



FutureDairy investigated options to mitigate the ever-increasing limitations imposed by land, water and labour availability and cost in Australian dairying.

A key strategy for farmers is to increase home-grown forage production and consumption. This, in turn, can improve profitability. FutureDairy has proved that forage yields from complementary forage rotations (CFR) can be more than double those of pasture. This has been demonstrated on both research and commercial farms.

Complementary forage systems (CFS) integrate CFR into pasture-based dairy systems. This can be done in many different ways and tailored to individual farmers' needs.

When using forage crops, FutureDairy's approach is to start by setting goals that are based on what is possible (and then determine what is feasible) rather than constraining goals based on known limits to the current farm situation.

FutureDairy has shown that production of ~30,000L milk/ha or ~2,000kg milksolids/ha from home-grown forages and more than 7,500L/cow (>500 kg milksolids) are achievable with only ~1t of concentrate/cow.

Complementary forage systems may allow you to:

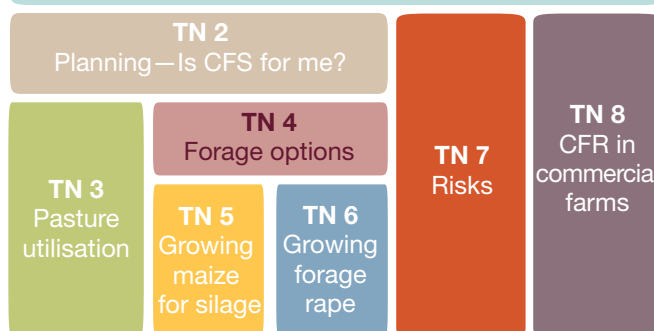
- Increase total forage yield, and therefore milk from home-grown feed, and farm productivity and profitability.
- Replace more expensive bought-in supplements (thus potentially reducing economic risk).
- Increase the efficiency of use of nutrients and water.

This tech note will:

- Help you understand how different forage rotations may suit different needs.
- Give you the key facts from FutureDairy's research into complementary forage rotations (CFR).
- Help you decide which CFR may better suit your farm's needs.

This tech note reports on FutureDairy's findings. Further work/discussion is needed regarding the specific application of these findings in different commercial dairy systems.

TN 1 More milk from home-grown feed



Complementary forage systems (CFS) could be an option for your farm to increase productivity or reduce reliance on brought-in feeds.

If you have read other tech notes of this series, you may have more specific questions about the type of complementary forage rotation (CFR) and specific forages that could best suit your farm. Remember, achieving high pasture utilisation (Tech Note 3) is essential for a successful CFS and should be the first thing to improve before introducing any forage or making the system more complex.

This tech note describes the factors affecting forage selection from a CFS perspective and provides examples from several years of research by FutureDairy.

This tech note does not describe the agronomic practices for each forage crop or rotation. These will vary substantially across regions and soil type. FutureDairy recommends checking with your agronomist or consultant before growing any of the forage rotations or combinations described here.

Key points

There are forage options to suit any individual farm's needs.

Triple-crop CFRs are the best option to achieve a substantial increase in total forage yield.

Double-crop CFRs yield 20–30% less than the triple-crop CFR, but are simpler to manage.

Combinations of forages that are wholly harvestable or wholly grazable are possible.

Brassica crops, in particular forage rape and leafy turnips, are popular due to their high growth rate in early autumn and their consistently high nutritive value.

Forage options for summer grazing remain a significant challenge. Forage sorghum is the benchmark in terms of forage yield. Quality issues have improved with the newer brown mid-rib (BMR) varieties. Legumes such as soybean or cowpeas may be an alternative summer option, although yields are much lower than sorghum and quality may not be much better. They may require lower levels of nitrogen fertiliser and provide a degree of nitrogen fixation for subsequent crops.

When evaluating forage options, consider the associated risks, system or infrastructure requirements and planning needs.

The principles of forage rotations described here apply in most regions, but specific agronomic practices vary substantially across individual regions and farms.

Key considerations

Once you've decided a CFS may have a role in your farm (see related tech notes of this series), the next step is to choose which forages to grow. When choosing forages, consider:

- Feed-related needs of your system.
- Limitations to growing specific forages (e.g. climate, region, soil type).
- Limitations of your farm (e.g. irrigation, paddock layout, distance to the dairy).
- Agronomic and managerial skills required for different crops.
- External factors such as the availability of contractors in your area.
- Delivery of additional forages to your herd.
- How you will balance rations that may have higher content of conserved forages.

This tech note draws upon FutureDairy research results to provide a general guide to the different forage rotation options and the potential of different combinations.

Forage needs

To determine which forages will be grown, consider your forage needs. Forage needs usually fall within one of these groups:

- Forages to increase total forage yield.
- Forages to maximise harvestable forage yield, either 'grazable' or 'conserved.'
- Grazable forages to improve autumn-winter quality feed.
- Grazable forages to improve summer quality feed.
- Forages to mitigate grain risk.

Increasing forage yield

If your goal is to increase home-grown forage yield, you will need to explore forages with a greater capacity to convert solar radiation into biomass than the capacity of typical pasture species.

You will also need to use more than one forage crop to exploit the maximum potential of each growing season.

The best way to do this is through a combination of crops in a sequence (or rotation).

The term *complementary forage rotation* (CFR) refers to specific combinations of forage crops grown in a rotational sequence. The choice of crops is designed to sustainably increase forage production per hectare and improve the efficiency of use of limited resources (e.g. nitrogen and water).

To achieve these, forage crops must complement each other at three levels.

1. Soil-plant level: for example improve or at least not adversely affect soil status.
2. Plant-animal level: for example improve the nutritional balance of different forages/feeds.
3. Whole system level: that is 'complement' rather than 'replace' pasture.

In practice, a CFR can be a series of forages grown rotationally on either the same site over time or as part of a crop-pasture rotation.

Triple cropping

Triple-crop complementary forage rotations involve growing three crops a year on the same area. Triple-crop CFRs provide the highest forage yield, so they are an attractive option if you need to maximise forage production per hectare.

FutureDairy evaluated several triple-crop options at plot, paddock, and whole farm level, including on commercial farms.

A key part of the FutureDairy project was the evaluation of a triple-crop CFR in a 3-year field experiment at Elizabeth Macarthur Agricultural Institute, NSW DPI, Camden NSW. The experiment compared a pasture system (kikuyu oversown with a short-rotation ryegrass in early autumn, managed to best practice), against a triple-crop CFR comprised of:

1. Brassica sown in late February—early March as a break crop.
2. An annual legume (either Persian clover broadcast after the first grazing of the brassicas, or maple peas, sown in early August).
3. Maize (a bulk crop), sown in early October and harvested for silage in February.

Both treatments (CFR and pasture) were irrigated and fertilised as required to maximise yield. For guidelines on maximising yield refer to other tech notes in this series on pasture utilisation, brassicas, and maize).

Table 1. Total annual forage yield (t DM/ha) of complementary forage rotation (CFR) and pasture treatments over the three experimental years.

Forage	Year			Mean
	1	2	3	
Pasture	17.3	18.0	16.7	17.3
CFR				
Brassica	12.0	10.7	11.6	11.4
Legume	3.5	4.6	3.9	4.0
Maize	26.7	26.2	28.9	27.3
Total CFR	42.2	40.8	44.4	42.7

This experiment demonstrated the potential of triple-crop CFR to achieve total annual yields of more than 42 t DM/ha (see Table 1).

The CFR treatment required a larger investment per hectare than the pasture, mainly due to the cost of growing maize for silage. However, due to the higher forage yield of the CFR (including 20% of wastage), the average total variable costs of the CFR and pasture treatments were similar (about \$110/t DM) for both treatments. As the mean metabolisable energy (ME) content was similar for the CFR and pasture treatments, the cost per megajoule of metabolisable energy was also similar for both treatments (about \$0.011/MJ ME).

These costs include all inputs (sowing, seed, fertiliser, irrigation, herbicide, pesticide, conservation, etc.) as well as labour at contractor rates. Maize silage yields were reduced by 20% due to wastage. These costs need to be considered with caution as they depend on the high yields obtained with the CFR option. Production of high yielding crops, such as maize, requires attention to detail and commitment to supply appropriate input. However, these costs indicate that CFR feed can be produced at a similar cost to pasture.

Table 2. Apparent nutrient and water use efficiency (i.e. kg DM utilised or conserved per unit of input applied) for each crop of the CFR and the pasture.

	CFR				Pasture
	Brassica	Legume	Maize	Total CFR	
Nitrogen	49	135	74	69.9	30
Water (t DM/ML)					
Irrigation water	4.7	4.6	7	4.7	2.3
Total water	2.9	2.1	3.6	2.9	1.2

Table 3. Forage yield of individual crops and total CFR under 12 different combinations of N input ranging from 0 to 523 kg/ha (full irrigation).

Nitrogen applied to maize (kg N/ha)		Nitrogen applied to forage rape (kg N/ha) ¹				Total CFR
Pre-sowing	at V6	Maize	Forage rape	Field peas		
0	0	22.1	0	4.4	4.2	30.6
	79	31.0		5.1	4.1	40.1
	158	32.2		5.8	3.8	41.7
135	0	26.6		5.3	3.3	35.1
	79	32.1		5.5	4.1	41.6
	158	32.9		5.4	4.0	42.3
Mean	29.5	5.3		3.9	38.6	29.5
0	0	22.1	230	11.6	3.8	37.5
	79	31.0		10.9	4.4	46.2
	158	32.2		10.5	3.9	46.5
135	0	26.6		10.9	3.2	40.6
	79	32.1		11.0	3.8	46.8
	158	32.9		11.6	3.7	48.2
Mean	29.5	11.1		3.8	44.3	29.5

¹Nitrogen application was distributed as follows: 70 kg/ha at sowing; 90 kg/ha after first cut and 70 kg/ha after second cut.

The other key finding of this experiment was the increase in the efficiency of nitrogen (N) and water use.

To understand the potential when nitrogen and water are not limiting, for both pasture and CFR treatments, we applied almost 600 kg N/ha and 7.5 ML/ha of irrigation water (to ensure that neither nitrogen nor water would limit forage yield). As CFR yields were much higher than pasture, the 'apparent' efficiency (i.e. kg of DM/unit of input) of use of nitrogen, in terms of forage yield and water use were also about 2.5 times higher for the CFR (Table 2). The investigation was conducted with no limitation of nitrogen (N) and water. However these are key limiting resources to grow forages in most regions, and therefore we investigated the impact of varying these two nutrients on the triple-crop CFR.

The first trial was done on very fertile soils with relatively high initial nitrogen content. The experiment evaluated nitrogen treatments ranging from nil to 520 kg N/ha over the whole annual cycle. Up to about 300 kg/ha was applied to the maize crop of the CFR and 230 kg N/ha was applied to the forage rape.

The results in Table 3 show a substantial response to nitrogen by both maize and forage rape crops despite the relatively high initial nitrogen level in the soil. It is important to note that the nitrogen applied to forage rape was split into three applications (pre-sowing; first and second cut, see Table 3). This practice maximises response and minimises risk of nitrate poisoning (which is much greater at first than subsequent grazings) and nitrogen losses by leaching.

These results clearly show that, under full irrigation, there is little or no residual effect of nitrogen for the subsequent crops. Farmers should not rely on achieving maximum yields of brassicas crops based on nitrogen fertilisation to the previous maize crop, even if this was relatively high.

The marginal nitrogen response of the CFR as a whole under full irrigation was linear and equivalent to 28 kilograms of dry matter for each extra kilogram of nitrogen applied (Figure 1a). This is 2.5–3 times higher than the average expected response in temperate pastures (e.g. the average response of four different farmlets at the Greener Pasture projects in WA was 10.2 kg DM/kg N).

The apparent efficiency of use of nitrogen for maize (total kg of DM per kg N applied) decreased as nitrogen fertiliser increased, although it was 2.6 times higher for fully irrigated than for non-irrigated treatments (Figure 1b).

Terminology

Complementary Forage System (CFS) refers to the whole farming system; that is the combined pasture and forage cropping area; **Complementary Forage Rotation (CFR)** refers to the area allocated to double or triple cropping.

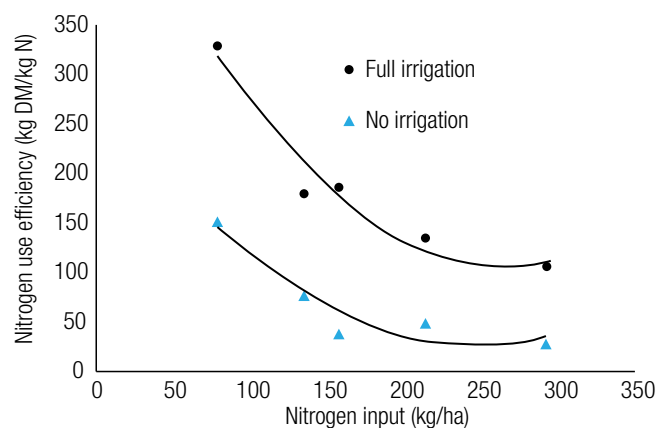
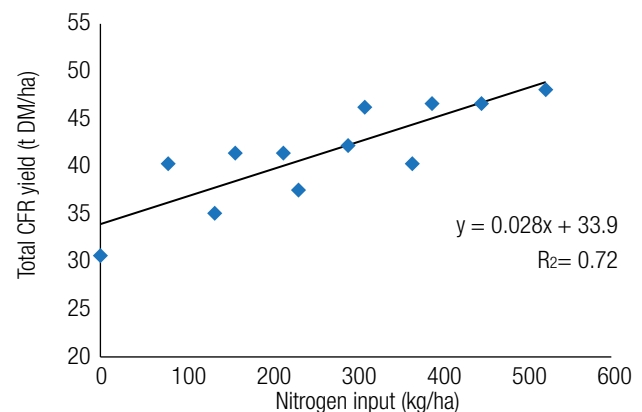


Figure 1 Relationship between nitrogen applied as fertiliser and (a) total CFR yield in a triple-crop CFR comprised of maize, forage rape and field peas; and (b) nitrogen use efficiency of maize with or without irrigation. Note that apparent response in Figure 1b is quantified as kg DM harvested per kg of N applied as fertiliser. This gives a general indication of 'efficiency' (how much was produced per unit of input) but it could be misleading at lower or non-input (at zero input the efficiency would be infinity) and should not be confused with 'marginal' response, which indicates rate of change in outputs per unit of input (as in Fig 1a).

Despite these high responses up to the highest level of nitrogen, there is a good trade off at about 200–250 kg for maize or about 400–450 kg for the total CFR (i.e. nitrogen to maize and forage rape).

In another controlled study, FutureDairy compared the same twelve nitrogen treatments of the above experiment (0–523 kg/ha) but this time all treatments were evaluated under zero, 33%, 66% and 100% irrigation. Again the total CFR yield was more than 40 t DM/ha. There was also again a substantial response to nitrogen, but this response varied from just an extra 12 kg of forage dry matter/kg N applied under no irrigation to more than 25 kg extra dry matter/kg N applied for the full irrigation treatment (Figure 2).

Combined, these results clearly demonstrated the feasibility of achieving more than 40 t DM/ha/year through a CFR with a more than double (apparent) efficiency in the use of key limiting inputs: nitrogen and water.

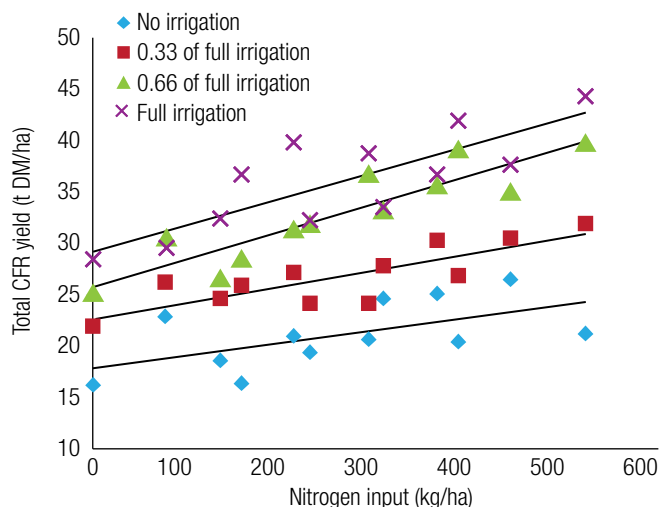


Figure 2. Relationship between nitrogen applied as fertiliser and total CFR yield in a triple-crop CFR comprised of maize, forage rape and field peas under four irrigation regimes (0, 33%, 66% and 100% irrigation).

The practical messages from this research are:

- Input and management of both nitrogen and water are crucial to maximising forage yields.
- A well-managed CFR can increase marginal response to nitrogen by 2–3 times compared with that of pasture.
- Water availability is the key to achieving maximum response to nitrogen. Only apply maximum amounts of nitrogen when water is not likely to be a limiting factor.

Complexity

A triple-crop CFR has the greatest potential to increase total home-grown feed. However, growing three crops in 12 months is more demanding in agronomic skills, timelines and management than double-crop rotations. It also carries additional risk with crop establishment and harvest. This can be both climatic or contractor risk (refer to the Risk Tech Note in this series).

In addition, some farmers perceive that individual crops such as forage rape are difficult to manage. Others may want to know whether a CFR could be grown as a fully ‘grazable’ option instead of a combination of grazing and harvesting as in our original triple-crop CFR. Questions our partner farmers asked included:

- Can we achieve the same forage yield with two crops per year instead of three?
- Can we replace the brassicas-clover mixture with just brassica or just clover?
- Do CFRs need to have a mixture of grazable (e.g. brassicas and clover) and harvestable (e.g. maize)?

These questions triggered more research at Camden to address them.

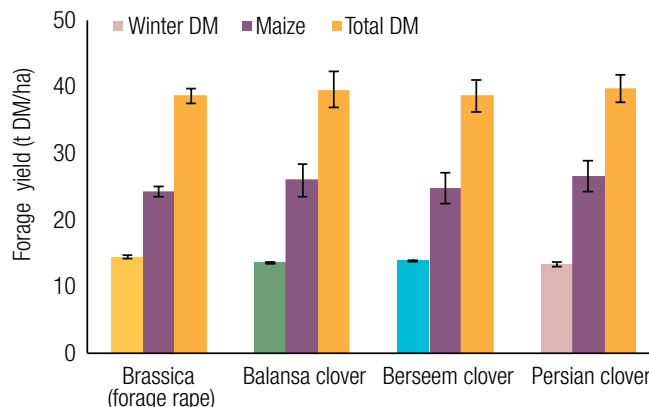


Figure 3. Forage yields of double-crop complementary forage rotations comprised of maize as a bulk crop and either forage rape or annual clovers as autumn-winter forage options.

Double cropping

Figure 3 shows the results from small plot experiments conducted at Camden comparing forage yields from a triple crop CRF with a double-crop CFR comprised of maize as summer harvestable option and either forage rape (brassicas) or three different annual clovers as grazable options. The forage yields from the double-crop CFRs were close to 40 t DM/ha, which is relatively similar to the triple-crop.

In a 3-year whole farm system study FutureDairy compared a double and triple crop CFR:

- Double-crop CFR: Persian clover for grazing and maize for silage.
- Triple-crop CFR: forage rape followed by Persian clover or field peas and followed by maize for silage.

The forage yield of the double-crop CFR was about 80% of the yield of the triple-crop CFR (Table 4), although in this case double-crop rotations did not have the extra nitrogen input of the brassica crop in the triple-crop CFR.

There is no *one size fits all* in terms of forage options. The choice between a double or triple crop depends on the specific needs of your farm and the complexity you are prepared to manage. **Maximum forage yields come at a price in terms of complexity and input management, particularly nitrogen and water!**

Table 4. Mean forage yield of individual forages and total complementary forage rotations (CFR) for the double and triple crop CFR used at a whole system study at Camden.

	Double-crop CFR	Triple-crop CFR
Brassica (forage rape)		7.1
Legumes	8.0	4.6
Maize	20.8	25.3
Total yield	28.8	37.0

Forages options

Maximising yield

Forage crops for grazing are normally the first choice because it is the cheapest option. However, harvestable crops may have a role; for example on a run-off or lease block, which cannot be accessed easily by the cows (machine-harvestable options).

FutureDairy evaluated different combinations of grazable and harvestable crops. We compared either maize (harvestable) or sorghum (grazable) as the summer forage options in combination with canola (brassica) and maple pea (harvestable) or clover-mix (grazable) as autumn/winter forage.

The treatments comprised three autumn/winter forage options combined with two spring/summer forage options forming six forage combinations as shown in Table 5.

The autumn/winter forages were canola, clover-mix (balansa, berseem and Persian clover) and maple pea. All were followed by either maize or forage sorghum in spring. Unlike canola and maple pea, the clover-mix grown prior to sorghum was kept for one more harvest than the clover-mix prior to maize.

These CFR systems were evaluated in terms of forage yield and quality as well as their impact on soil characteristics and soil health. Figure 4 shows the results. With late February sowing, the annual clover mix (Persian, balansa and berseem clovers) yielded more than 12 t DM/ha/year after six cuts (when followed by maize) or seven cuts (when followed by sorghum).

These clovers can be an alternative to forage rape as an autumn-winter forage for double-crop CFRs. However, if the bottle neck of your system is the lack of quality forage in early autumn, then the advantages of brassicas over the Persian clover are more evident as explained below.

Economic and/or financial aspects are beyond the scope of this tech note but should clearly be considered in any decision about forage options. For example, maize can provide the largest bulk yield, but a well-managed maize crop may require an investment of \$2,000–\$3,000 or more, much of which will have to be spent up front.

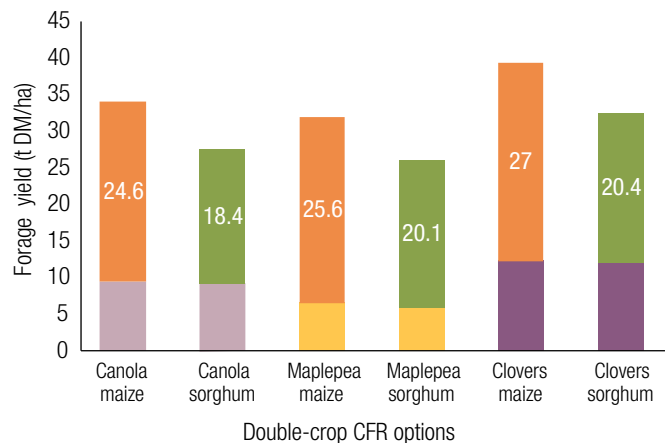


Figure 4. Forage yield of wholly 'harvestable' or wholly 'grazable' double-crop complementary forage rotations (top bars: summer crop; bottom bar: autumn-winter crop).

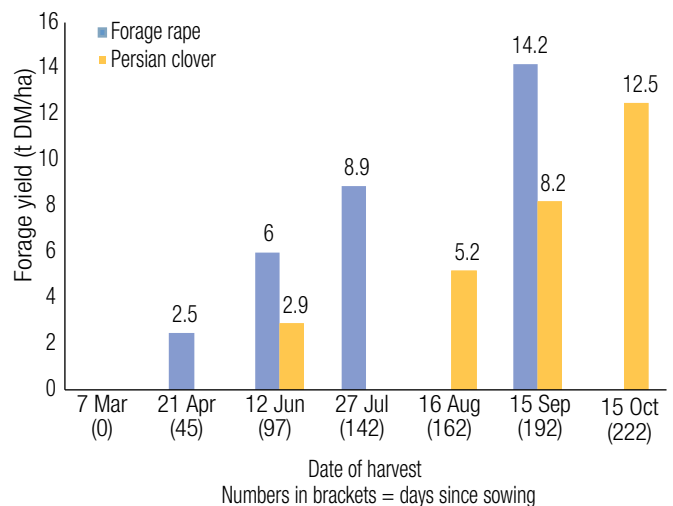


Figure 5. Cumulative yield of persian clover and forage rape over the autumn-winter period at Camden, NSW.

Table 5. Six forage treatment combinations comprising three autumn/winter and two spring/summer forage species (group).

Forage option	Brassica base		Legume base	
	Autumn/winter	Canola (harvestable)	Clover mix: Balansa, Berseem and persian (grazable)	Field pea: maple pea (harvestable)
Spring/summer	Maize (harvestable) or sorghum (grazable or harvestable)	Maize (harvestable) or sorghum (grazable or harvestable)	Maize (harvestable) or sorghum (grazable or harvestable)	

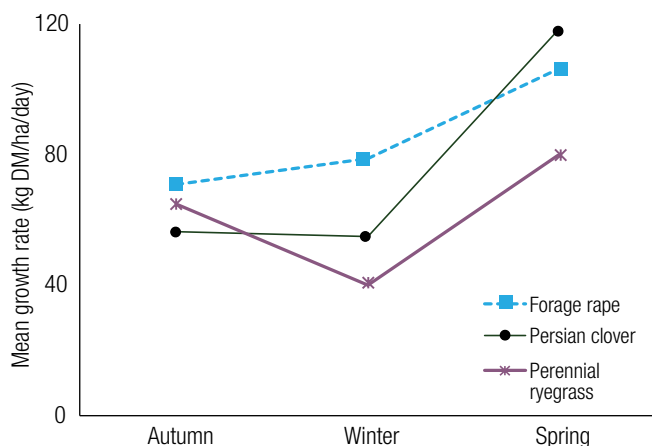


Figure 6. Average growth rate of forage rape (brassicac), persian clover and perennial ryegrass at Camden, NSW.

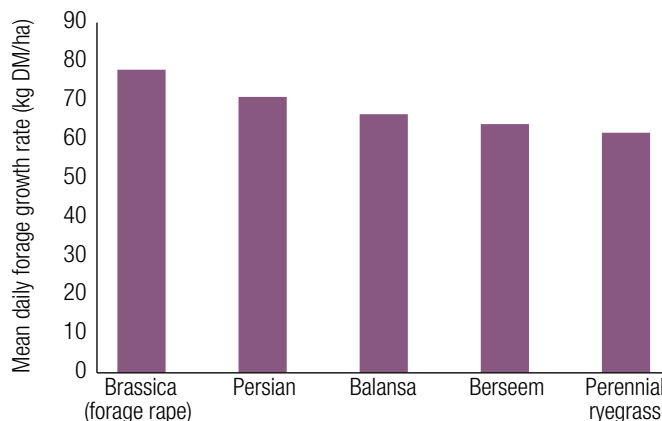


Figure 7. Mean daily forage growth rate of forage rape, annual clovers and perennial ryegrass at Camden, NSW.

We compared forage rape and Persian clover in another controlled comparison in small plots. In this experiment we achieved 14.2 t DM/ha from the brassicas after four cuts, with the last one in mid September. It took the Persian clover an extra 30 days to achieve a cumulative yield of 12.5 t DM (Figure 5). Forage rape clearly has a faster growth rate in autumn and winter, even when compared to perennial ryegrass (Figure 6).

Canola can yield more than 9–10 t DM/ha in a single cut but forage quality drops significantly and the ability of this crop to be ensiled is doubtful. Brassica crops in general contain lots of water and are therefore difficult to wilt.

Maple peas may fit nicely into a triple-crop rotation, allowing the paddock to be available in time to be sown to maize. They are best sown in winter, and are less suitable for early sowing, with an average total forage yield of 5–7 t DM/ha in one cut for silage after 6–7 months of growth.

Maple or field peas perform very well when used as late winter crop for silage. For several years we sowed field peas from late June to early August and consistently harvested 4–7 t DM/ha in one cut for silage in early October.

Sorghum is a high yielding option for grazing within a double- or triple-crop CFR. However, maize consistently out yielded sorghum by about 30% in FutureDairy trials. Maize has consistently the highest water use efficiency of all crops and also the highest nitrogen use efficiency (with the exception of legumes, Table 6).

The choice will depend on the individual circumstances.

The combination of annual clovers for grazing with maize for silage in a double-crop CFR can result in the highest combined nitrogen and water use efficiency (NUE and WUE).

Despite being the highest yielding forage option for autumn-winter at Camden, some farmers perceive that pure brassica crops are difficult to manage, particularly in relation to grazing allocation and residuals. Sowing brassicas together with winter grasses (eg. short rotation ryegrass) is more appealing to some farmers, as the management is simpler and the risk of losing the entire crop is lower. For more detail refer to the tech note on brassicas in this series.

Within the brassicas group, forage rape and leafy turnips (a hybrid cross between a turnip and other brassicas species) are the best options to be intersown with short rotation ryegrass. On commercial farms we have measured total utilised yields of 11–13 t DM/ha after five or six grazings for leafy turnips sown with short rotation ryegrass.

Double-crop CFRs:

- Are easier to manage than triple crop CFRs.
- Allow a combination of two different double-crop CFRs (eg. maize, followed by brassica and maize, followed by clover) to be rotated within the whole cropping area. This minimises the risk of disease outbreaks due to 'mono-cultivation'.
- Have more flexibility for implementation on farm.

Table 6: Apparent [kg of forage DM per unit of input] nitrogen use efficiency (NUE) and water use efficiency (WUE) of individual crops used in double-crop CFR's. Note that 'apparent' efficiency should not be confused with marginal response.

	Clover mix	Canola	Maple pea	Sorghum	Maize
NUE (kg DM/kg N)	177	57	90	61	80
WUE (t DM/ML total water)	2.1	1.6	2.5	3.9	4.8

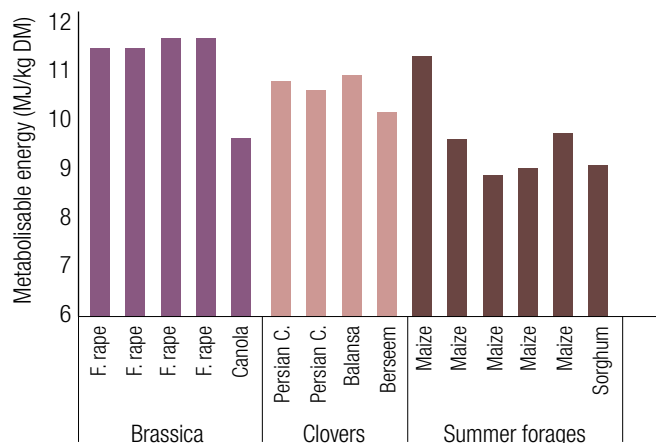


Figure 8. Average metabolisable energy (MJ/kg DM) of forage rape (4 studies); canola (1 study); Persian clover (2 studies); balansa and berseem (1 study); maize (5 studies/years); and sorghum (1 study).

Autumn–winter feed

Brassicas and annual clovers are key forage options to maximise yield in autumn-winter. Brassicas provide the highest early-autumn growth while annual clovers (particularly Persian clover) provide feed in late winter and early spring. In FutureDairy trials, all the annual clovers had higher average growth rates than perennial ryegrass, with forage rape being the highest, as shown in Figure 7.

Farmers working with FutureDairy wanted to know more about the nutritive value and potential impact of these ‘newer’ forages, particularly brassicas, on rumen function and animal performance.

Figure 8 shows that of all the forages evaluated by FutureDairy, forage rape consistently had the highest average metabolisable energy content (ME, which is expressed in MJ/kg DM).

The range of average metabolisable energy content of crops in our trials was:

Forage rape: 11–12 MJ/kg DM.

Clovers: 10–11 MJ/kg DM.

Maize for silage: 8.8–11 MJ/kg DM.

Sorghum and canola: 9–9.5 MJ/kgDM.

More detailed evaluations using sheep have shown that the higher nutritive value of forage rape is associated with its a higher rate of rumen degradability, even when compared with that of the vegetative growth of perennial ryegrass during the same season (Figure 9).

Higher rumen degradability means more rapid digestion of feed and therefore lower retention time of the feed in the rumen, which in turn can result in higher dry matter intake and milk production, providing cow condition is monitored closely.

FutureDairy research has demonstrated the this higher nutritive value of forage rape is maintained for a much longer grazing window than other typical forages used in the autumn, as Figure 10 shows.

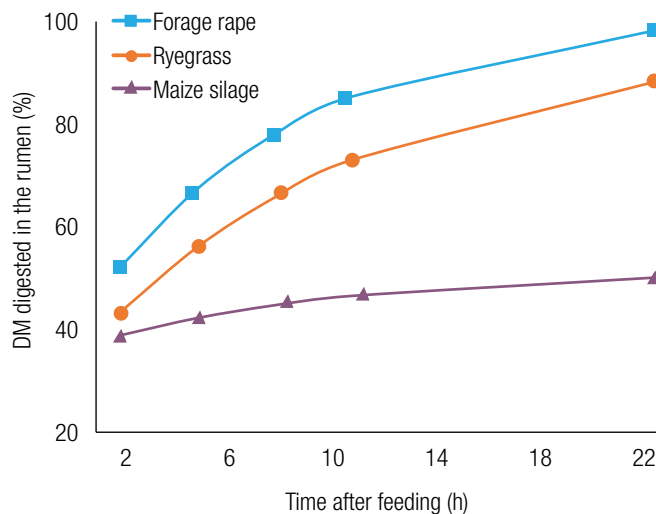


Figure 9. In situ dry matter rumen degradability of forage rape, ryegrass, and maize silage.

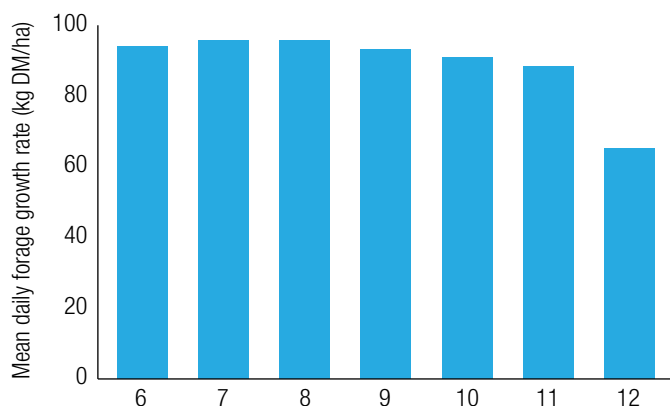


Figure 10. Dry matter degradability in the rumen of sheep after 12 hours of incubation of forage rape plants harvested at different maturity (weeks after sowing).

Although brassicas and legumes are higher in energy, the excessive degradability and very low fibre content (NDF, both chemical and physically effective) can be a potential risk, depending on the composition of the rest of the diet. For example, if cows are also grazing high quality ryegrass pasture, it may be necessary to add a fibrous feedstuff such as oaten hay.

There can also be limits on the amount of brassica used in diets due to nitrate risks and tainting. At the planning stage, it is important to budget for only one feed per day from grazed legume or brassica. This will reduce risk of acidosis or other digestive disturbance and taint.

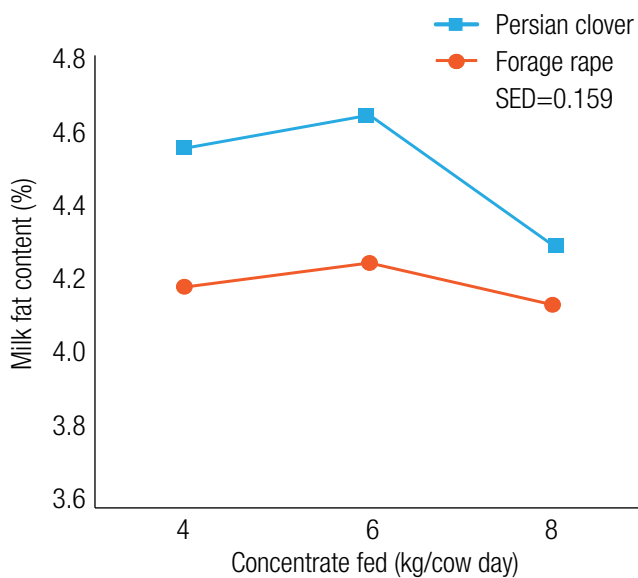
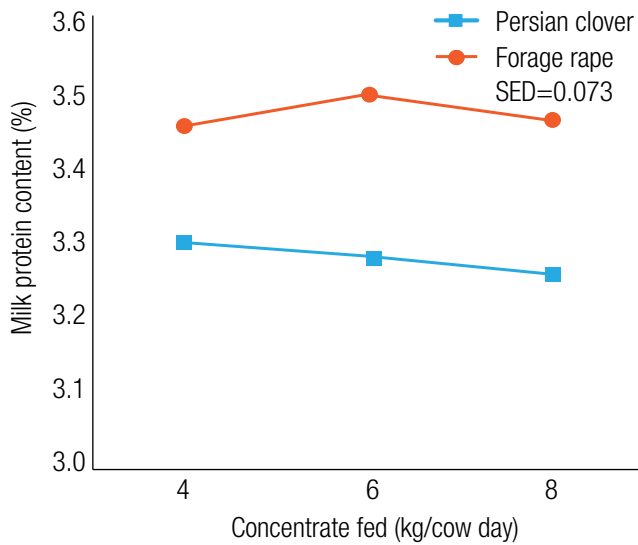


Figure 11. Effects of forage type (diamond=clover; square=forage rape) and concentrate level on milk protein and milk fat content (%).

Forage rape and Persian clover

Brassicacae are normally fed in restricted amounts (25–30% of total daily DM intake) to avoid the health issues associated with their high nitrate contents. Anyway, cows will not eat much more if given the choice.

If given the chance, lactating dairy cows can graze larger amounts of annual clovers (e.g. Persian clover), which explains the common improvement in milk yield observed when cows are moved into Persian clover pastures.

FutureDairy compared brassicas and clovers offered at about 25% of the total diet of cows in an experiment using 96 lactating cows. The diets comprised 10 kg DM of maize silage, 4 kg DM of grazed ryegrass-based pasture, 4 kg of forage rape or Persian clover (treatments) supplemented with 4, 6 or 8 kg of concentrate per cow.

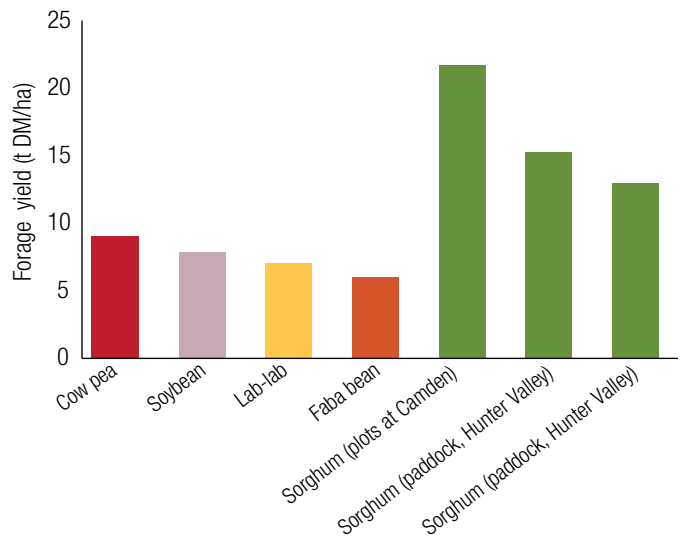


Figure 12. Forage yield of summer legumes in comparison to sorghum at Camden (cut trial in small plots) and the Hunter Valley (grazed crops in commercial farms).

Milk yield increased with increased concentrate but was similar for both forages. However, cows grazing forage rape had higher milk protein and lower milk fat contents than cows grazing Persian clover (Figure 11). These effects on milk composition were possibly due to the lower fibre content of forage rape (25.8% NDF and 24.4% ADF) compared with Persian clover (41.2% NDF and 34.6% ADF).

This study with grazing lactating dairy cows highlighted the potential of high yielding forage crops such as forage rape and Persian clover to manipulate milk composition in pasture-based dairy systems.

Summer feed

Summer is a critical period for forage quantity and quality in most regions. In warm-temperate and subtropical climates, well managed irrigated kikuyu grass can provide enough quantity of feed, but not quality. Kikuyu's high levels of fibre (>60% NDF) limits voluntary intake. In cool-temperate regions, both pasture quality and quantity may be an issue, for example with perennial ryegrass.

There are several alternatives to minimise the impact of the summer temperatures, particularly in a CFS with kikuyu as the main pasture. If a summer crop is grown for silage (e.g. maize or sorghum), the reduction in the grazing area will result in a higher stocking rate on the pasture area. You will have to feed more supplements to the cows as the amount of pasture available is divided by a larger number of cows. The result is that more kikuyu is utilised per hectare but less per cow, which helps reduce the adverse impact of the high-fibre content kikuyu on dry matter intake and milk yield.

Alternatively part of the cropping area can be used to grow grazable forages for the summer.

Summer forages suitable for grazing include grasses such as sorghum and millet; and summer legumes such as cow peas, faba bean, soybean or the subtropical species lab-lab. Faba bean tends to provide more feed in the spring than the summer. In temperate regions, brassica crops, particularly turnips and forage rape are an option for summer feed.

FutureDairy compared most of these species over the summer. Legumes were sown on 19 December and harvested in a single cut after 60 days. The range of total yields was 5–7 t DM/ha (Figure 12). This compares poorly with the higher yields of forage sorghum (although over a longer time period) of 10–12 t DM/ha on commercial farms and 18–20 t DM/ha at Camden (Figure 12).

All legumes contained 16–19% of crude protein, making them a viable option for the summer, but they were also high in fibre (45–50% NDF) and relatively lower in metabolisable energy (about 9 MJ/kg DM).

In another controlled experiment FutureDairy evaluated soybean under different irrigation regimes with up to three harvests (to simulate grazing), compared with one take-all harvest for silage. Forage yield was 8–12 t DM/ha over three cuts, and the quality was better maintained in the multiple-harvest system.

All these options should be considered in relation to the potential of the existing pasture system. For instance, a kikuyu-based pasture can easily achieve 10–12 t DM/ha over the summer-early autumn period, making any of the crops discussed here less attractive.

If this is the case in your farm or region, summer forage options may be still considered if they can have additional benefits (other than yield). For example they may have a role in increasing forage quality, shifting the pattern of forage growth, or for paddock renovation or weed control prior to establishing perennial pastures. Cultivar selection (e.g. sorghum ‘brown mid rib’ hybrids) and the timing and height of grazing are important. Yield may need to be compromised at times in favour of forage quality.

Intercropping two species is another strategy to improve forage yield and quality in summer and early autumn. A cheap maize seed (old hybrid or variety) can be sown in early autumn for grazing. High temperatures in late February or early March will ensure a very rapid germination and growth of maize plants.

Maize can be drilled at high densities (i.e. 120–140,000 plants/ha) with a normal maize seeder at 70 cm between rows while the other species can be drilled separately or broadcast with fertiliser. Fertiliser requirements will depend on soil analysis but a minimum of 100 kg DAP/ha is recommended.

FutureDairy evaluated maize sown with either brassicas (forage rape), Persian clover or short rotation ryegrass.

A total of four cuts from April to September resulted in total yields of more than 17 t DM/ha with the maize plus forage rape and 10–11 t DM/ha for the other treatments (Figure 13).

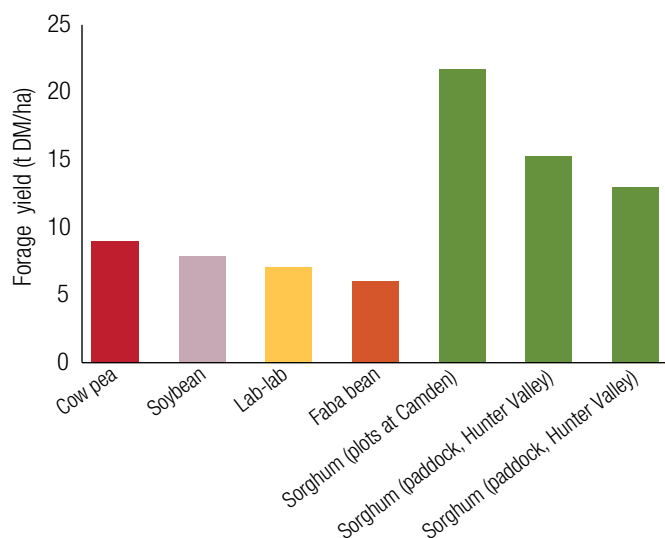


Figure 13. Total forage yield of maize intersown with forage rape, clover or short rotation ryegrass.

These yields should be considered in relation to nitrogen input, as this varied across treatments (e.g. from nil post-sowing for the maize-clover treatment to 120 kg N/ha for the maize-ryegrass and 230 kg N/ha for maize-brassica).

Overall, maize contributed about 5 t DM/ha in the first cut. Maize in early vegetative stages is very palatable and can be grazed from about 60 cm to 1.5 m of height without problems. Grazing before maize reaches 60 cm is not recommended as yield will be reduced. Utilisation and quality will drop if maize reaches more than 1.5 m before grazing.

The better yield of the brassicas was due to better early establishment of this species. Both the clover and the ryegrass were more affected by the rapid growth and shade of the maize plants.

FutureDairy also investigated intercropping maize with either soybean or lab-lab when the crop was sown in spring to be harvested in February for silage. The results suggest this intercropping option has little value. The forage yield of the intercropped maize was 24.8 t DM/ha, but the yield of soybean and lab-lab was only 0.8 and 2.7 t DM/ha, respectively. In addition, the practical complication of harvesting maize with a developed crop grown in between its rows needs to be addressed.

Grain risk

Forages that contain a component of starch, such as maize and grain forage sorghums, can be strategically used to reduce the risk associated with grain availability and pricing. Decisions to grow summer crops that yield a high proportion of grain (e.g. 30–50% of total dry matter yield in maize for silage) can be made relatively quickly and in response to likely grain prices and availability. This allows farmers to provide starch from home-grown forages. Similarly, brassica crops which have very high levels of plant-based soluble carbohydrates can follow maize crops in rotation to further reduce exposure to grain concentrates when supply is challenging.

Summary

There are forage options to suit any individual farm's needs.

Triple-crop CFRs are the best option to achieve a substantial increase in total forage yield. FutureDairy has consistently demonstrated the potential yield of these triple-crops exceeding 40 t DM/ha. Target yields of 30–38 t DM/ha may be more realistic on commercial farms.

Double-crop CFRs have a similar potential yield on small plots, but in reality yields are 20–30% lower than the triple-crop CFR. Economic/financial aspects must be considered as the lower yield of double-crop CFRs can be compensated by their lower cost due to lower nitrogen fertiliser input.

Simpler management is the main advantage of the double-crop CFR. A good trade-off is a double-crop CFR with a mix of two autumn-winter species (e.g. brassicas and short rotation ryegrass), followed by a summer crop such as sorghum for grazing or silage or maize for silage. These combinations are higher yielding than the more common double-crop CFR (e.g. short rotation ryegrass followed by maize) without the increased complexity of sowing three crops in one year. Refer to the Hunter Valley case studies tech notes of this series for additional information on these forage rotations.

Combinations of forages to suit wholly harvestable or wholly grazable forage needs are possible. High-yielding combinations of legumes (e.g. annual clovers for the autumn-winter period) and grasses (e.g. sorghum or maize) are very attractive due to the relatively high water use efficiency of the maize crop and the very high nitrogen use efficiency of the clover.

Brassica crops, in particular forage rape and leafy turnips, are becoming increasingly attractive to farmers in different regions. Forage rape consistently out-yielded clovers and the more traditional short rotation ryegrass but has a higher requirement for nitrogen. The greatest advantage of forage rape is its higher growth rate in early autumn, beaten only by late season maize sown in February or early March. FutureDairy has demonstrated the consistently high nutritive value or quality of forage rape, as shown by the maintenance of high quality and rumen degradability for much longer than other species and also by the improved milk protein content in grazing cows.

More suitable forage options for summer grazing remain the biggest challenge to achieve improved animal performance from home-grown feed. Forage sorghum, remains the best in terms of forage yield. Quality issues have improved with the newer brown mid rib (BMR) varieties, and better understanding of grazing management.

The use of legumes such as soybean or cowpeas may be an alternative, although yields are much lower and quality may not be much better. Legumes offer an alternative that may require lower levels of nitrogen fertiliser and may provide a degree of nitrogen fixation for subsequent winter crops.

When evaluating forage options, pay special attention to the risks associated with a CFR and the systems or infrastructure requirements and planning needs. These aspects are covered in more detailed in other tech notes of this series.

Although the principles of the different CFR rotations described here apply in most regions, the practical aspects of their implementation and the specific agronomic practices will vary substantially across regions and farms. FutureDairy strongly advocates involving your local agronomist, consultant or service provider decisions about the use of forages on your farm.

More information

Contact Associate Professor Sergio (Yani) Garcia
ph 02 9351 1621 or sergio.garcia@sydney.edu.au

References

Copies of these articles are available from FutureDairy. Contact 02 9351 1631 or the Dairy Australia library on 1800 824 377, email library@dairyaustralia.com.au

- Complementary forage system tech note series (www.futuredairy.com.au).
- Farina SR, Garcia SC, Fulkerson WJ (2011) A complementary forage system whole-farm study: forage utilisation and milk production. *Animal Production Science* 51(5) 460–470.
- Garcia SC, Fulkerson WF, Brookes SU (2008). Dry matter production, nutritive value and efficiency of nutrient utilization of a complementary forage rotation compared to a grass pasture system, *Grass and Forage Science*, 63, 284–300.
- Islam MR and S.C. Garcia (2011) Rates and timing of nitrogen fertilizer application on yield, nutritive value and nutrient use efficiency of early and late sown forage maize. *Grass and Forage Science* (in press).
- Islam MR and S.C. Garcia (2011) Effects of sowing date and nitrogen fertilizer on forage yield, nitrogen and water use efficiency and nutritive value of an annual triple-crop complementary forage rotation. *Grass and Forage Science* (in press).
- The Greener Pastures Project: Nitrogen for intensively grazed dairy pastures. Bulletin 4815 February 2011 ISSN 1833-7236. Department of Agriculture and Food, WA, Australia.