forage brassica development group

Management practices for forage brassicas

John de Ruiter, Derek Wilson, Shane Maley, Andrew Fletcher,
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Andrew Dumbleton and Wayne Nichol

June 2009

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Information presented in this booklet was compiled by members of the Forage Brassica Development Group (FBDG) as part of a MAF Sustainable Farming Fund project on "Forage Brassica Crops for New Zealand's Pastoral Industries". It summarises current knowledge on good management practices for brassicas.

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1. Introduction

Forage brassica crops are grown widely both as a supplement and as an alternative to pastures in New Zealand's animal production systems. Brassicas are important for their potential to produce high quality and high yields of forage that can be fed '*in situ*' from early summer through to late winter and for their role as break crops during pasture renewal.

- They produce high quality feed in periods of pasture feed deficit.
- They are a feed substitute to avoid pasture-related health problems such as facial eczema and ryegrass staggers.
- Brassica break crops provide advantages for pasture renovation by reducing weeds, pests and diseases, and creating better soil conditions and cleaner seed beds for establishing new pastures.

Many problems with brassica production arise from poor sowing techniques and inadequate seed bed preparation. Once a good crop has been established, the aim is to utilise it with minimum wastage. Various options for crop establishment have been investigated in field trials and demonstrations. Many cases of poor crop growth can be traced to inadequate preparation of the seed bed.

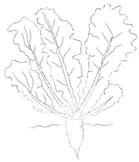
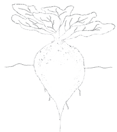
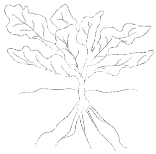
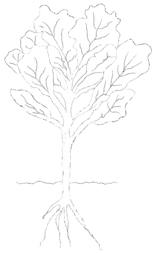
Direct drilling can have advantages for establishment when conditions are ideal for germination and early growth, and for reducing pugging during winter grazing and therefore less loss of valuable standing feed. However, this practice must also be done well to produce a good crop.

In most crop trials, the best results are achieved by conventional drilling. When crops are established with conventional cultivation, desired plant populations are more likely to be achieved and there is less pressure from weeds and insects. The influence of management of brassica crops during growth and consequent effects on feeding and utilisation are described in this booklet.

2. Brassica species and cultivars

- Brassicas used for forage in New Zealand are classified into five types: swedes, kale, rape, turnips and leafy turnips (Table 1) (Stewart 2002).
- Different species and cultivars within each species have characteristics that suit different farming systems.
- All are biennials – they grow vegetatively in the first season (storing yield in bulbs or stems) and produce seed in the second season.

Table 1: Forage brassicas most commonly used for animal feeding in NZ (Adapted from: Stewart A, Charlton D ed. 2003. Pasture and forage plants for New Zealand. Grassland Research and Practice Series No. 8).

Common name	Latin name	Growth habit	Vegetative description
Leaf turnip (or turnip cross)	*Brassica rapa*; syn. B. *campestris*		• Non-bulb producing • Swollen tap root provides multiple growing points • Able to regrow after grazing • Leafy
Bulb turnips	*Brassica rapa*; syn. B. *campestris*		• Fleshy bulb • No neck • Yellow fleshed (hard) • White fleshed (soft)
Swedes	*Brassica napus* spp. *napobrassica*		• Fleshy bulb • Obvious neck • White or yellow fleshed
Rape	*Brassica napus* spp. *biennis*		• Numerous leaves • Fibrous stem • No bulb or fleshy stem • Grows to various heights
Kale (Chou Moellier)	*Brassica oleracea* spp. *acephala*		• Large swollen stem with varying leaf percentage • Stem – woody outer layer, soft fleshy marrow • Grows to various heights

2.1 Summer/autumn feed options

Leaf turnip

- A multi-graze Chinese cabbage x turnip hybrid brassica that is grown widely in New Zealand, mainly to supplement pasture production from mid-summer to early winter.
- Leaf turnip produces vigorous growth of high quality leaf, with little stem or bulb. The low growing point allows for multiple grazing.
- Sowing can be from October through to early autumn. They are fast maturing with each growth cycle taking from 50 to 70 days, depending on sowing time and temperature.
- Plants are shallow rooted and therefore susceptible to drought and low soil fertility. Multiple graze rapes may be more suitable in these environments.

Leaf turnip (‘Pasja’) grown in mid Canterbury with ‘Barkant’ turnips (left) and ‘Gruner’ kale (right). Crops were sown on 28 November 2008 (photo taken on 19 February 2008).

Rape

- Rapes have traditionally been used as a single graze finishing crop for lambs during summer, and regrowth used for finishing ewes in summer dry environments.
- New cultivars, e.g. 'Titan' and 'Goliath', are multigraze rape x kale hybrids that are suitable for sowing in spring and autumn with feeding to all stock classes.
- They may be mixed with Italian and short-rotation ryegrasses for multiple grazing.
- Rape is a high quality feed, with high protein content and good acceptability to stock but needs to mature before the crop is fed to livestock. Maturity dates differ with cultivar.

Early maturing types

Rape cultivars 'Titan' (centre) and 'Goliath' (right).

- Take 70–90 days to produce a potential yield from 8 to 10.5 t DM/ha.
- Crops can be multi grazed.
- Common cultivars are 'Winfred' and 'Titan'.
- The cultivar 'Titan' has improved herbage yield, winter keeping quality, stock palatability and regrowth.
- Older cultivars such as 'Rangi', 'Emerald', 'Giant' and 'Maxima Plus' are more suited to summer grazing.

Late maturing types

- Take 90–110 days to produce a potential yield up to 10.5 t DM/ha.
- Multiple grazing is an option.
- New cultivars have kale in the genetic background (interspecies rape x kale cross).
- The cultivar 'Goliath' is a typical late maturing type.

Turnips

- Can be sown from October to February and fed from summer through to late winter.
- Well adapted to grow in most locations throughout New Zealand.
- There are a wide range of types with differing bulb shape, flesh colour (yellow and white), leaf:bulb ratio and keeping quality.
- The hard flesh types, e.g. ‘Green Globe’, are adapted to cool, moist conditions and keep better than soft types, e.g. ‘York Globe’.
- Yield is variable, depending on crop management and growth environment.

‘Green Globe’ turnips produce large bulbs given good fertility and space to grow.

Early maturing types (Tankard types)

- Take 60–90 days to reach grazing maturity.
- Are most commonly grown for summer grazing in dairy systems to boost milk solid production when pasture quality is in decline.
- Are less frost tolerant than slower maturing types.
- Have a higher leaf:bulb ratio than later-maturing cultivars.
- Have a distinctive tankard-shaped bulb, with 2/3 of the bulb above the soil surface.
- Often are less tolerant of low soil fertility than later maturing 'Green Globe', and respond strongly to fertiliser application.
- Typical cultivars are 'Barkant' and 'Rival'.

Medium maturing types (Soft turnips)

- 'York Globe' and 'New York' take 80–100 days to reach grazing maturity.
- Features are similar to 'Green Globe' except for their earlier maturity.

Late maturing types, e.g. 'Green Globe'

- Take 90–120 days to reach grazing maturity.
- Have a lower leaf:bulb ratio, better frost tolerance and better winter keeping properties than early maturing types.
- Can tolerate lower soil fertility so can be useful on lighter alluvial soils.
- Often favoured for winter feed in areas where a cool, short growing season limits the use of slower maturing swedes and kale.

2.2 Winter feed options

Kale

- Kale is the traditional winter feed crop, although it can also be used as a summer feed and does regrow after light grazing in February/March (e.g. 'Kestrel' and 'Regal').
- Has a deep root system and, therefore, good tolerance to drought.
- Has good tolerance to most insect pests and can be used as a second brassica crop because of its tolerance to club root and dry rot.
- Usually sown in November and December to provide large amounts of high quality feed during winter.
- Kale can be grazed at any time, but optimum maturity is around 18–26 weeks and it is usually single-grazed from about late May to late August.
- Yield is variable, depending on crop management and environmental conditions. It responds well under favourable soil moisture conditions and high soil fertility.
- Yield, stem quality and palatability differ with cultivar selection. Quality is usually better with smaller stems when sown at higher plant populations.
- Used as a first and second crop due to greater tolerance to diseases such as club root and dry rot than other brassica options.

Good kale grazing management is a key to profitable winter feeding.

Test crop of kale sown on 26 October, Canterbury (photo taken on 20 March).

Short types, e.g. 'Kestrel'

- They have a higher leaf:stem ratio, higher whole-plant digestibility and produce lower yields than taller types but are of higher quality and palatability.
- Potential yields of 12,000 kg DM/ha.
- They are suited to grazing by sheep, lambs, weaner cattle and deer because of their shorter height.

Intermediate types, e.g. 'Sovereign' and 'Regal'

- They are intermediate in height with the highest leaf yield and high leaf:stem ratio.
- They produce yields up to about 15,000 kg DM/ha.
- They are suitable for grazing by sheep, cattle and deer.

Giant types, e.g.'Gruner', 'Rawera' and 'Caledonian'

- Their height (sometimes up to 2 m) means that they are only suitable for cattle and older deer.
- They have a lower leaf:stem ratio, lower whole-plant digestibility and produce higher yields (up to about 17 t/ha DM/ha) than shorter types. In favourable conditions, yields above 20 t DM/ha are possible, but utilisation is poorer than short and intermediate types.
- Giant kale will regrow from light grazing or cutting, but regrowth rates are slow and it is advisable to use 'Kestrel' or 'Regal' kale if regrowth is required.

High yielding 'Gruner' kale grown at Lincoln. Optimum management resulted in a yield of 18.2 t/ha by 12 March.

'Gruner' kale cut at varying heights. In the foreground is regrowth from cutting to 15 cm height, followed by cutting to 30 cm and uncut at the rear.

Kale regrowth following cutting to 5 cm above ground.

Swedes

- Swedes have low tolerance to drought and perform best in cool, moist environments.
- Usually sown from 20 November until the end of December to produce high yields of high quality winter feed. Yields above 20 t DM/ha are possible in favourable conditions.
- Swedes are a first year cropping option only because of their susceptibility to disease (particularly dry rot and club root).
- Animal performance is often better on swedes than on kale because of the high feed quality of the bulbs. Whole plant digestibility is usually higher in swedes and higher utilisation can often be achieved with good grazing management.
- Swedes can be sown with rape (3–4 rows of swedes: 1 row of rape) to raise protein content in a winter crop.

Early maturing types, e.g. 'Major Plus' and 'Dominion'

- Have yellow-flesh soft bulbs, which makes them suitable for grazing by young stock.
- Have less disease tolerance than newer cultivars like 'Aparima Gold' and 'Keystone' but produce 10–12% higher yields than older ones like 'Doon Major'.

Late maturing types, e.g. 'Aparima Gold' and 'Keystone'

- 'Aparima Gold' (a yellow-fleshed cultivar) has better club root resistance and higher leaf:bulb ratio than older cutlivars.
- 'Keystone'' (white-fleshed cultivar) also has high high leaf:bulb ratio and improved resistance to dry rot but not to club root.
- Fast and slow maturing crops can be sown together to spread the grazing. Animals adapt faster if they graze the early-maturing, soft-flesh ones first and then move on to later maturing types that keep better into late winter.

Rape

Although they are principally summer/autumn feeds, ‘Goliath’ and ‘Titan’ rape are also good winter options as they have some kale genetics in their parentage.

High quality ‘Goliath’ rape sown on 3 February at Lincoln and ready for early winter feeding (photo taken on 27 April).

2.3 Brassica cultivars

- A wide range is available in New Zealand.
- Inclusion on this list does not represent endorsement by the FBDG, and the FBDG is not responsible for any errors or omissions.
- Farmers requiring further information about cultivars should seek advice from the marketing companies.

	Cultivar	Characteristic	Marketer
Leafy turnips			
	Hunter	Early maturing	Agricom
	Pasja	Early maturing	PGG Wrightson Seeds
	Tyfon	Early maturing	Agriseeds
Rape			
	Bonar	Medium height / late maturity	PGG Wrightson Seeds
	Giant	Tall / late maturity	Various
	Goliath	Tall / late maturity	PGG Wrightson Seeds
	Greenland	Tall / late maturity	Seedforce
	Interval	Tall / late maturity	Agriseeds
	Leafmore	Tall / late maturity	Stevens Seeds
	Maxima Plus	Medium height / early maturity	PGG Wrightson Seeds
	Rangi	Medium height / early maturity	Various
	Titan	Medium height / early maturity	PGG Wrightson Seeds
	Wairoa	Medium height / early maturity	PGG Wrightson Seeds
	Winfred	Medium height / early maturity	Agricom
Turnips			
	Appin	Multiply crowned stubble turnip	Wrightson Seeds
	Barkant	Tankard bulb / early maturity	Wrightson Seeds
	Dynamo	Summer turnip / early maturing	Agriseeds
	Green Globe	Globe bulb / late maturing	PGG Wrightson Seeds
	Green Resistant	Globe bulb / late maturing	PGG Wrightson Seeds
	Manga	Globe bulb / late maturing	PGG Wrightson Seeds
	Marco	Globe bulb / early maturing	Cropmark
	New York	Globe bulb / medium maturing	Agricom
	Rival	Tankard bulb / early maturing	Agricom
	York Globe	Globe bulb / early maturing	PGG Wrightson Seeds
	White Star	Stubble turnip / mid maturing	Seedforce

Kale			
	Burly	Giant type	Speciality Grains and Seeds Ltd
	Caledonian	Giant type	Agriseeds
	Coleor	Medium type	Cropmark
	Gruner	Giant type	PGG Wrightson Seeds
	Keeper	Medium type	Agriseeds
	Kestrel	Short type	PGG Wrightson Seeds
	Sovereign	Intermediate type	Agricom
	Rawara	Giant type	Various
	Regal	Intermediate type	PGG Wrightson Seeds
Swede			
	Aparima Gold	Medium maturity / yellow fleshed	Wrightson Seeds
	Dominion	Early maturity / yellow fleshed	Agricom
	Doon Major	Early maturity / yellow fleshed	Various
	Highlander	Late maturity / white fleshed	PGG Wrightson Seeds
	Invitation	Late maturity / yellow fleshed	Agriseeds
	Major Plus	Early maturity / yellow fleshed	PGG Wrightson Seeds
	Keystone	Medium maturity / white fleshed	PGG Wrightson Seeds
	Winton	Medium maturity / yellow fleshed	PGG Wrightson Seeds
	Virtue	Early maturity / yellow fleshed	Agriseeds

3. Crop establishment

3.1 Paddock selection

- Planning for brassica crops should include a long-term strategy that takes account of crop sequences, maintenance of soil fertility and structure, ability to create a suitable seed bed and weed and pest control as well as the required feed supply.
- Care should be taken to manage soil fertility in low fertility paddocks designated for regrassing.
- Access to water, ease of subdivision and provision of a run-off need to be considered.
- Brassicas perform better on well drained sites.

3.2 Soil preparation and sowing

Sow seeds in a fine, firm, moist seed bed, with good seed-soil contact. Aim to achieve a good distribution of seed to produce a uniform plant population.

Definition of sowing methods

Broadcasting/oversowing = seed distributed on to the surface with a seed or fertiliser spreader followed by rolling and/or harrowing.

Direct drilling/no till = sowing into an uncultivated soil without prior soil disturbance. Spray treatment may be single or multiple applications to reduce the residual cover and for conserving soil moisture. Direct drilling is also referred to as overdrilling or conservation tillage. Sod seeding is direct drilling into uncultivated pasture.

Conventional drilling = drilling with coulter type drill after ploughing and several implement passes to create a fine tilth.

Roller drilling = surface broadcasting with light rolling with or without harrowing and rolling.

Undersowing = establishment of one species under another.

Conventional cultivation and drilling


Traditional cultivation practices produce the best seed bed for brassica establishment.


Consolidation using tyne harrows and a Cambridge roller is highly recommended.


Ideal firm cultivated seed bed with all trash buried.

Cultivation should produce a seed bed at minimum cost.

- Bury plant material, such as turf or crop residues, at least 25 cm deep with a mouldboard plough.
- Discs do not bury plant material.
- Reduce the bulk density to encourage root penetration.
- Encourage mineralisation of plant nutrients. Mineralisation may take several months under low fertility and a high soil C/N (carbon/nitrogen) ratio.
- Take action to control both annual and perennial weeds.
- Conserve soil moisture through fallowing and spraying out old pasture at least 3 weeks before sowing. In low rainfall environments, a 3–4-month fallow may be required.
- Power harrows produce a fine tilth but do not produce a consolidated seed bed.
- Subsoiling may increase yield by up to 30% if there is restricted root penetration due to compaction.

Direct drilling and coulter drilling

- Places the seed in contact with soil moisture to promote rapid, uniform germination and emergence.
- Allows fertiliser and/or insecticides to be sown close to the seed for maximum benefit.
- Uses less seed than broadcasting, but are slower and more expensive than broadcasting.

Direct drilling

Good establishment with direct drilling requires good preparation.

- Direct drilling of seed into uncultivated soil requires a complete kill of existing vegetation with 1–2 applications of herbicide before sowing.
- Under dry conditions the first spray should occur at least 2 months prior to drilling to conserve soil moisture.

Land preparation and result with direct drilling. Block was sprayed out on 17 October with Roundup at 5 L/ha. Soil water conservation was significant in the period before sowing on 18 December. Good populations were achieved (63 plants per m^2.) This crop was subsequently sprayed with Gallant for grass weeds, but was not sprayed for broadleaf weeds.

Paddock management before direct drilling. A double spray programme comprising 4 L/ha Roundup on 20 November and a second spray on 11 December in preparation for direct drilling on 18 December.

- Higher rates of N fertiliser are required with direct drilling as there is little mineralisation compared with full cultivation (see section 4.2).
- Pests such as slugs and springtails are more likely to cause damage when direct drilling.
- There is some evidence that less soil pugging occurs during grazing of direct drilled crops than in those sown using full conventional cultivation.

Direct drilling into cereal stubble in autumn can ensure rapid crop turnaround and rapid autumn growth in warm soils.

Ridging

- Typically used for swedes.
- Places the seed on top of ridges spaced 66 cm apart.
- Allows the incorporation of high analysis (acid) fertiliser well under the seed and places Superphosphate with the seed.
- Allows inter-row cultivation for weed control if required.
- Ridging provides better drainage and the bulbs are more accessible to animals as some soil falls away with treading.
- Uses less seed than drilling or broadcasting (Table 4).
- Allows for kale and swedes to be sown in separate rows, which makes break fencing easier.
- Is unreliable in dry conditions (< 800 mm rainfall) as the seed is placed on top of the ridge where it is likely to dry out.

Excellent result for ridged swedes in Southland. This crop was grown with thorough cultivation, and with optimum fertility and weed management.

Broadcasting

- Seed is distributed on to the soil surface using a range of spreading devices.
- Where the seed bed is cultivated, broadcasting may be followed by harrowing and rolling or using stock to bury the seed.
- Enables a large area to be covered quickly, but fertiliser and insecticide cannot be placed next to the seed where it is most effective.
- Is unreliable in dry conditions and requires higher sowing rates than coulter drilling (Table 2).

Patchy result with broadcasting seed.

Roller drill

- No facility to place fertiliser and agrichemicals adjacent to the seed.
- While most seed falls into the grooves formed by the roller, there is less control over sowing depth and soil/seed contact than with a conventional drill.
- Used widely for sowing pastures and brassicas in higher rainfall areas, particularly in the North Island.
- Roller drills still require a well consolidated seed bed to avoid sowing the seed too deep.

A Cambridge or specialised rung-type roller with a seed box fitted to the back.

Sowing rate

- Seed size differs between brassica types and also between and within lines of each type.
- Recommended seeding rates are given in Table 2. The recommended rate differs among brassica types and for different sowing methods.

Table 2: Recommended seeding rates for forage brassica types and sowing methods (coated seed).

Crop	Sowing method	Sowing rate (kg/ha)
Turnips	Ridged	0.5–0.7
	Drilled 15 cm rows	0.8–1.0
	Broadcast	1.0–3.0
Swedes	Ridged	0.5–0.7
	Drilled 15 cm rows	0.8–1.0
	Broadcast	1.0–3.0
Kale	Ridged	1.7–3.5
	Drilled 15 cm rows	3.0–5.0
	Broadcast	5.0
Rape	Drilled 15 cm rows	2.5–4.0
Leaf turnips	Drilled 15 cm rows	3.0–4.0
	Broadcast	5.0

- Low sowing rates may be more accurately applied by adding the seed to a carrier such as inert seed (killed by heating). Seed can also be mixed with ‘drilling’-type fertilisers, but mixing with acid fertilisers should be avoided.
- Typical seeding rates and target populations for brassica types are shown in Table 3.

Table 3: Thousand seed weight (TSW), number of seeds per kg, typical seeding rate, and target establishment for the brassica types (uncoated).

Crop type	TSW (g)	Seeds per kg (x1000)	Sowing rate (kg/ha)	Target plants per m^2
Turnips				
– Barkant (Diploid)	2.5	400	1.0	30
– Green/York Globe (Diploid)	2.5	400	1.0	30
Swedes	3.0	333	0.7	20
Kale	4.0	250	4.5	80
Rape	3.5	286	4.0	100
Leaf turnips				
– Diploid, e.g. Pasja	2.8	357	3.5	110
– Tetraploid, e.g. Appin	4.0	250	5.0	110

Sowing depth

- The optimum sowing depth for brassica seed is 1.0–1.5 cm.

Growth responses to temperature

- Sowing time and thermal time requirements for maturation have a major effect on yield potential. Therefore, choose cultivars that are appropriate for the location and have the appropriate maturity range.
- Thermal time (˚C days) above 4˚C determines the rate of leaf appearance, the amount of light a crop intercepts, and therefore drives growth. ‘Green Globe’ turnips require about 50˚C days to produce each leaf.
- As a guide, brassicas accumulate yield at about 1.10 t DM/ha per 100˚C days.
    - A kale crop sown on 1 December near Invercargill experiences about 1540˚C days from November to April, so has a potential yield for the period of about 17 t DM/ha.

Crop failures and alternatives

- About 20% of brassica crops are poor, mainly because they fail to establish successfully.
- The number of salvage alternatives declines rapidly as the season progresses.
    - A failed crop of swedes or kale sown in December can be resown with turnips. Sow ‘Green Globe’ in January or ‘York Globe’ in February.
    - Rape can be sown after a failed kale crop.
    - A cereal greenfeed crop can be either direct drilled into a failed brassica crop or sown alone. This option is possible until April in most parts of New Zealand. Herbicide application history on the failed brassica crop must be considered due to withholding periods for sowing cereal green feed crops.

4. Soil fertility and fertiliser management

Brassicas are grown on soils with a wide range of background soil fertility. There are no standard recommendations for fertiliser management because each crop has a different yield potential and therefore different nutrient requirement. Also, the type and amount of fertiliser needed to get optimum crop performance depends on the gap between nutrient demand to support yield and the nutrient supply from the soil. The yield response varies according to nutrient availability from soil and fertiliser.

New forecasting systems ('Brassica Calculators') have recently been developed to predict fertiliser application rates that optimise the profitability of each crop based on:

- an estimate of potential yield
- the availability of each nutrient from the soil, based on a soil test result
- the threshold soil fertility level for each nutrient
- the yield reduction caused by inadequate availability of each nutrient
- an economic analysis based on the crop value and cost of each nutrient.

Variation in paddock fertility, in particular, the variation in N availability and inadequate fertiliser supply have a strong effect on the yield potential.

4.1 Principles

- High yielding brassica crops have large mineral nutrient requirements.
- Crops respond to total nutrient availability from soil and fertiliser and every crop has a different fertiliser requirement. Use the kale calculator available from Ballance Agri-nutrients to calculate the economics of response to fertiliser and determine the balance between the value of the additional yield and the cost of the fertiliser required for optimum growth.
- The challenge is to decide how much fertiliser, and what type, to apply to each crop to get an optimum response in terms of both yield and economic return.
    - N requirement in most brassica crops ranges from 250 to 500 kg N/ha. They respond strongly to N application, especially on soil with less than 150 kg N/ha anaerobically mineralisable N.
    - Low-yielding crops or soils with high N fertility may not give a response to N.
    - The crop requirement for P is quite low, but P is vital for brassica establishment. For shallow-rooting brassicas and those grown on soils with low P, the application of P 'down-the-spout' at sowing gives the greatest response.
    - Most New Zealand soils (except volcanic soils) supply enough K to meet crop demand. Although the crop requirement for K is high, yields seldom respond to K.
    - Brassica yields seldom respond to S fertiliser.

Typical symptoms of N deficiency in kale.

4.2 Fertiliser guidelines

Pre-sowing

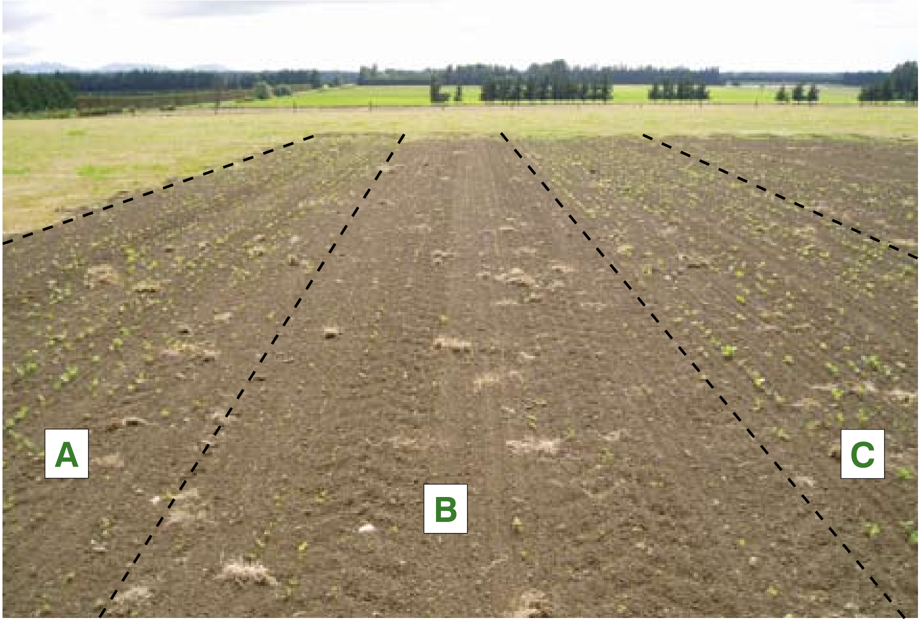
Measure soil pH and get a soil test done well before sowing as part of paddock selection and preparation. Soil tests should include standard quick test values for macronutrients, as well as elemental boron and anaerobic mineralisable N levels.

pH should be at least 5.6 but ideally between 5.8 and 6.2. If pH is low, apply lime to increase it (1 t lime/ha will increase pH by ~0.1).

Lime should be applied up to 1 year before sowing to allow time for soil pH to change.

At sowing

- Macronutrients (N, P, K, S and Mg):
  - Make a realistic estimate of the crop's expected yield, taking account of factors such as sowing date, water availability and anticipated pest problems. Use the kale calculator to determine potential yield.
  - Calculate the crop's demand for each nutrient, based on the estimated yield and the crop's content of each nutrient (Table 5).
  - Estimate the soil's ability to supply each nutrient by comparing the soil test results with the information in Table 5.
- Estimate the amount of each nutrient required from fertiliser to meet the nutrient shortfall needed to reach the target yield. Work out appropriate fertiliser mix and application timings as follows:
  - All P, K, S, Mg and micronutrients such as B should be applied at sowing.
  - Apply a small amount of starter N at sowing, and apply the bulk of the N requirement later.
  - Down-the-spout application of fertiliser at sowing has been shown to be more effective than fertiliser broadcast at sowing (especially P) for shallow-rooted crops such as 'Pasja' and turnips.



Fertiliser effect on early seedling growth in cultivated soil (seed drilled). Plots had 350 kg/ha DAP broadcast at sowing (**A**), control with no fertiliser (**B**), or 350 kg/ha DAP driller below the seed (**C**).

Demonstration of the value of fertiliser for the germinating seed that was sown by drilling (**A** and **B**) or broadcasting (**C**). Fertiliser treatments were either control (no fertiliser) A and C or 350 kg/ha DAP drilled below the seed.

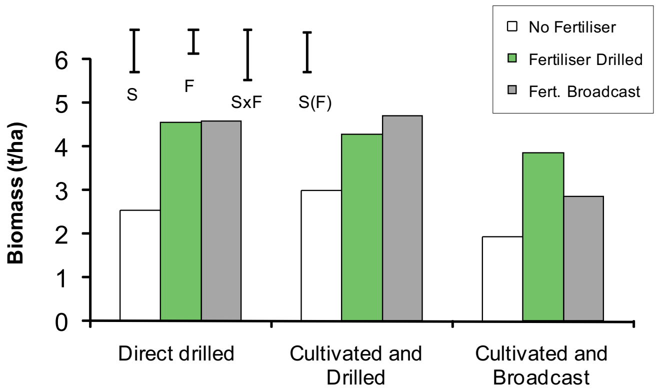
Typical N deficit in kale during mid growth stage.

N deficiency in direct-drilled kale. Management of N fertility is essential for good yield of kale in a direct drilled situation. The base N and P levels were as above.

Effect of soil N release from cultivation. The treatments are direct drilled crop (left) and ploughed + cultivated block (right).

Comparison of control (no N) and well fertilised (350 kg/ha DAP) direct drilled treatments at Methven on 4 April (sown 28 November). Base fertility comprised Olsen P=10 and anaerobically mineralisable N=190 kg/ha.

A seeding method (direct drilled, conventional drilling or broadcast) x fertiliser (control, fertiliser drilled or fertiliser broadcast) trial at Methven 2007–08 showed that crops sown by broadcasting were less productive than either direct drilling or conventional sowing. Fertiliser placement (drilled with the seed or broadcast) had an effect on early plant survival, but differences were not apparent close to crop maturity. The control treatment (no fertiliser) always yielded less than treatments supplied with 350 kg/ha DAP at sowing. Applying the fertiliser down the spout gave no advantage for yield in 'direct drilled' or 'ploughed + cultivated' treatments (Figure 1). However, when seed was broadcast, there was a slight yield improvement by drilling the fertiliser rather than broadcasting.



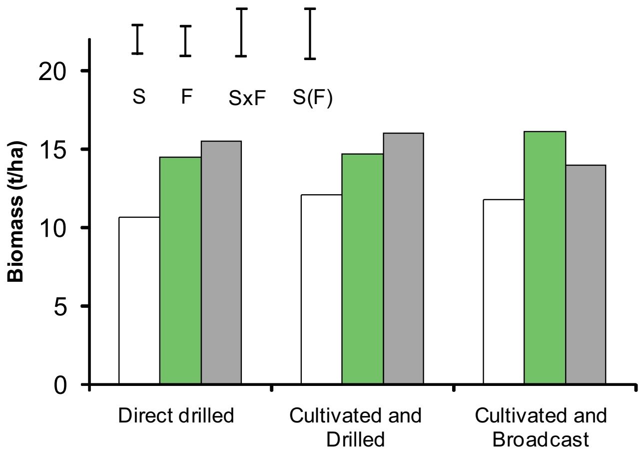


Figure 1: Kale crop yield measured on 12 February 2008 (**A**) and 26 May 2008 (**B**), (sown on 28 November). Vertical bars are LSD (5%) for sowing treatment (S), fertiliser (F), sowing x fertiliser interaction (S x F) and fertiliser treatments within sowing treatments (S(F)). Fertiliser (DAP) was applied at 350 kg/ha.

Responses to P and N fertiliser were not consistent across all trials (Table 4).

- The response to P rate was mostly not significant for deep rooting kale crops.
- There was usually a response to N rate.
- Yield was usually not affected by sowing method.

Response to N and P applied at sowing. Plot on the right had 150 kg/ha applied at sowing while the centre plot (control) had none. Olsen P level at sowing was 8.9.

Table 4: Summary of significant effects (Y = Yes and N = No) in brassica trials involving P fertiliser rates, sowing method (direct drilling, conventional cultivation, seed broadcast) and N fertiliser rate.

Site	Year	Mean Olsen P (Range)	AMN Available soil N (Range)	Crop	Crop response			
					P rate	Sowing method	N rate	N x P interaction
Lincoln	2007/08	13.3 (9-17)	76 (63-107)	Kale Pasja	Y Y	N N	- -	N N
Central North Island	2004/05	22 (10-46)[a]		Kale	N	N		N
Waikato	2007/08	11 (7-18)	187 (143-225)	Kale	N	N	Y	N
Canterbury (Te Pirita)	2004/05	10.7 (6-18)	65 (51-86)	Kale	N	N	Y	N
Canterbury (Fairlie)	2004/05	30.9 (26-36)	126 (85-176)	Kale	N	Y	N	N
Canterbury (Bankside)	2007/08	7.1 (5-11)	187 (143-225)	Kale	N	N	Y	N
Canterbury (Methven)	2007/08	18	190	Kale	Y	N	Y	Y
Southland (Wallacetown)	2007/08	8.9 (7-12)	157 (113-255)	Kale	N	N	Y[b]	N
Southland (Gore)	2007/08	10	160	Kale	Y[b]	Y	N	N

[a] Central North Island, P retention = 62%.

[b] Probability = 0.08.

Post-sowing N applications

Applications of N are recommended at 4–6 weeks and again at 8–12 weeks after emergence. The amounts depend on the soil supply and crop demand, as discussed previously.

- Use a 50:50 split application, about 6 and 12 weeks after crop establishment.

Nitrogen fertiliser response from application of 80 kg/ha N (urea) applied 4 weeks after sowing on a low N site. A visual effect (background) was present 10 days after application. Foreground plot was the control (no N applied).

Nutrient demand – macronutrients

- Crop nutrient demand depends on yield and nutrient concentration.
- Take into account location, species and water supply. Longer duration crops have higher yield potential and greater nutrient demand. Dryland crops on shallow soils require less nutrients than fully irrigated crops.
- Typical yields ranges are: leafy turnip 2–8 t/ha, rape 3–10 t/ha, turnips 2–12 t/ha, kale 5–20 t/ha and swedes 5–20 t/ha.
- Multiply potential yield by nutrient content (Table 4) to calculate nutrient requirement.
- Regardless of the test results, it is possible that a soil will not be able to supply nutrients fast enough for a rapidly growing crop with high yield potential. Therefore, even if fertility is high, an economic response to fertiliser application can occur.
- There are major differences among the macronutrients.
    - P reacts strongly with the soil, so Olsen P values change slowly.
    - In contrast, levels of N and S can change quickly and, as they are mobile, they can be leached by rainfall or irrigation. Most of the N and S in soil are bound to organic matter. Significant, but very variable, amounts are released by mineralisation during the growing season.
    - Most New Zealand soils have a high capacity to supply K, so yield responses to K fertiliser application seldom occur.
- Too much N or S fertiliser may cause potential animal health problems.
    - High nitrate content in forage can poison grazing animals. Recent research has demonstrated that forage brassica crops can take up large amounts of N that are not necessary for growth. Therefore, avoid excessive N applications.
    - SMCO (s-methyl cysteine sulphoxide) is a S compound in forage brassicas that can cause animal disorders (Section 7). Both N and S are important components of this compound.
    - On a high S (>5 Quick test) site do not apply S as there is seldom a yield response.

Table 5: Typical nutrient concentrations (%) of brassica crops.

Crop		N	P	K	S	Mg
Kale	Leaf	2.5–3.5	0.31	1.7	0.77	0.17
	Stem	1.5–2.0	0.27	2.8	0.48	0.17
Swede	Leaf	2.5–3.5	0.30	1.5	0.76	0.17
	Bulb	1.5–2.5	0.27	1.5	0.40	0.09
Turnips	Leaf	2.5–3.5	0.34	2.8	0.74	–
	Bulb	1.5–2.5	0.30	3.8	0.61	–
Rape	Leaf	3.0	–	–	–	–
Leafy turnip	Leaf	2.5	0.3	1.6	0.57	0.17

- For example a leafy turnip crop yielding 6 t/ha would take up:
  - 6000 kg × 2.5% = 150 kg N/ha; and 6000 kg × 0.3% = 18 kg P/ha.
- While a 20 t/ha kale crop (comprising 4 t/ha leaf and 16 t/ha stem) would take up:
  - 4000 kg × 3.0%N + 16000 kg × 1.8N% = 408 kg N/ha.
  - 4000 kg × 0.31%P + 16000 kg × 0.27%P = 55.6 kg P/ha.

Nutrient demand – micronutrients

- The demand for micronutrients in high yielding winter brassicas is comparatively small.
  - Copper (Cu) content is about 3.0 mg/kg (i.e. 3.0 ppm), so the requirement ranges from 18 to 45 g/ha for yields from 6 to 15 t/ha respectively.
  - Cobalt (Co) content is much lower at about 0.06 mg/kg so the requirement is less than 1 g/ha, even for high-yielding crops.
  - Boron (B) content is relatively high, about 26 mg/kg, so the requirement ranges from 156 to 390 g/ha for yields from 6 to 15 t/ha respectively. Values for ryegrass and clover are about 6–12 and 13–16 mg/kg, respectively.
- The corresponding figures for leafy turnips are:
  - Copper, about 3.5 mg/kg, so the requirement ranges from about 7 to 28 g/ha for yields from 2 to 8 t/ha, respectively
  - Cobalt, about 0.08 mg/kg so the requirement is less than 1 g/ha
  - Boron, about 27 mg/kg, so the requirement ranges from about 54 to 216 g/ha for yields from 2 to 8 t/ha.
- Trials have shown that applying Cu in fertiliser does not increase Cu uptake.
- In contrast, Co and B applied in fertiliser increases uptake in both cases. However, recovery of the applied nutrients is very low because of their low mobility in soil.
  - Indicative minimum soil test values for three important micronutrients, Cu, Co and B, are 0.8, 1.0 and 0.8 mg/kg, respectively. Applications of Cu, Co or B seldom affect yield but can influence nutritional value for grazing animals.
  - A base application of B at 1.5 kg B/ha is usually recommended to reduce the incidence of hollow heart in swedes.

Typical symptoms of hollow heart in swedes.

5. Water management

5.1 Guidelines for dryland crops

Without irrigation, water availability is the main environmental source of yield variation in brassicas.

- Yield is limited by the amount of stored soil water and in-season rainfall.
  - Assuming a full profile, the amount of available soil water is determined by the depth of the root zone and the ability of crops to extract the water.
  - Unless root growth is impeded, most brassica crops will extract water to a depth of ~1.0 m.
  - Water available in the 1.0 m root zone ranges from about 80 mm in light, shallow soils to about 140 mm in heavier, deeper soils.
  - Crops differ in their ability to extract water from the root zone. In general, kale and rape have more vigorous root systems than root crops (swedes and turnips) and, therefore, they can utilise more of the stored water.
  - Without rainfall, stored soil water to 1.0 m depth is enough to produce DM yields ranging from about 1.6 to 2.8 t/ha (assuming 20 kg DM/ha/mm of water used).
  - Additional yield depends on rainfall, which can be variable from year-to-year.

- Avoid growing dryland crops in light soils with low water holding capacity.
    - The small amount of water available in light soils is used quickly and the risk of low yields is very high in seasons with low rainfall.
    - Heavier soils store more water and retain more from within-season rainfall.
- Provide an optimum rooting environment for crops to maximise rooting depth.
    - This will maximise access to stored soil water.
    - Swedes and turnips have relatively weak root systems, and soil conditions should be managed to minimise restrictions to root penetration.
    - Avoid heavy, poorly drained soils or soils with barriers to root penetration, such as pans, and poor aeration. Deep cultivate if necessary.
- Sow early and choose brassica types that avoid mid and late season drought.
    - Low rainfall and damaging water deficit occur most often late in the season. The risk of encountering deficits can be reduced by sowing early and/or choosing quicker maturing brassica types (Section 2).
- Maximise productive use of available water.
    - Minimise the component of evapotranspiration (ET) lost from the soil and thereby ensure that most of the water is transpired by the crop.
    - Control weeds to avoid non-productive water use by weeds.
    - Minimise soil evaporation by maintaining a healthy leaf canopy.

Example of soil water exploration by turnip roots. Plants on the plot edge had access to a larger stored water reserve.

5.2 Guidelines for irrigated crops

With irrigation, yield responses to applied water are variable, depending on season and location. Irrigation requirements will depend on the prevailing conditions. Irrigation can be scheduled using the following principles.

- Monitor the water deficit during crop growth.
  - Use a soil water monitoring service to measure it regularly, or
  - Keep a running balance of PET, rainfall (R) and irrigation (I).
  - The water deficit is the gap between rainfall and ET, and it peaks during summer.
  - ET varies greatly throughout the year. It is highest during the summer months. At Lincoln, ET per month ranges from about 30 mm in June to 150 mm in January.

Rainshelter facility for evaluating soil water responses.

Stressed and unstressed rape.

Stressed and unstressed turnip.

Stressed and unstressed ‘Pasja’.

Water balance calculation

This can be **done on weekly or daily time steps**.

Data required

1. Potential soil moisture deficit (PSMD) at the start of the season. This will be close to 0 if the spring has been wet.
2. Record the PET (potential evapotranspiration). These can be obtained from the Met. Service or newspapers.
3. Record rainfall, ideally at a location close to the paddock or farm.
4. Record irrigation applied.

Calculations

1. Calculate the PSMD each week (or daily) as follows:

   PSMD = PSMD (last observation) – PET + Rainfall + Irrigation
   (all units in mm).

   To achieve a potential yield, the PSMD should not fall below a refill point (RP) equal to half the available water capacity (AWC) of the soil.

   Example with starting PSMD of -34 mm

Week	Rain (mm)	PET (mm)	Irrigation (mm)	PSMD (mm)
1	12	15	0	-37
2	0	20	0	-57
3	0	18	0	-75*
4	0	20	50	-45

   *RP exceeded therefore irrigate in next period.

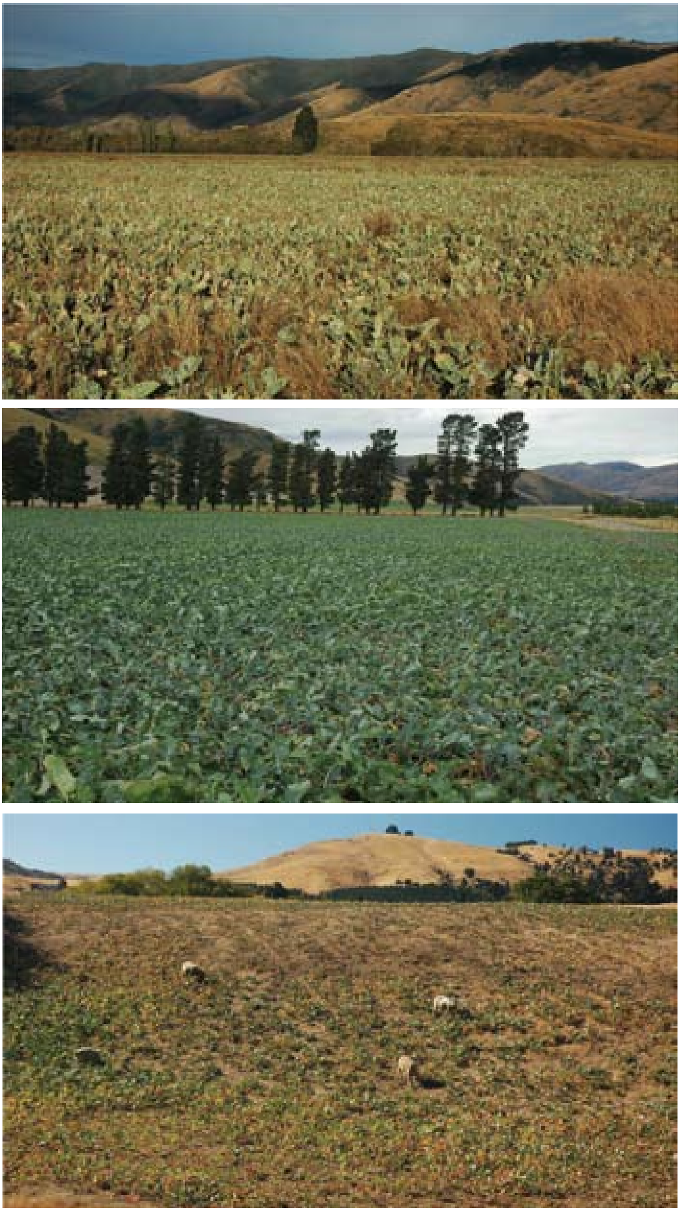
2. Determine the AWC for particular soil type (e.g. 0.8 m to gravel):

   AWC depends on the rooting depth and soil type (depth to gravel) and is calculated assuming a maximum rooting depth of 1 m. This assumes a general rule of 1.65 mm water per cm of soil depth and 55 mm/cm of gravel to a total depth of 1 m.

   AWC = (165 x soil depth (m) over gravel) + (55 x depth (m) of gravel in top 1 m of profile)
   = 132 + 11 = 143 mm

3. In week 3, the PSMD exceeded the RP of -71.5 mm (143/2).
   Therefore, irrigation should start in week 4.

- Irrigate when the crops need water, regardless of growth stage.
    - To achieve the potential yield, crops should be irrigated to ensure that the soil water deficit never exceeds the "refill point" (when approximately half the available soil water remains).
    - Irreversible yield loss occurs whenever the refill point is exceeded.
- Small frequent irrigations are better than large infrequent ones.
    - Water from small frequent irrigations is used more efficiently because availability and crop demand are better balanced, and rain is utilised better when it occurs.
    - There is less likelihood of water logging and nutrient losses by leaching.
    - Avoid over or under-watering caused by irrigation overlaps and/or misses.
    - Any irrigation over the "full point" is wasted.
- Provide an optimum rooting environment for crops.
    - Encourage root development to maximise rooting depth and, therefore, the volume of soil water that a crop can access.
    - Deep cultivate if necessary to disrupt pans and allow better root penetration and aeration.
- Give the best crops priority for irrigation as the best irrigation responses are on crops with higher yield potential.
- Don't start irrigating too late.
    - Water deficits develop slowly early in crop growth, but they have an irreversible effect on yield potential if they are allowed to exceed the refill point. There is no recovery from a late start, especially if the season turns out to be dry.
- Irrigate fully during peak growth and don't stop irrigating too early.
    - Water deficits during peak growth, usually in summer and early autumn, are potentially more damaging because water use is high (up to 5 mm/day) and deficits develop fast. Also the potential growth during this part of the season is high (up to 1 t DM/ha every 4 days), so the potential yield loss is high.



Poor performance in brassica crops is often caused by stress at some point during the growing season. Typical examples of water-stressed crops are shown in these three photographs for kale, swedes and rape respectively.

6. Weeds, pests and diseases

Weed, pest and disease problems in brassicas vary from year to year, either because of cultural and environmental factors in the preceding season or weather patterns during crop growth.

Crop failures are often caused by insect or fungal attack on emerging or newly established seedlings. For example, mild autumns and winters lead to increased over-wintering populations of many pest species. Surplus winter crops or trash from existing crops provide an ideal habitat for carryover of disease and pests. Seed treatments with insecticides and fungicides may reduce the number of crop establishment failures.

Weed populations can be managed effectively with chemicals and cultural practices. Often, a healthy brassica crop that is well fertilised will outgrow weed and pest problems because of the constant addition of new leaves and the competition that the crop exerts over the competing weeds.

6.1 Cultural control methods

- Agronomic practices that maintain plant health help to combat pests and diseases. Good leaf growth, for example, will compensate for minor defoliation by chewing insects. However, crops with high leaf area index and a closed canopy may assist the development of fungal disease, especially in periods of prolonged wet weather.
  - After grazing, plough in all trash early and work well to ensure maximum breakdown and burial before resowing into any crop, including pasture.
  - Swede planting should coincide with low dry rot ascospore numbers. This varies from season to season, but typically occurs well into December.
  - If no dry rot was noted (but some infection may have been present), replant with kale as the second-year option.
  - Avoid carry-over of pests and diseases between crops to reduce the inoculum or over-wintering stages.
- Site selection, cultivation and crop rotation may reduce the source of infection or infestation. The following practices can be effective in managing disease and pest levels. The aim is to reduce opportunities for a favourable environment for the disease or pest to develop.
  - It is best to rotate crops into land that has not previously been used for that crop. For example, if dry rot has been a problem in the past use a dry rot tolerant swede cultivar. Do not follow swedes with swedes.
  - Use only treated (Superstrike, Ultrastrike or Gaucho), certified brassica seed.
    - Good seed bed preparation with minimal crop residue. Thorough cultivation should reduce the incidence of fungal and bacterial diseases at germination and emergence.
    - Crop rotation and fallowing reduce pest populations and help to break insect life cycles.
  - Monitor crops regularly for insects to detect population build-up early and then apply the appropriate insecticide.
  - After emergence, count plants to determine if target populations have been achieved.
  - Before and after emergence, assess the incidence of pests and diseases.
  - Plant emergence should be monitored daily if untreated seed is used.

- A white cloth spread on the ground near emerging seedlings is helpful for identifying springtails.
- A contact insecticide should be applied immediately if springtails or Nysius fly are detected.
- Drought-stressed crops in particular are most likely to be attacked by aphids, diamondback moth, white butterfly and leaf miner.
- Chemical controls are available for pests in stressed crops, but crop yield potential and economics need to be considered.
- Well established crops with adequate rainfall/irrigation and fertiliser normally require no insecticide.
- Control weeds, which may act as an alternate host and disease reservoir.

6.2 Chemical control of weeds, pests and diseases

Effective chemical control depends on using the correct chemical for the target weed, pest or disease, correct application rates and timings, correct water rate, and appropriate application method. Consult the latest agrichemical manuals before spraying.

For more detailed descriptions of pests and diseases of brassicas refer to 'Diseases and Pests of Brassicas" (Harvey 2007); the 'Compendium of Brassica Diseases' (Rimmer et al. 2007); and 'Integrated Pest Management for Brassicas' (Berry 2000).

Herbicides

Ideal growth stage to spray for weeds as there is sufficient open canopy for effective herbicide contact with the target weeds.

Brassicas are especially susceptible to weed competition during the early crop development phases. During seed bed preparation, ample time is required for sprayed out pasture to break down before ploughing. A single spray with a high rate of Roundup 2–4 days before ploughing is usually sufficient for a good kill. However, double spraying is preferred followed by deep ploughing to bury turf.

If direct drilling, the best results are achieved with a double spray initially with Roundup 4–6 weeks before sowing followed by Roundup + insecticide within a week of sowing. Subsequent spraying for broadleaf weeds with Radiate or TordonMax may be required later. Persistent grass weed may be controlled with Gallant or Centurion Plus. Consult chemical manuals for latest product recommendations.

- Weeds are less likely to be a problem when sowing brassicas into old pasture rather than a previously cropped paddock. If sowing after previous crops, use fallow periods with several shallow cultivations to manage weed populations.
- Pre- and post-sowing chemicals can give effective control for many broadleaf and grass weeds.
- Wild turnip cannot be selectively controlled with chemicals commonly used on brassicas.

Typical spraying options include:

- Pre-emergence Treflan at 2 L/ha on a light soil or 3 L/ha on a heavy soil. This is only effective in drier environments and effectiveness may be severely reduced in organic or peaty soils. Frontier pre-emergence herbicide can be mixed with Treflan.
- Alachlor (4 L/ha) applied pre-emergence can be used to control Shepherd's Purse.
- Radiate at 350 ml/ha (plus contact oil) at the 6th leaf stage or TordonMax (1–1.5 L/ha) for control of broadleaf weeds. Both chemicals may cause residual effects on leguminous crops for extended periods after use. Radiate may check growth of some varieties. TordonMax is not currently registered for use on brassicas and care should be taken when applying to brassica seed crops.
- Use post-emergence herbicide (Centurion Plus at 1–2 L/ha or Fusliade at 1–2 kg/ha) for grass weed control. Gallant (1 L/ha) is not registered for brassicas but can be effective in some situations but care should be taken.
- Clopyralid (Versatill) at 0.5–1 L/ha can be used for a range of broadleaf weeds including thistles and yarrow in brassicas. Apply at the second true leaf stage of the crop and before the canopy closes. This is a cheaper option than using Radiate.
- Dicamba at 700–850 ml/ha for control of broadleaf weeds. Note, this should not be applied to bulbing crops such as turnips and swedes, and will check growth of rape and kale if applied at higher rates.

Insecticides

White butterfly damage to kale leaves.

A range of insecticides are available. Typical recommendations include:

- Use treated seed (Ultrastrike or Superstrike) at sowing time to control springtails, nysius, argentine stem weevil and aphids for the first 6 weeks of establishment.
- Diazinon 800EC (organophosphate) at 1 L/ha 1–2 days before emergence to control springtails and greasy cut worm.
- Diazinon 800EC at 460 ml/ha 1–2 days before emergence to control springtails alone.
- Diazinon, 800EC at 800 ml/ha in 200 L/ha water for diamondback moth. Apply early morning or late in the evening when insects are actively feeding.
- Lorsban organophosphate applied post emergence at 1.5 L/ha to control chewing and sucking insects during early growth.
- Karate (synthetic pyrethroid) at 40 ml/ha at the 3–4th leaf stage for white butterfly. Following applications at 10–14-day intervals are required to break the insect life cycle. Karate is not recommended for diamondback moth as it has developed resistance.
- SlugOut at 10 kg/ha just prior to or at planting for slug control. Slug control is mandatory in direct drill situations.
- Sumi-Alpha (formally Halmark) has been used on diamondback moth but is becoming ineffective because of the development of resistance. Recommended application rates are 250 ml/ha, preferably in late afternoon or evening.
- Perfekthion at 650–800 ml/ha for early systemic control of leaf miners and aphids. This can be added to a post-emergence herbicide.
- A mix comprising Uptake spraying oil (100 ml/ha) + Success Naturalyte (200 ml/ha) + Lorsban (300 ml/ha) for springtails, aphids, diamondback moth and white butterfly.

Many of these treatments are, however, not sustainable because of a build-up of insect resistance. Control of diamondback moth is difficult as the insect has developed resistance to commonly used broad spectrum chemicals, in particular, the synthetic pyrethoids and organophosphate insecticides. These insecticides also eliminate non target species and natural predators of the pest species. New research is defining better integrated pest management protocols involving less reliance on broad spectrum chemicals and use of parasitoids of target pests.

White butterfly damage on ‘Green Globe’ turnips.

Broad spectrum insecticides are cheaper than selective ones. Use an insecticide rotation policy featuring selective types such as spinosad macrocyclic lactone (Success) for the first half of the season and indoxacarb oxadizine (Steward) in the second half. This will enable maximum control by natural enemies.

Fungicides

Foliar sprays of fungicides may have a place in high disease pressure situations as an added insurance. Use of fungicides adds to the cost of growing the crops and the treatments are not usually effective.

Seed treatment does not always protect the crop but does have some practical benefits as it is cheap and easily applied. It may have a role in giving a low level background protection and providing another level of defence in protecting new, resistant cultivars.

- Use only treated (Superstrike, Ultrastrike or Gaucho), certified brassica seed.
- Fungicides slow the progress of dry rot, but may not be cost-effective.
    - Proline (Prothioconazole) is relatively new to New Zealand. It is used predominantly in cereals and is the standard fungicide for oil seed rape crops in Europe. Activity is primarily as a protectant although it has some curative and eradicant properties. It is not registered for use on brassicas in New Zealand.
    - Pristine (Boscalid + Pyraclostrobin) is a new fungicide not yet registered for New Zealand brassicas. It is purely a protectant chemical.
- Check the registration of chemicals for use on brassicas. Late applications may be a risk to stock. For a complete list of fungicides registered for use on brassica crops in New Zealand see Harvey (2007).
- Research on the use of seed treatment and foliar fungicides for dry rot control have shown some reduction in the level of dry rot infection. However, in situations of low level infection there was no significant increase in yield in the fungicide-treated plots. The addition of fungicides slowed the rate of infection and reduced the overall severity of the disease and increased yield. Often, two sprays are necessary to achieve positive results. These chemicals are expensive to apply.

6.3 Insect pests

The main insect pests of brassicas are **springtails**, **diamondback moth**, **white butterfly** and **aphids**.

Springtails (*Bourletiella* spp.)

- Attack cotyledons and emerging growing points and cause damage until the fourth leaf stage.
- Control can be achieved by:
  - Reducing trash during seed bed preparation
  - Using treated seed
  - Inspecting crops regularly and applying the appropriate insecticides.

Typical springtail damage.

Diamondback moth (*Plutella xylostella*)

- Usually most prevalent in warm, dry seasons. The adult is a nocturnal, small greyish insect with wings folded close to the sides.
- The eggs are oval, very small (<1 mm) and yellow.
- Larvae are 8–12 mm long and vary from light brown at hatching to dark green at full maturity.
- Diamondback moth is particularly dangerous as it feeds on the growing tips and can decimate whole crops very quickly. The generation cycle is short in warm conditions.
- Larvae burrow into leaves when they are very small and later feed on the underside of leaves, leaving the veins and often the upper cuticle intact. Larvae wriggle away and drop off leaves when disturbed.

White butterfly (*Pieris rapae*)

- The adult has a grey to black body with four broad white wings with black spots. The adults fly during sunny conditions.
- Eggs are bullet-shaped and stand on end.
- Larvae are dull green with a velvety appearance. Small larvae are sluggish when disturbed and have a sideways head swinging motion.
- The larvae grow to be much bigger than diamondback moth, cause large irregular holes in leaves and leave green to black droppings. This pest is active in the summer.

Aphids

Cabbage grey aphid (*Brevicoryne brassicae*)

A common aphid on brassicas produces dense colonies of wingless aphids covered with a white waxy powder. The aphids suck plant sap and cause yellowing, wilting and curling of plants.

Cabbage grey aphid on kale.

Green peach aphid (*Myzus persicae*)

This aphid is not as widespread on brassicas. Aphid feeding causes yellowing and wilting.

Green peach aphid.

- Continuous rapid reproduction can quickly form large populations.
- Dispersal flights of aphids by winged forms occur in spring or early summer. Offspring are usually wingless.
- Dispersion can occur again in late summer.
- Aphids overwinter in sheltered positions on a range of plant species, including kale.
- Most damage occurs in summer.
- Control can be achieved using aphicides and treated seed. There is little cultivar resistance to the common aphid species although turnips are usually more resistant.

Leaf miner

- The main species is the European leaf miner (*Scaptomyza flava*).
- Larvae live and create tunnels within leaf tissue.
- Pest damage can be minimised by maintaining a good crop rotation and/or using insecticide at sowing or using treated seed.
- Larvae are particularly prevalent in turnips in autumn and often responsible for mass yellowing and loss of mature leaves.

Other insect pests include:

- Nysius or wheatbug (*Nysius huttoni*)
- Weevils (*Catoptes* spp.)
- Slugs and snails
- Greasy cutworm (*Agrotis ipsilon*)
- Grass grub (*Costelytra zealandica*)

6.4 Fungal diseases

Disease incidence can be reduced by seed treatment, targeted chemical application and cultural control methods.

The main fungal diseases are **club root** and **dry rot**.

Club root

- Causal agent *Plasmodiophora brassicae*.
- Club root develops when the fungus invades the roots and stimulates cell division and growth. Club formation interferes with root function, restricting water and nutrient uptake (Cheah & Falloon 2000).
- Disease is spread by spores in dust, water and soil, and by infected seedlings.
- Plants often appear wilted and stunted, and will eventually die, releasing dormant fungal spores into the soil. These can infect other brassicas and a number of cruciferous weed species, and are transported by machinery or stock.
- Club root is mainly confined to heavy soils and to areas with heavy rainfall, and its effects are worse in acid soils. Crop rotation and hygiene are important for brassica crops in high-risk areas. Tolerant brassica cultivars are available, although new races of the disease may overcome such tolerance.

Dry rot/black leg

- Causal agent *Leptosphaeria maculans*.
- Mainly an airborne disease, although it may occasionally be seed-borne.
- Commonly called ‘black leg’ in rape and kale and can cause crop losses up to 80%.
- Primary infection is from diseased organic material. Initial symptoms show up as small, circular lesions on young leaves. Wet, windy weather favours spread of secondary infection by rain splash as well as following physical contact between fallen leaf material and stem/bulb. The fungus grows systemically down the petiole (rape only).
- Dry rot is mainly a problem in swede crops held for winter feed, but may affect other brassicas to a lesser extent. Symptoms are seen on leaves as small, sunken, brown to grey circular spots that are covered with tiny black spore bodies, which are the main source of further infection. Similar lesions appear in brassica bulbs, usually in the neck region. In small bulbs, this may result in plant death.
- Dry rot can be particularly bad when a crop is sown into an area with a lot of trash remaining from a previous brassica crop. This should be avoided where possible.

- Kale is also affected by dry rot. The woody nature of kale stems makes this disease appear more persistent and results in a longer lasting source of infection following harvest.
- Control of dry rot is usually by avoidance using crop rotation, hygiene and tolerant cultivars. Late sowing to avoid early infection may also alleviate the problem.
- ‘Winton’ and ‘Aparima Gold’ have good dry rot resistance.

Sclerotinia watery soft rot

- Sclerotinia initially develop as white mould from germinating ascospores.
- Infected plants wilt and die.
- Sclerotinia develop in the stem lumen of kale and are released into the soil where they can persist for up to 4 years.

Other diseases

Causal agents are given in brackets.

- Foot rot fungi (*Fusarium* and *Pythium* spp.) cause damping-off of young seedlings. These pathogens thrive when the soil is maintained at high moisture levels for long periods. The only practical control measure is through seed treatment.
- Leaf spot (*Alternaria brassicicola*)
    - Forms grey, circular leaf lesions containing black pinhead bodies that release spores when the leaves remain wet for long periods. Spores are spread by wind and water, and with crop debris.
    - The fungus may produce small dark spots on older leaves in cool wet conditions, which are surrounded by a ring of lighter tissue. Control is best achieved by crop rotation.
    - Caused by *Alternaria brassicicola* (producing black spots) and *Alternaria brassicae* (brown/grey spots).
- Ring spot (*Mycosphaerea brassicola*)
- Light leaf spot (*Pyrenopeziza brassicae*)
- Downy mildew (*Peronospora parasifica*)
    - Infects the lower sides of leaves, often in humid, cool, moist conditions. Seedlings and young plants are most susceptible.
- Wire stem (*Rhizoctonia solani*)
- White rust (*Albugo candida*)

Leaf spot lesions.

Ring spot lesions.

6.5 Bacterial diseases

Black rot

Black rot symptoms.

- Caused by *Xanthomonas campestris.*
- Attacks the vascular system in warm humid conditions, affecting sap flow. Present in soils and crop debris but also can be seed borne.
- Appears first in leaf margins as V-shaped areas that become yellowish before the veins darken. It is also characterised by small black hypersensitive entry spots.
- Spread by rain splash, wind and machinery and develops in wet, warm conditions. Infection spreads inwards, attacking the vascular bundles, and leaves may turn yellow, drop off and cause the plant to wilt. The plant usually will grow through the infection.
- Crop sanitation is the most effective control.

Peppery leaf spot

- Caused by *Pseudomonas syringae* pv. maculicola.
- Persists on crop residues and infects early vegetative plant stages.
- Can be seed-borne and is also spread by water on leaf surfaces and by machinery. It is favoured by prolonged cool, wet conditions and can develop rapidly following plant stress.

6.6 Viruses

Turnip mosaic virus (TuMV)

- Causes stunted growth, with mottling and crinkling of the leaves, followed by yellowing and death of older leaves. Swedes and turnips show poor bulb development and are susceptible to other infections.
- Turnips are highly susceptible to viral diseases and crops can occasionally be severely damaged at an early stage.
- Viral diseases are not known to be transmitted in seed and control is best carried out by eliminating the vector aphids.
- Many crops other than Crucifers can act as a host, for example: *Capsella bursa-pastoris* (shepherd's purse), *Raphanus sativus* (radish), *Stellaria media* (common chickweed). TuMV can be spread by many species of aphid; however, the green peach aphid and the cabbage grey aphid are the most important. TuMV is not spread via infected seed.
- Applying an insecticide at sowing can also minimise the effects by delaying aphid arrival and build-up but will not prevent the disease from occurring.
- Brassica cultivars differ in susceptibility and reaction. Choose a virus resistant/tolerant cultivars.
- Control of aphid populations should be maintained to minimise virus spread.
- Control weeds around the crop as they act as a disease reservoir.

Turnip yellows virus (TuYV) or Beet western yellows virus (BWYV)

- Causes leaf redness or purpling, plant stunting and rosetting of leaves. This Luteovirus has been a serious problem in the past in all brassica crops especially in crops with limited insecticide use.
- Use of pelleted insecticide can give good disease protection.
- Virus symptoms in maturing crops of most brassica are usually confined to the outer leaves. On older leaves symptoms appear as small, pale spots, sometimes with an indistinct mosaic mottling. Leaves of turnips and swedes may show bright yellowish purple margins.
- BWYV can be spread by many species of aphid; however, the green peach aphid, cabbage grey and the false cabbage aphid are the most important in brassicas. BWYV is not spread via infected seed.
- Many crops other than Crucifers can act as a host, e.g. *Linum usitatissimum* (flax), *Lupinus albus* (white lupin), *Lupinus luteus* (yellow lupin), *Pisum sativum* (pea), *Trifolium subterraneum* (subterranean clover), *Vicia faba* (broad bean), and *Vicia sativa* (common vetch).
- Virus infection can be reduced by controlling aphid populations in the crop.
- Insecticide coated seed is useful to give seedling protection in autumn and spring.

Selected photos courtesy of PGG Wrightson, NZ Agrichemical Manual and Plantwise and Plant & Food Research.

Table 6: Seasonality of brassica diseases–general guide for all regions (Adapted from IPM for Brassicas. John Fletcher, pers. comm.).

	J	F	M	A	M	J	J	A	S	O	N	D
Fungal diseases												
Alternaria	I	I	•	•						•	•	I
Blackleg	•	•	•	•	•	•	•	•	•	•	•	•
Club root			•	•	•	I	I	I	•	•		
Downy mildew	•	•	•	•	•	•	•	•	I	I	I	I
Light leaf spot			•	•	•	I	I	I	•	•		
Ringspot	•	•	•	•	•	I	I	I	I	I	•	•
Rhizoctonia	I	I	•	•							•	•
Sclerotinia rot	•	•	•	•	I	I	I	I	I	I	•	•
Bacterial diseases												
Bacterial soft rot	I	•	•						•	•	•	I
Black rot	I	I	•	•	•			•	•	•	I	I
Head rot	I	I	•	•	•				•	•	I	I
Peppery spot	I	I	•	•					•	•	•	I
Viral diseases												
Turnip mosaic virus	•	•	•	I	I	I	I	I	I	I	I	•
Beet western yellows virus	•	•	•	I	I	I	I	I	I	I	•	•

• = Present I = Important in month

7. Feeding

7.1 Animal production on forage brassicas

- Brassica crops grown under good cultural practices are good accumulators of biomass and store comparatively well as standing feed for use later. However, they can have variable quality, depending on the time of feeding and the maturity of the crop.
- Brassicas can be fed as 100% of the total diet, but this is not best practice. If feeding high percentages then animals should be monitored closely for nutritional disorders.
  - Milking cows should not have more than 33% of the diet as brassica.
  - Dry cows should not have more than 70% of the diet as brassica.
  - In lambs, a high intake of brassica increases the risk of photosensitivity.
  - In sheep systems brassicas may make up 90–100% of the diet.
- For best lamb growth, summer brassicas need to be grazed for more than 4 weeks to allow for a period of adaptation.

Typical weaned lamb growth rates on summer brassicas	
Days from introduction	g/day
1–10	0–50
10–20	150–200
20 onwards	> 300

- Balancing the diet
  - Brassicas are low in fibre and high in sugars, increasing the risk of rumen acidosis, especially during the introductory phase of brassica feeding. To help avoid this, always give access to hay/straw or silage, and ensure animals are full before introducing a new break, especially for grazing cattle.
  - Spring cut silage can be a good supplement for swedes to balance the low protein content of the bulb. However, a fibre source such as hay or straw should also be fed.
- Known factors causing poor or variable livestock performance on brassicas are:
  - High water content – therefore low DM intake
  - Low NDF – therefore the need to add fibre to the diet
  - Anti-nutritional compounds – nitrates, SMCO and glucosinolates
  - Under allocation of DM – therefore low forage intake
  - High plant S levels – interferes with other trace elements, e.g. Cu and Se.

7.2 Nutritional properties

Fibre

- Forage brassicas contain little effective fibre. Therefore, other feeds are required to stimulate rumination, especially in grazing cattle.
- Feeding hay or straw as supplements to brassicas has many advantages:
  - Stabilises gut function.
  - Gives better winter weight gain.
  - Minimises anti-nutritional problems for animals.

Feeding straw helps prevent nutritional disorders relating to rumen function.

- Fibre has the important functions of:
  - Slowing the rate of passage of material through the rumen and gut, allowing increased absorption and utilisation of nutrients.
  - Increasing saliva secretion by promoting chewing. The saliva helps to stabilise the pH in the rumen by acting as a buffer and promoting normal microbial function.
  - Diluting the concentration of SMCO, nitrates and glucosinolates.

Anti-nutritional properties

Some compounds in brassicas can potentially limit production or cause death to livestock. However, in most cases they can be managed by good husbandry.

SMCO (*S-methyl cysteine sulphoxide*)

- High levels of SMCO cause red water in ruminants.
- Red water is caused by damage to red blood cells, which are excreted in the urine.
- Causes depressed intake and eventually anaemia.
- Can be managed by restricting excess N and S fertiliser applications.
- Avoid feeding flowering brassicas (these have the highest levels of SMCOs).
- Ensure animals have an adequate Cu and Se status. Low levels of these minerals within an animal exacerbates SMCO effects.

Glucosinolates

- Are goitrogenic and influence metabolism in the thyroid gland.
- Can be managed by supplementation.

Nitrate poisoning in dairy cows fed brassicas

Nitrate poisoning is one of the major health risks associated with feeding off a winter crop. This is a problem with all winter cropping options, but can occur at any time of year. Crops should be monitored carefully to minimise stock losses. Both dairy and beef animals are equally susceptible.

Clinical symptoms

- Cows may be unable to stand with noticeable milk fever symptoms.
- Affected cows that remain standing appear uncoordinated.
- Respiratory rate increases.
- Death occurs rapidly and surviving animals may abort their calves.

Causes of nitrate accumulation – in the plant

- Periods of rapid growth following a period of stress, i.e. drought, frost.
- High use of N fertilisers.

Ways to minimise the risk of nitrate poisoning

- Nitrate levels exceeding 2% of DM are considered unsafe or toxic. Levels between 1 and 2% may cause problems while levels less than 1% are considered safe to feed. If you suspect the forage is unsafe arrange for a lab test to be done.
- Cows must be gradually introduced to the crop. This reduces the risk of nitrate toxicity. Initially the grazing period should be no longer than an hour a day.
- Do not introduce hungry cows to a crop. Feed cows on their pasture allocation or hay before moving them to the brassica crop.

7.3 Mineral composition of brassicas fed during the winter

Concerns arise when feeding brassicas to dairy animals for wintering because of potential nutritional disorders and the possibility of acidosis when stock are not introduced gradually to the crop. Acidosis may also develop when stock are fed on brassicas that are low in fibre and high in soluble carbohydrates.

Calcium

- Feeding brassicas in the transition around calving period is risky because of the effects on cow calcium (Ca) metabolism. Ideally, dairy cows should not be fed brassicas in the 3-week period before calving or 4–5 days after calving.
- Calcium levels in brassicas are typically high (up to 40 g/kg DM in the leaf).
- Springer cow requirement for Ca is less than 60 g/cow per day.
- If the springer cow consumes excess Ca before calving, it will reduce the cow’s ability to mobilise stored Ca.
- If brassicas must be fed to springer cows, then the rest of the daily ration should be made up of low Ca feeds such as cereal grains, straw or grass hay.

Phosphorus

- Phosphorus (P) levels in brassicas are marginal for dry cows.
- The daily requirement of P for a dairy cow is around 24 g P/day. The typical P level in brassicas is 2–4 g/kg DM. Therefore, an intake of at least 6 kg of brassica DM/cow per day is required to meet the P requirement.
- A possible deficiency in brassica P content is intensified if other feeds or supplements have low P. Cereal straws and poor quality hay also have low P.
- Low P intake prior to calving can further suppress the appetite and cause symptoms similar to red water.

Potassium and magnesium

- Brassicas contain a high concentration of potassium (K). In combination with low magnesium (Mg) this also increases the risk of metabolic disorders especially in the last 4 weeks of pregnancy.
- Transition cows fed low Mg diets can cause hypomagnesaemia (low blood Mg) and hypocalcaemia (low blood Ca). Both conditions may lead to metabolic disorders and low milk yield in early lactation.
- Magnesium supplementation normally starts in early July for early August calving cows. If Mg deficiency is suspected it may be beneficial to supplement with $MgCl_2$, magnesium oxide, or $MgSO_4$ through the entire dry period.

Dietary Cation Anion Difference (DCAD)

DCAD = (K + Na) - (Cl + S)

where the ion concentrations are given in mEq/kg DM.
Factors for converting element (K, Na, Cl and S) concentrations in herbage from %DM to mEq/kg DM are x 256, 435, 282 and 624, respectively.

Addition of anionic salts comprising Cl or S ions may have a beneficial effect by reducing the incidence of milk fever. Acidogenic feeds tend to prevent milk fever while alkalagenic feeds tend to cause milk fever.

DCAD needs to drop below zero to have a significant effect on blood pH. Rumen pH may be more sensitive to diet composition, including the DCAD value. The effects of brassicas with high DCAD may not be dissimilar from good quality pasture.

DCAD of the diets fed to springing cows should be <100 mEq/kg DM. Most brassica crops have high DCAD values (>400 mEq/kg DM). Although this is higher than the recommended level, it is still lower than most winter pastures in New Zealand.

Copper

- Cattle that are fed on brassica diets for prolonged periods of time can be susceptible to Cu deficiency. Cattle are more susceptible than sheep because their Cu requirements are higher.

Selenium

- Selenium is essential for the production of an enzyme, glutathione peroxidase. This enzyme plays an important role in preventing the effects of red water (haemoglobinuria) caused by SMCOs (s-methyl cysteine sulphoxide).

Iodine

- Pregnant animals feeding on winter brassicas may suffer from primary or secondary iodine deficiency.
- Iodine is recommended to be supplemented through the drinking water system for cattle. Typical rates are 15–25 mg iodine per cow per day. It is important to check with your veterinarian regarding the rate suitable for your circumstances.

For more detailed information on nutrient requirements of grazing animals refer to Grace (1983), NRC (2001), Nichol et al. (2003), and Nichol (2007).

8. Utilisation

Utilisation can be defined as the proportion of the total crop that is actually eaten by the animal. The remainder is what is left in the paddock after grazing. This includes all defoliated leaves and plant material trodden into the soil.

High animal growth responses are often closely associated with low utilisation efficiency.

Many factors potentially affect utilisation. The most important is the daily allowance, but crop characteristics and grazing management can also influence the proportion of the crop eaten.

8.1 Optimising feed use

- High rates of utilisation can be achieved on most brassica crops through high stocking rates. However, high utilisation rates are often associated with reduced intake. At 90% utilisation cows need to be offered 7.7 kg DM per head per day to have an intake of 7 kg DM per head per day.
- Kales with a higher leaf percentage are generally utilised to a higher degree than stemmy cultivars. Therefore, cultivar choice based on growth habit should be carefully considered. Some cultivars have low leaf to stem ratios (20%). Cultivars with high leaf ratios (50%) are more likely to be more fully utilised. A survey of dairy cows grazing kale in the winter of 2006–07 suggested kale used in this way is typically utilised at a rate of 80% (Judson & Edwards 2008).
- Sowing rate of standing crops can also affect utilisation indirectly. Lighter sowing rates can promote thicker stems in some cultivars. This can potentially result in lower utilisation.
- When break feeding crops, ensure allocation of crop reflects desired intake. Knowledge of crop yield, break area and stocking rate are important components in achieving this.
- Some farmers sow one to two rows of swedes within tall crops. This makes it much easier for the farmer to put in breaks. Otherwise, breaks need to be cut in the crop, which can increase the risk of wastage through crop rejection in some environments.

Long narrow breaks are better than square breaks.

Paired rows of swedes and kale make fence set-up easier.

- Frequency and timing of break shift:
  - Shift the break at least once a day when winter feeding dairy cows. In some environments this may improve utilisation compared with a shift every 2 days.
  - Feed out supplementary silage/hay/straw in the morning and shift the break in the late morning/early afternoon. This will allow the crop to defrost, reducing the intake of cold forage and potential health problems.
  - For lamb finishing systems where summer brassica crops are employed, a rotational grazing system is beneficial compared with a set stocked system. Liveweight gain per hectare increased by 18% when lambs were rotated around a leaf turnip crop compared with a set stocking system. Most of this advantage came through increases in stocking rate rather than lamb growth rate.
  - In rotationally grazed lamb finishing systems daily allowances and rates of utilisation are important components of highly productive systems. Liveweight gain per hectare is maximised where lambs are offered 2–2.5 kg DM per head per day, consume 65% of the crop being offered and leave residuals of 1500 kg DM/ha.

Position feed supplement in paddock well in advance of winter feeding to avoid soil damage by feeding out.

Situation depicted here can be avoided with planning.

Soil pugging damage can be minimised by back fencing.

8.2 Feeding swedes to hoggets during winter

- Swedes are traditionally grown to fill a winter feed deficit and the practice is well proven, especially in Southland.
- Hogget ill-thrift when grazing for long periods (6–12 weeks) on swedes and turnips has been related to teeth wear and incisor loss (Orr & Suckling 1985).
- Tooth loss is reduced when the total daily ration is made up of feed sources other than a swede-only diet.
- Hoggets should be offered ad lib quantities of hay (either average or high quality) whilst grazing swede crops.

Swede grazing during winter. Teeth wear can create problems for utilisation. Large breaks result in low utilisation and feed quality losses.

8.3 Animal issues

Water requirements of dry cows on brassica crops

- Cattle eating 11 kg DM per day (made up of 7 kg brassica and 4 kg grass silage), have a daily water requirement of 19–20 L/cow (NRC 2001).
- This requirement is in addition to the amount of water contained in the brassica.
- Dry cows on a brassica crop must always have access to fresh water.
- If water access is limited, cows will eat less and performance will suffer.
- Portable troughs should be positioned close to the crop face to minimise walking time.
- Minerals supplemented through the drinking water may reduce water intake.

Adaptation to brassicas

- Animals can take at least 2 weeks to adjust and then consume their maximum voluntary intake when adjusting from a full pasture diet to one that contains 50% brassica. The lead time depends on the crop type, animal and the environment.
- The main aim of gradual adaptation is to create a microbe population in the rumen that can cope with the above changes in diet.
- The main reasons for rumen adaption:
    - Shifts in ratio of non-structural carbohydrates (sugars) and crude protein.
    - Low fibre intake.
    - Mineral imbalances.
    - Other anti-nutritional properties, e.g. SMCOs.

Choking on turnips and swedes

- Choke is caused when a brassica bulb catches in the throat (pharynx) or lodges further down in the oesophagus.
- Choke is more common in cows grazed on turnips in summer, but small immature bulbs of winter brassicas can also cause choke problems.
- Allow bulb brassicas to fully mature. This ensures bulbs are of sufficient size and are less likely to be swallowed whole.

8.4 Practical steps to ensure effective adaptation to brassicas

- Initially allow access to the brassicas for only a short period of time.
  - Run animals on the crop for a maximum of 1–2 hours a day.
  - Build up the final allowance (ration) of the brassica by only 1 kg/cow per day over the next 10 days.
  - Complementary forages should be high in fibre (baleage, hay or straw, pasture and pasture silage).
  - Observe animals closely in the first 1–2 hours of grazing for any signs of nitrate toxicity or bloat.
- Do not allow hungry animals on to the crop during the adaptation period.
  - Individual cows that are hungry can gorge themselves (particularly if they are the dominant cows in the herd).
  - Best practice is to feed other rations first for a couple of hours and then move animals on to the crop.
  - This minimises gorging as well as animal health problems such as acidosis, bloat, choke and nitrate poisoning.

8.5 Measuring crop yield in brassicas

- Bend a 4 m long piece of wire into a square, or a 3.54 m length of alkathene into a circle to form a quadrat of 1 m^2.
- Measure the crop from 5 different areas within the paddock (representative areas away from fences and troughs).
- Total DM yield (kg/ha) = Fresh weight (kg) of 5 m^2 x DM% x 0.02, where DM% = DW (g)/FW (g) x100 of a subsample dried at 90°C for 24 hours.

Reliable yield estimation means sampling at least 3 m^2 quadrats and determining a reliable dry matter content.

9. Cost of production

For it to be profitable to feed brassicas to dairy stock, high yields must be produced and crop production costs minimised. Economic value is currently not linked to quality.

- Much of the cost of production is committed early on in crop life, but the difference between achieving a poor yield and acceptable yield is often related to the effective use of fertiliser and chemicals. Good agronomic practices are essential to achieving a crop yield near its potential.
- Yield drives profitability.

> Raising the yield means the cost of production goes down (on a cents per kg basis). However, if the yield potential has been reached, additional inputs will reduce the profitability. Therefore, knowledge of the likely yield and quality gains of cultural practices is important when additional inputs are planned.

- Gross margins for brassicas are very dependent on the year, climatic environment, cropping history, level of inputs, farm labour, availability of machinery and the economic climate. The commercial value of feed also fluctuates with season, type of feed and reflects the supply and demand patterns. The value placed on feed if sold on the open market provides a benchmark for comparing relative profitability and is useful for making comparisons between feed options.
- Feed grown on farm may be of more value to the farmer than is apparent given the production costs. It is therefore inappropriate to make broad generalisations on the comparative value of the crop. Nevertheless, it is wise to monitor the cost of inputs and calculate the cost of production compared to the sale value.

The cost of growing brassica crops can exceed $1300/ha. This figure is based on actual yields achieved in trial situations, but does not account for the cost of land or time required to return the land to pasture. The costs of grazing or silage making are also not included.

There is a point when higher rates of N fertiliser will not be cost-effective because of the saturated yield response. Likewise, the gross margin increases in line with the reduction in production costs.

Calculations of the break-even yield may be informative for deciding whether late applications of fertiliser or crop protection chemicals are warranted. However, this approach requires that yield is monitored during growth so that an informed decision can be made on the real value of the crop.

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