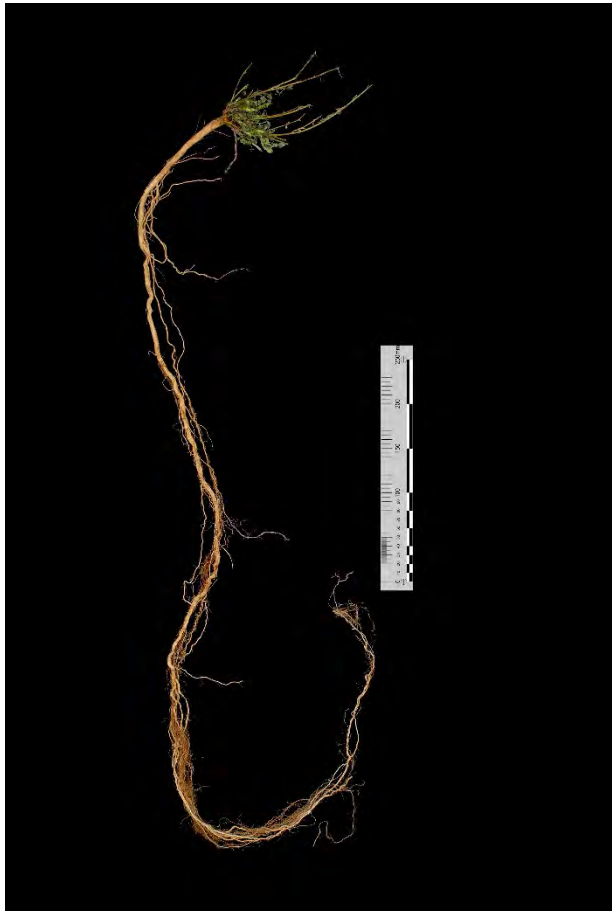
Yield data and photos are used to document the performance of the lucerne monocultures in this section.

Lucerne…

Lucerne is a taprooted, summer active, perennial legume. Its benefit in summer dry regions comes from its deep taproot which allow it to extract water from lower in the soil than grass based pasture species. This allows growth to continue for longer as drought conditions develop.

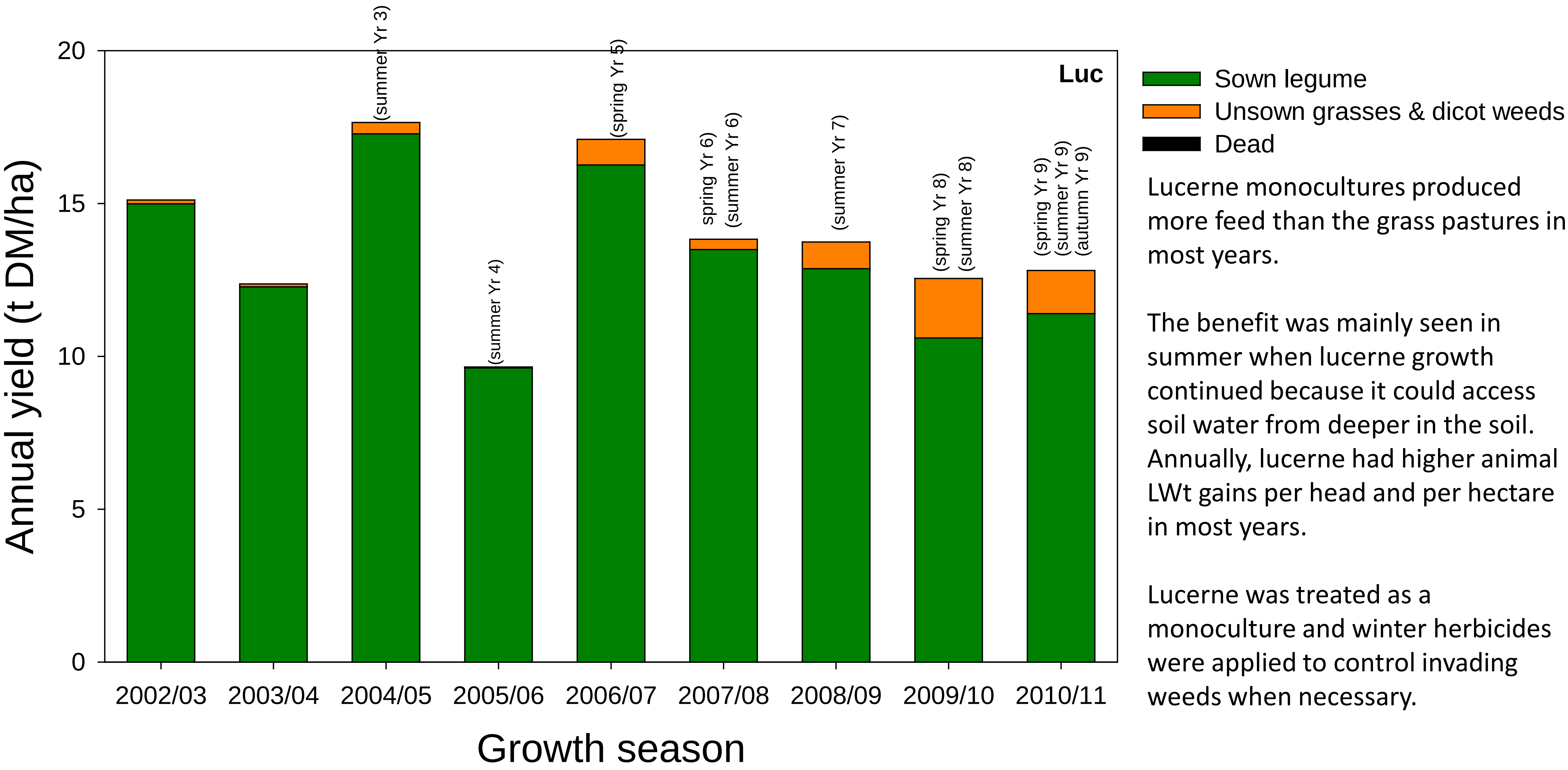
Spring growth is more than expected because carbohydrates stored in the roots are remobilised to boost above ground yields. However, to maintain a productive and persistent stand lucerne must be allowed to flower once after the longest day. It is this environmental trigger which changes the partitioning priority of the plant and carbohydrates are preferentially directed back in the roots to replenish the reserves. Failure to replenish the reserves means there are less reserves for growth in the following spring. A lucerne stand can be destroyed within two years if not managed correctly.

Lucerne was rotationally grazed throughout active growth over nine years and weed control applied in winter when required. Spring grazing was initiated when lucerne in the first paddock reached 20 cm in height.



Lucerne plant with roots – 18 months after sowing
Photo: D. Hollander

Luc – Annual Botanical composition

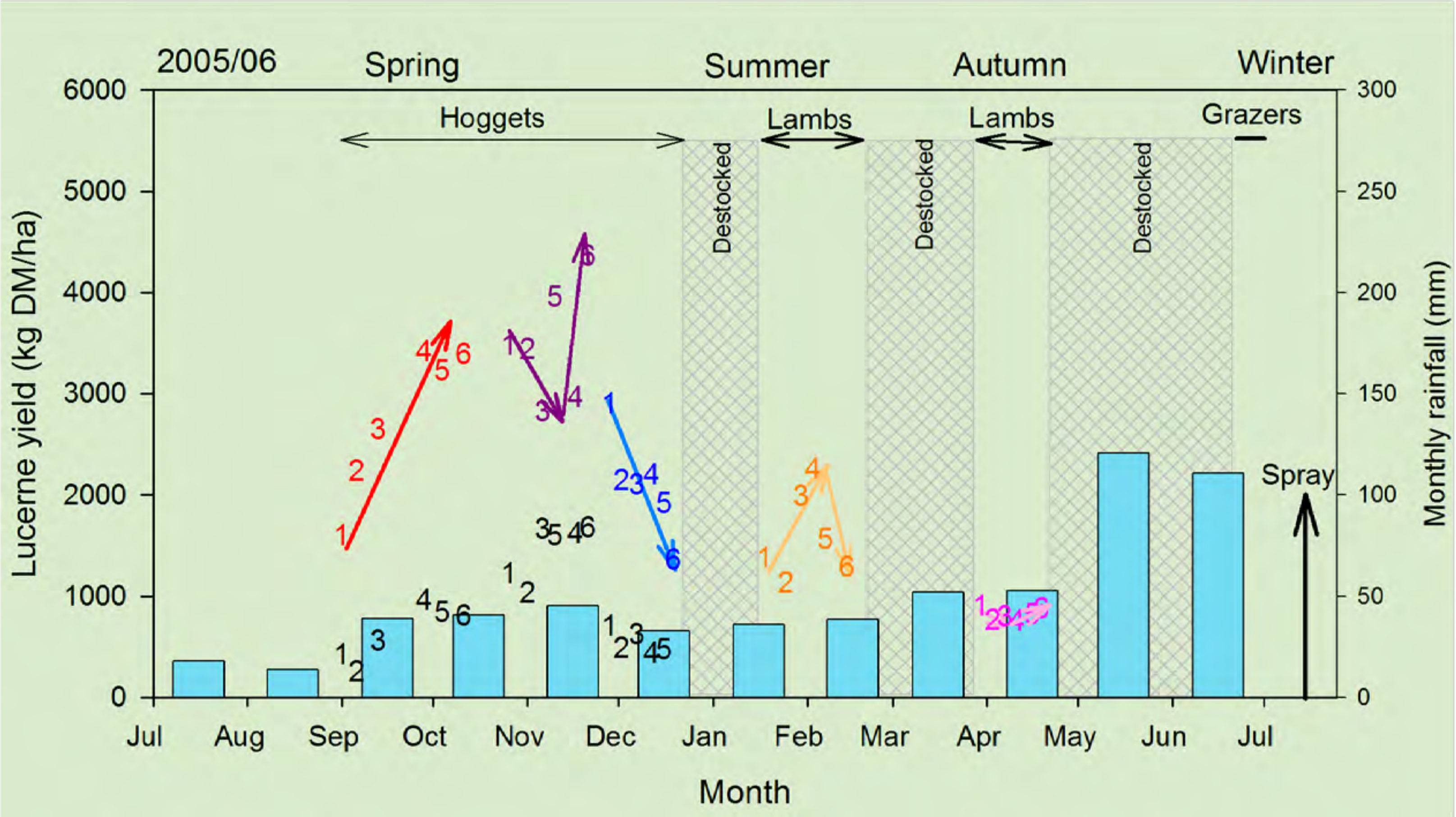


Lucerne monocultures produced more feed than the grass pastures in most years.

The benefit was mainly seen in summer when lucerne growth continued because it could access soil water from deeper in the soil. Annually, lucerne had higher animal LWt gains per head and per hectare in most years.

Lucerne was treated as a monoculture and winter herbicides were applied to control invading weeds when necessary.

Rotational grazing of lucerne



This shows the pre-grazing yields in the six paddocks (1-6) throughout five grazing rotations in 2005/06 (Year 4).

In the first rotation (red) the yield in paddock 1 was about 1.5 t/ha when grazing started. Growth continued in paddocks 2-6 and increased ahead of the grazing mob to reach about 3.3 t/ha prior to the start of grazing in paddocks 4-6.

In the second rotation (purple) paddocks 3 and 4 had lower production as water stress developed but rainfall allowed paddocks 5 and 6 to recover.

Rotation 3 (blue) was compromised by water stress. In summer a change in partitioning meant above ground yield was reduced as the plant replenished root reserves .

Yields were lowest in Rotation 5 (pink) due to the seasonal decline in temperature.

(Numbers in black are the post-grazing residuals.)

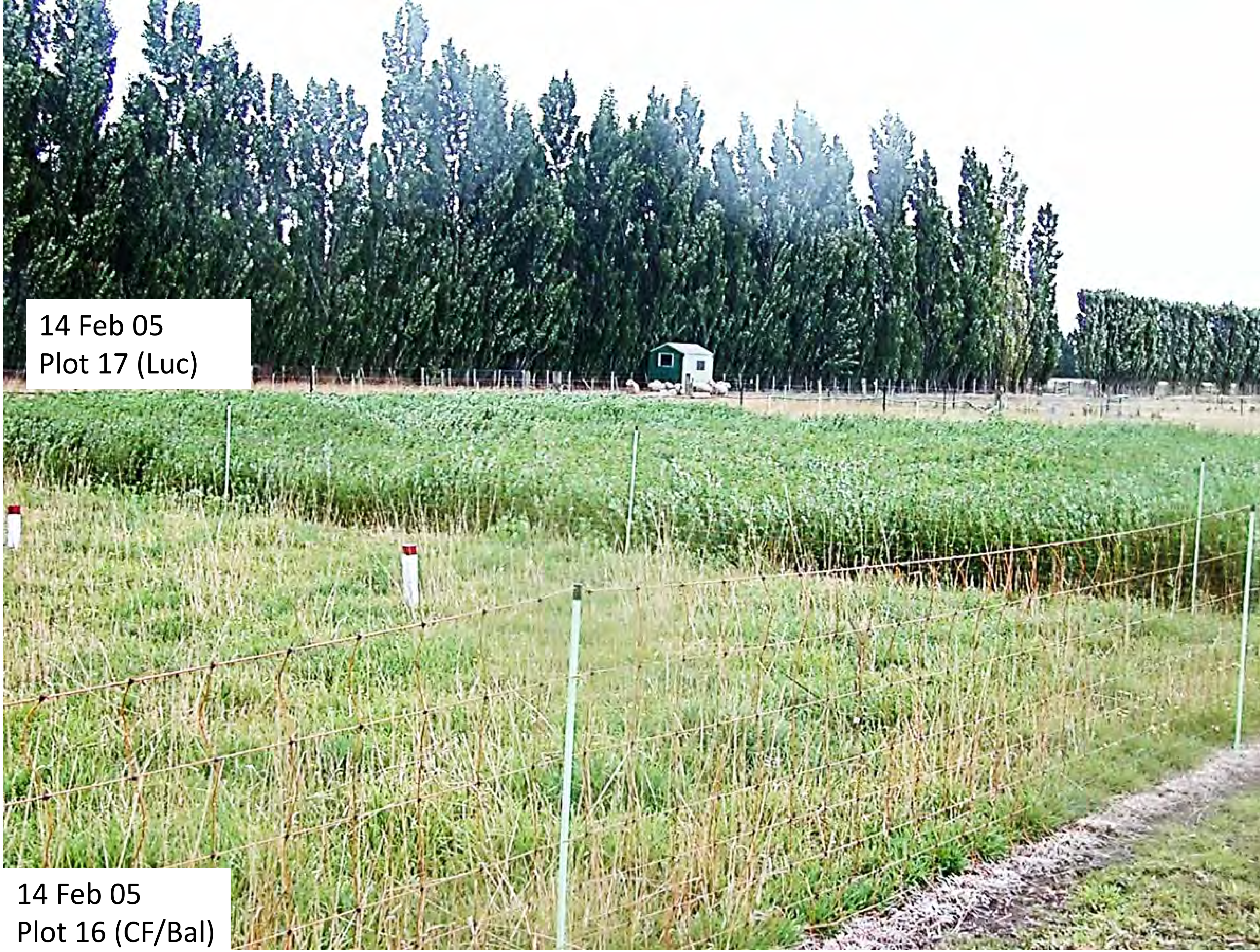
Moot & Smith 2011

Yr 3 Summer (Feb 2005) Luc

In Year 3, (2004/05), lucerne yielded 18.5 t DM/ha.

This was 65% more than the 11.2 t/ha produced by the CF/Wc pasture and more than double the 9.0 t/ha produced from the CF/Cc pasture.

Summer rainfall totalled 184 mm which was 28% above average.



This photo shows the lucerne in Plots 25 & 30 (Reps 5 & 6). It is included to show the effect of soil depth and water holding capacity on lucerne growth and variability of soil depth on a floodplain.

The green lucerne is growing on an area with a deeper soil formed on an old river channel. In the foreground the soil is shallower and holds less water. This shows why lucerne should be sown on the best and deepest soils to gain full benefit.

Lucerne can access the water at depth and continue growing whereas if sown on the shallower soil it has already extracted the little available water at depth and growth has ceased.

Yr 4 Summer
(Jan 2006)
Luc

Lucerne yield was lowest in Yr 4 (10 t/ha). This was due to snow in September which meant that standing lucerne stems broke and could not be measured/grazed.

However, subsequently the lucerne regrew and showed no detrimental effects.

This photo shows Plot 25 (Rep 5) on 5 Jan 2006 during early regrowth (sheep finished grazing this plot on 8 Dec 2005).

Summer rainfall was 108 mm which was about 25% below average.

Yr 5 Spring (Sept 2006) Luc

In Year 5 total annual lucerne yield was 17.3 t DM/ha compared with grass pastures which yielded 8.4 (CF/Bal) to 10.4 t DM/ha (CF/Sub and CF/Cc pastures).

Yr 6 Spring (Nov 2007) Luc

Lucerne yield was 14.0 t DM/ha in Yr 6 compared with grass based pastures which yielded 7.1 (CF/Wc) to 11.2 t DM/ha (CF/Sub)

Yr 6 Summer
(Dec 2007)
Luc

Lucerne in Plot 19 (Rep 4) in summer of Year 7. Note the drought stressed CF/Cc pasture in Plot 20 in the immediate foreground.

Overall annual rainfall was about average (645 mm) but for the summer period rainfall was 177 mm which was about 23% above average for the Dec-Feb period.

Yr 7 Summer (Jan 2009) Luc

Plot 19 (Rep 4) Pre-graze DM. Lucerne monocultures yielded 14.0 t DM/ha compared with 5.7 (CF/Wc) to 9.8 t DM/ha (CF/Sub) from grass based pastures in Year 7.

This was the wettest of the nine years with annual rainfall of 783 mm compared with the long-term average of 635 mm.

Note the presence of dandelion in the base of the sward (arrow).

Yr 7 Summer
(Jan 2007)
Luc

Also Jan 2007 but later in than the previous photo. This shows Plot 19 (Rep 4) during grazing in late Jan 2007 is in the foreground.

Note the destocked, reproductive, drought stressed grass based pastures in the background

Yr 8 Spring
(Sept 2009)
Luc

First spring grazing with ewes and twin lambs at foot.

Lucerne yield was 12.8 t DM/ha compared with the 6.7 (CF/Wc) to 9.5 t DM/ha (CF/Sub) produced by the grass based pastures.

Rainfall for the Jul-Nov period was 195 mm and almost 30% below average. Summer rainfall was also below average in Year 8.

Yr 8 Summer (Dec 2009) Luc

The lucerne sward has opened up as individual lucerne plants have died over time.

The main perennial weeds invading the lucerne were dandelion and hawkbit and the annual shepherds purse.

Some grass weeds have also established in the lucerne.

Yr 9 Spring
(Sept 2010)
Luc

Plot 12 (Rep 2) Lucerne in the final year (2010/11).

Lucerne yielded 12.9 t DM/ha/yr in Yr 9 compared with 5.8 (CF/Wc & CF/Bal) to 8.7 t DM/ha (CF/Sub) from the grass based pastures.

Yr 9 Spring
(Nov 2010)
Luc

Pre grazing DM in Plot 19 (Rep 4) in spring of the ninth year.

Spring rainfall was about average in this year.

Yr 9 Summer (Jan 2011) Luc

Reproductive lucerne in summer of Year 9 . Allowing lucerne to flower before grazing at this time of year allows the lucerne to recharge root carbohydrate reserves depleted in spring for the subsequent season.

Note sward remains more open than in the earlier years and yellow hawkbit flowers (arrow) are visible in the gaps.

Yr 9 Autumn (Mar 2011) Luc

Lucerne in Plot 25 (Rep 5) in full flower to recharge root system. This feed would not be recommended for flushing or mating livestock due to the increase in coumestrol content in reproductive lucerne.

However, non breeding stock will still benefit from eating lucerne which is likely to be of higher quality than other drought stress pastures available on a dryland property at this time.

For this lucerne stand we would now recommend overdrilling with brome or cocksfoot to create a runout mix suitable for grazing with ewes and lambs in early spring.

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