The Best From Forage Brassicas: Improving the Health and Productivity of Brassica-fed Cattle

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Introduction

Crops of forage brassica are used to supplement young stock, milking and dry cows at times of the year when pasture growth is slow and/or of low quality. Potentially, a high-yielding forage brassica crop can:

- Provide a bulk of high quality DM that can be fed *in situ* to fill a pasture deficit and help balance the annual feed budget.
- Reduce the cost of production per kg of milksolids and/or minimise feeding costs for replacement or dry stock. Typical costs to grow a crop of forage brassica range from 6 to 15 cents per kgDM 'standing' in the paddock, depending on crop yield, soil fertility, species and cultivar selection, agronomic practices including cost of inputs, climatic conditions and exposure of the crop to disease and pest challenge. Forage brassicas will in most cases out-compete other bought in feeds as a cost effective source of DM to augment a pasture-based diet.
- Complement the nutritional inadequacies of pasture and/or other supplementary feeds. An example is the use of high quality turnips as a portion of the daily milking cows' diet during the summer months when pastures are often slower growing and/or of lower nutritional value. Additional benefits include reduced intake of anti-nutritional, pasture-related factors including; sporidesmin, *fusarium* and endophyte-associated alkaloids.
- Assist with the re-establishment of pastures following the grazing of crops. As a 'break-crop,' forage brassicas help break both pest and disease cycles associated with pastures. This allows for investment in modern, high performance pasture species and associated technologies such as novel endophytes.

On the few occasions that the performance or well-being of brassica-fed cattle fails to meet expectations, the dairy practitioner has an opportunity to be proactive in the investigation and resolution of animal production challenges. To actively engage with your dairy client, you will require a working knowledge of why and where a brassica crop fits within a dairy business. This paper introduces the non-brassica practitioner to some of the challenges of brassica feeding and offers some discussion as to the resolution of most issues that you may encounter. For the more experienced practitioner, we hope to offer some thoughts to further progress your current clinical approach to investigating cases of sub-optimal performance and health challenges occasionally seen on crop.

The intent of this paper is NOT to discuss the specific health problems of cattle on brassicas on a disease by disease basis as this has been well covered elsewhere (Prache, 1994; Morton, 1997; Nichol, 2007). The following is a summary of typical challenges when cattle graze forage brassicas, including references that should be consulted for more information about each challenge.

Involvement by the cattle veterinarian with forage brassica crops:

As a dairy cattle veterinarian, you need to gain a multi-level understanding of the role forage brassica crops have in dairy systems.

Level 1: At a whole farm system level. Understand the fit brassica cropping has as a source of forage within the total feed supply for both the milking platform and dairy support block, even if you are not actively involved in feed budgeting, agronomy and whole farm advisory services.

Level 2: Investigation into problems of cattle failing to perform on crop. An understanding of the brassica crop-cattle interface is a prerequisite when investigating why cattle may be underperforming.

Level 3: Investigation of cases of clinical disease in cattle grazing a forage brassica crop. Whilst this remains the least desirable, 'ambulance at the bottom of the cliff' scenario, we do require an understanding of brassica-associated factors that may cause disease, and how to differentiate these cases from disease from unrelated aetiologies.

Very occasionally, you may be engaged by a client to assist with trouble-shooting the sub-optimal performance of health of cattle grazing forage brassicas. These farm visits can be potentially daunting for practitioners with limited field experience of forage brassicas. Thankfully, as experienced practitioners will tell us, most performance and health challenges are readily diagnosed and resolved, in most cases by proactive planning for crop management *before* cattle are introduced to the crop.

Tempting as it may be, don't always assume that the brassica crop is directly responsible for cattle failing to perform or for cases of clinical disease. Take a holistic approach, and look at the total situation within which the issue has occurred.

Remember that every year more than 300,000 ha are sown to forage brassicas, and annually very FEW problems arising from cattle grazing brassicas are reported.

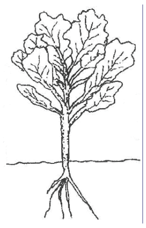
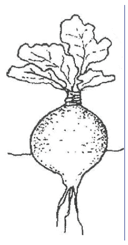
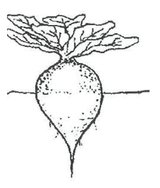
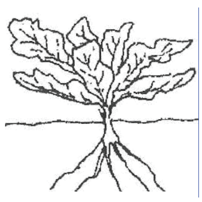
The basics of forage brassicas: A brief overview

The forage brassica crops of major importance to New Zealand dairy businesses are summarised in Table 1. All are members of the genus *Brassica*, part of the family *Cruciferae*.

Excellent reviews of the role of forage brassicas for New Zealand dairy businesses, including descriptions of species, sowing, pests and diseases and brassica crop use are provided by Scott and Fleming (2003), Stewart and Charlton (2003) and de Ruiter et al (2008) as such a brief overview only is provided here.

Summer crops of turnips, hybrids and forage rape offer a high energy, moderate protein feed that complement the often variable DM yields and forage quality offered by dryland, non-irrigated summer pastures. Higher quality summer brassicas can help balance a feed budget and improve forage quality to improve milk yields through the summer months. Summer forage brassicas are well utilised by lactating spring calved cows to help 'flatten' the summer lactation curve and keep cows in milk, as well as providing a valuable forage source for heifer replacements and autumn calving dry cows.

Table 1. Forage brassicas commonly used for the feeding of dairy cattle in New Zealand. *(Adapted from: Stewart A, Charlton D. (Ed). 2003. Pasture and Forage Plants for New Zealand. Grassland Research and Practice Series No. 8).*

Common name		**Sowing time**	**Growth habit**	**Typical system 'fit'**
Kale (choumoellier)	*Brassica oleracea* spp *Acephala*	Early to mid summer		Late autumn / winter feed. Single graze May to September. Cultivars for cattle vary from medium height (e.g. cv. Regal, cv. Soverign) to tall (e.g. cv. Gruner), Generally the taller the kale the higher the DM yield but leaf to stem ratio falls with taller kales.
Swede	*Brassica napus* spp. *napobrassica*	Early to mid summer		Winter feed option for cattle. Cultivar options include both yellow flesh (e.g. cv. Aparima Gold) and white flesh (cv. Winton). Types used depend on time to feeding following sowing and level of disease tolerance to dry-rot and clubroot.
Bulb turnip	*Brassica rapa;* syn. *B. Campestris*	Early to mid summer		Summer feed to augment summer pastures for milk production or young stock (e.g. cv. Barkant, cv. Rival); autumn / early winter feed for milking, young stock or dry cows (e.g. cv. Green Globe). Early maturing sowing to grazing 60 days, late maturing 120 days. Early maturing tankard type summer turnips popular as a milking feed due to good leaf to bulb ratio, short time to grazing and good utilisation.
Leaf turnip	*Brassica rapa;* syn. *B. Campestris*	Spring, summer or autumn		Multigraze option (e.g. cv. Pasja, cv. Hunter), 3 to 4 summer grazing. Short sowing to grazing interval and regrazing intervals as short as 50 days. Less requirement for ripening than rapes. Shallow rooting leaves more prone to low soil moisture than rapes.
Forage rape	*Brassica napus* spp *Biennis*	Spring, summer or autumn		Summer feed for young stock, milking cows, winter feed for young stock, dry cows, milking cows. Later maturing cultivars are rape x kale parentage. Sowing to grazing 90-110 days (late maturing; eg. cv. Goliath) to 70-90 days (early maturing: eg. cv. Titan, cv. Winfred). Can multigraze or single graze.

Winter brassica crops such as kale (chou), swede and bulb turnip, historically the domain of Canterbury, Westland, Otago and Southland dairy businesses, are becoming increasingly common in cooler regions of the north island. Winter brassicas produce a bulk of high quality forage that is fed *in situ* when daily pasture growth rates cannot meet the demand of dairy milking or runoff units. Brassicas continue to grow at low temperatures (less than 6°C) when growth rates of perennial ryegrasses slow or cease. Historically, wintering of dry cattle on brassica crops is assumed to simply maintain the liveweight of cattle. More recently, acceptable liveweight gains and body condition score benefits are being reported for cattle on brassicas as a result of improved management practices, better supplementary feeding techniques and improved agronomic performance of modern forage brassicas.

The potential DM yield from a forage brassica crop is influenced by the selection of the appropriate brassica species and cultivars, paddock and seedbed preparation, identification and remediation of soil nutrient challenges, seed placement, and ongoing agronomic monitoring of the crop (de Ruiter et al, 2008). Notwithstanding the sometimes variable DM yields as a result of agronomic and climatic challenges, forage brassicas offer substantial advantages to dairy clients, with the efficient conversion of forage brassica to liveweight or milksolids being the ultimate measure of success.

Reasons why clients choose to sow a brassica crop, and what influences selection of species and cultivars?

1. **The production of more forage DM per ha than the existing pasture base alone**. In most instances, the decision to sow a forage brassica crop is driven by a need for more forage (kgDM / ha) when pasture supply is limiting:

    a. **Summer** – feed deficit due to moisture deficit. With crops sown in late spring / early summer, much of the DM accumulation occurs before a dry period is encountered. Crops (particularly turnips) can, to some degree, be carried through a dry spell. As for pasture, a moisture deficit will limit the potential yield (and quality) of summer crops. A common and often said expression is that “the turnip crops yield best when you need them the least” – there is much truth in this statement, conditions that encourage good yields of summer turnips also support good yields of summer pasture.

    b. **Winter** – feed deficit due to cold temperatures. Summer or autumn sown forage crops can accumulate substantial quantities of DM by late autumn, allowing the carrying of the brassica through the winter. The carrying capacity of forage brassica through the winter is dependent on the yield of the crop, but typically is best for swede or kale.

2. **Deliver a high quality forage that complements other feeds.** Forage brassicas deliver a high quality, high MJME forage that complements other feeds well. Examples of complementary feed options include the use of summer turnips to complement dried off, moisture stressed pasture and winter swedes to complement slow growing pasture or cereal silages and/or cereal straws.

3. **Species and cultivar selection.** Reasons that clients may choose one type of forage brassica over another include the following examples:

    a. **Swede vs. kale.** Swedes, long the mainstay of Southlanders may be chosen over kale due to their ability to ‘carry’ well into late winter or even early spring and ease of ‘break-feeding’ a swede crop relative to a kale crop. Swedes won’t lodge under snow and hold their quality well through the winter. Kale is more prone to leaf senescence through the winter, lodging and the stems can thicken and become very 'woody' by later winter. Many clients perceive that cattle "do better" on swede than kale due to potentially better forage utilisation and higher feed value of swede bulb vs. the stem of kale; because generally the whole plant digestibility (and MJME) of swedes is higher than for kale grown under similar growing conditions.

Conversely, kale is more popular than swedes with some clients due to the recent improvements in forage quality, with more modern kale cultivars and the relatively better tolerance by kale to dry rot, club root and turnip mosaic virus. Kale fits as a second brassica crop behind swedes due to its superior disease tolerance. Clients who are sowing in drier summer conditions may choose kale over swede, since kale is more tolerant of moisture deficits.

b. **Kale vs. forage rape.** The later sowing date for rape vs. kale, and the potentially higher quality of forage rape vs. kale has seen increasing areas of forage rape sown by traditional kale growers. For example, dairy grazers often sow rape following cereal grain crops, and use the straw residue to complement the feeding of forage rape to dry cows and replacement stock. Due to the later autumn sowing date of rape, DM yields of rape relative to kale are lower but are offset by a combination of the reduced opportunity cost of land out of production for rape vs. over 200 days in the case of kale, and typically better forage quality for forage rape compared with kale.

c. **Leaf turnip vs. bulb turnip.** Leaf turnips are typically grown from mid summer to early winter and offer a multi-graze option for cattle especially replacement stock. The short time from sowing to grazing (50 to 70 days) offers a fast forage 'fix' to fill a forage deficit. Up to 3 to 4 grazings can be obtained from leaf turnips depending on grazing management, soil fertility and climatic conditions.

Bulb turnips are chosen over leaf turnips when a higher yield from a single grazing is required, rather than the multiple grazings of a lesser tonnage from leaf turnips. Bulb turnips are characterised by high concentrations of water soluble carbohydrates, and this quality aspect can favour the selection of bulb turnips over leaf turnips for summer milk production. Late maturing bulb turnips (e.g. cv. Green Globe) can be carried well into the autumn to provide an autumn 'bank' of high quality feed into the winter, allowing farmers to build pasture covers heading into the winter.

Early maturing tankard bulb turnips (e.g. cv. Barkant, cv. Rival) are commonly grown for summer milk production.

Failure by cattle to perform on brassicas

- Possibly the most commonly encountered field challenge is the poor performing animal. In most cases, there is no apparent or limited evidence of clinical disease and as such, you may not be invited by the client to investigate the problem.
- A more structured approach to the investigation of poor performance is outlined later in this paper.
- Almost ALL cases of poor performance by cattle on forage brassicas crops is a simple case of:
    - Insufficient DM on offer to cattle on a daily basis. This is typically a combination of overestimate of tonnage of DM on offer And/or an overestimate of crop (and supplement) utilisation. Underfeeding is the net outcome from both factors, particularly when combined with inappropriate DM feeding targets for different stock classes. For example, a recent

survey by Judson and Edwards (2008) showed that ⅔ of dry cow herds grazing kale in winter were underfed by 1 kg DM/cow/day below target intake, with some herds as high as 8 kg DM/cow/day below target intake. Further, utilisation of crops that yielded between 5-17 t DM/ha varied from 40-90%. The methodology for objectively defining the DM on offer for a winter forage brassica crop was described by Nichol et al (2003). This methodology can equally be applied to summer forage brassicas crops to define quantities of feed on offer.

- Issues of break feeding methods, cattle access to the crop face, and access to supplements and stock water all influence animal performance (Nichol et al, 2003).
- Sub-clinical metabolic disease may impact on animal productivity. This is discussed in more detail below.

Clinical disease associated with the feeding of brassica crops

Most cases of poor performance and/or clinical disease are seen in cattle that have moved from a pasture-based diet onto a crop of forage brassica in the previous 10 to 14 days. There are a few exceptions to this rule, and these will be discussed in more detail later.

Table 2. Diseases directly attributable to the grazing of forage brassicas

Disease	**Aetiological agent (s) associated with brassica crop or indirectly with the brassica feeding system**
Abortion	Secondary to trucking, nitrate toxicity, mouldy hay, straw or silage
Diarrhoea	Ruminal acidosis, nitrate toxicity, high water content of crop, copper deficiency (young cattle)
Goitre (new born calves)	Goitrogens in forage brassicas
Hypocuprosis	Low copper, high sulphur in forage brassicas, compounded by soil ingestion
Hyposelenosis	Low concentrations of selenium in forage brassicas
Lameness	Footrot wet muddy conditions, secondary to nitrate, secondary to ruminal acidosis
Nitrate toxicity	Ruminal conversion of nitrate to nitrite
Photosensitisation	Unknown primary photosensitisation agent in forage brassicas
Polioencephalomalacia	Sudden dietary change and/or high dietary sulphur
Rape blindness	
‘Red water’, ‘kale anaemia’, haemolytic anaemia	S-methyl cysteine sulphoxide (SMCO) is converted to the toxic dimethyl disulphide (DMDS)
Ruminal acidosis	Low neutral detergent fibre, high non-structural carbohydrates
Ruminal distension	Bloat; oesophageal obstruction (“choke”)
Tryptophan toxicity	Acute interstitial pneumonia (rare)

As for ANY work up as part of an investigation of a disease or sub-optimal productivity on crop, the FIRST place to start is to ask the right questions.

History collection for cattle grazing on crop

History is often gathered concurrently with the examination of clinically diseased cattle and/or whilst walking the crop and cattle. Your ability to ‘multitask’ is often stretched and the collection of a full history may not always go to plan.

Critical clues can be gained from the client and/or the staff and if missed, clues that otherwise would assist with a diagnosis or with the development of ideas to remedy a problem may be gone forever! Do prioritise some focused time to gain more information about the crop, feeding history and management, and the cattle. Ideally involve all the staff in discussions. In larger herds the junior staff are often the ones spending the most time with the crop and the cattle. Staff involved with feeding the crop can not only be an extremely useful source of observational information, but also detail feeding practices to date vs. what is perceived/or required by senior staff/management.

Brassica forage crop related history

Species and cultivar or forage brassica. The type of crop may give a hint as to potential animal health or productivity-limiting conditions. Species specific examples include:

- Low DM percentage: Crops naturally vary in DM percentage, with advisors and farmers alike often over estimating the DM % of crop especially for late autumn / winter fed crops, However, between species, the late autumn / winter ranking for dry matter % from highest to lowest is as follows; kale > rape and leafy turnip > swedes > bulb turnips.
- Nitrate risk: Leafy winter crops are more rapidly prehended and chewed than harder, stemmy kale crops thus nitrate toxicity may occur more readily on leafier crops. Bulb crops potentially pose a lower risk due to a relatively low leaf percentage. However, like all green forages, leaf and petiole of brassica regardless of crop can potentially contain nitrates, and risk for nitrate toxicity should always be considered regardless of crop type, especially during the adaptation period by stock to brassica.
- Ruminal acidosis: As the ratio of water soluble carbohydrate (WSC) relative to neutral detergent fibre (NDF) increases with different species (bulb crops such as swedes and turnips > rape > kale) the risk of ruminal acidosis will increase especially if other low NDF / high WSC or starch supplements such as grain are fed. This is particularly true for hungry cattle accessing crops during the first 10 to 14 days of grazing, whilst adaptation by cattle to the crop is incomplete.
- Brassicas require fewer bites but more chewing activity than perennial ryegrass (Keogh et al, 2009) and younger cattle that are cutting teeth may fail to perform well on brassica crops. Consider the role of emerging teeth when investigating younger cattle that are failing to adapt well to forage brassicas, although social pressures must also be considered. Cattle that fail to adapt to crop should be monitored and if necessary, removed and grazed on pasture and silage. For cattle cutting teeth, softer bulb crops or leafier rape / kale crops may be easier to prehend than harder flesh bulb crops.
- SMCO concentration in kale is approximately double that of other brassica crops (Whittle et al 1976) and clinical cases of toxicity are more commonly encountered on kale. However, flowering brassica crops pose the greatest risk, with flower heads containing up to several times greater concentrations of SMCO than other parts of the brassica plant (Whittle et al 1976). The risk for SMCO toxicity varies between kale cultivars, with different growing conditions and between seasons, and toxicity may occur on other, non-kale crops despite the term 'kale anaemia' that is commonly applied to SMCO toxicity.
- Concentrations of glucosinolates concentrations vary between species and cultivars within species. Following hyrdolysis, glucosinolates can yield the metabolites, isothiocyanate, nitriles and thiocyanates, each of which can individually or in combination influence the animal, with signs ranging from reduced feed intake in young stock and adult cattle, to goitre in newborn calves. Kale can potentially produce significant amounts of the thiocyanate ion which acts as a goitrogen thus reducing iodine uptake by the thyroid gland. In forage rape, cultivars such as Maxima Plus and Titan have been bred specifically for lower concentrations of glucosinolates (*Nichol, pers comm*).

Sowing date of crop relative to grazing. The time of sowing has relevance for the potential DM crop yield for the crop and total feed levels on offer to cattle.

- A substantial quantity of water is ingested by cattle. Winter-fed crops will generally be lower in DM % than summer-fed crops, however immature summer-fed crops can also contain low levels of DM. Bulbs crops are characterised by low DM%, particularly if they have a low leaf percentage relative to bulb, for example both turnip and swede bulbs can be up to 94% water. This may have implications for harvesting efficiencies by the animal.
- The higher moisture content of immature crops may contribute to a higher faecal moisture content observed in cattle fed a high proportion of their diet as crop.
- Grazing bulb brassicas at an immature stage will increase risk of choke (oesophageal obstruction) by cattle. Bulbs of 4 to 8 cm diameter are more likely to cause choke (Stewart and Charlton, 2003). Most cases of choke occur at the level of the cervical oesophagus or at the base of the heart (Radostits, 2007).
- Grazing of immature, single-graze crops will reduce the crops DM yield potential by removing viable leaf area and reducing an opportunity for photosynthesis, and by treading damage to the plant. Note that some Southland kale and swede crops are lightly grazed by ewes but not cattle in late autumn.
- The grazing of immature rape crops, particularly late maturing cultivars increases the risk of photosensitisation ('rape scald,'). Note that 'rape scald' implies the role for rape only in photosensitisation of cattle on brassicas crops, when ironically most cases of 'rape scald' in New Zealand and south eastern Australia are seen on summer turnips.
- Current recommendations are that rape should be allowed to 'ripen' to reduce risk of photosensitisation in cattle. Ripening in rape is described as a change in colour from lush green to bluish / green with a red tinge on the leaves. Note that crop colour change is not an absolute predictor for risk of photosensitisation and scald may still occur on apparently 'ripe' crops. Autumn / winter fed rape crops are unlikely to ripen, however photosensitisation is not generally associated with crops fed at this time. If photosensitisation is observed during winter alternative causal agents should be investigated.
- Over-mature crops are utilised less well and are of poorer feed quality than crops harvested before or at maturity. Crude protein concentrations and DM digestibilities are reduced due to leaf senescence and stem lignification. Over-mature bulb crops may succumb to disease and rot, contributing to a net decline in DM yield. Depending on crop type and vernalisation requirements of the plant, over-mature brassica plants can are prone to reproductive development thus increasing the risk of disorders such as SMCO toxicity and nitrate toxicity.

Fertiliser history for the crop

- Recent applications of high rates of nitrogenous fertiliser increase risk of nitrate toxicity. Check how much was applied and when, and consider recent growing conditions since application of nitrogen (N). Nitrate concentrations may take up to 6 weeks to return to levels considered safe for grazing following the application of N.
- Excess N application has been linked to increased risk of brassicas-associated photosensitisation (Nichol, unpublished) and plant concentrations of SMCO (McDonald et al 1981).
- Excess sulphur availability to the plant has been linked to; increased risk of photosensitisation; increased risk for dietary sulphur-mediated cases of polioencephalomalacia (PEM), and increased plant concentrations of glucosinolates and SMCO.

- The key message is to identify IF the brassica crop has received excess N and sulphate that may have allowed the plant to accumulate these nutrients as nitrate, SMCO and glucosinolates.
- Sulphur levels in brassica crops are generally high and best practice is to reduce sulphur inputs, or to use non-sulphur fertiliser for the brassica crop when soil sulphate levels exceed 10mg/kg (Nichol, 2007). Brassica plants respond readily to N fertiliser, however when in excess will accumulate this N as non-protein nitrogen (NPN) forms of N, including nitrate. The risk for N related diseases will be heightened by the ploughing of pasture paddocks which allows N release during mineralisation.

Sowing rates for the crop kg per hectare. At lower sowing rates, kale and forage rape stems will be thicker resulting in potentially poorer utilisation of the crops by cattle and poorer feed conversion efficiency. Recommended rates for kale and rape are typically 4-5 kg/ha. The problems of denser woody stems become more apparent as the plants mature. Conversely, very high kale sowing rates result in many fine stems and less leaf, potentially reducing net yield of high quality forage per hectare. Inappropriately high sowing rates for swede or turnip can lead to smaller bulbs, pre-disposing the grazing animal to a greater risk of choke.

Information about recent growing conditions

- Periods of dull-overcast conditions and periods of extended rainfall can lead to over estimation of DM % and thus lead to over-estimation of feed intake. Ongoing high-rainfall events can reduce utilisation of the crop through crop damage and pugging.
- 'Stop – start' sporadic growing conditions and dull, overcast days are an important 'flag' for risk of nitrate toxicity.
- Frosted conditions increase risk of bloat and possibly ruminal acidosis for cattle grazing winter forage brassica crops.
- Intakes of DM may be slowed or prevented by frozen swede and turnip bulbs. Farmers should allow for this by increasing the amounts of alterative feeds on offer such as pasture silage, until the bulbs have the opportunity to thaw.

'Crop – cattle' interface, including grazing management, supplements and stock water

Time elapsed since cattle first accessed the crop. Most cases of brassicas-associated clinical diseases are seen within 10 to 14 days of cattle moving from a predominately pasture-based diet to a forage brassica based diet.

Risk of nitrate toxicity diminishes with ongoing exposure to crops that contain high concentrations of nitrate. Cattle can tolerate the ingestion of forage that contains high concentrations of nitrate many weeks after starting onto crop. Note that this tolerance to nitrate can be quickly lost if the cattle are stressed or undergo feed changes. The risk of nitrate toxicity is accentuated during the initial period of feeding because the area of 'break-feeding' is small relative to cattle numbers leading to a greater risk of break out and overconsumption of crop. Risk may be greater for younger cattle that may have limited experience of electric fencing.

Clinical cases of SMCO toxicity are typically seen three to five weeks after cattle go onto a high SMCO crop, and cattle can 'cycle' through apparent recovery and relapse with this condition. Cattle do not appear to successfully adapt to high concentrations of SMCO in the diet. The risk of SMCO toxicity is greatest when animals previously not exposed to brassica crop are introduced to act as a 'clean-up' late in the winter period when the crop is in flower.

Susceptibility of cattle to photosensitisation may occur at any stage on the crop (Morton and Campbell, 1997), but almost always occurs during summer / autumn feeding.

Cattle may take up to 28 days after leaving pasture to fully adapt to forage brassica feeding (Keogh et al, 2009), partly due to time for ruminal adaptation, as well as adaptation to the new feed (neophagia) if cattle have not eaten forage brassicas previously.

Amount of brassica fed per head per day as a proportion of the total diet. Check with your client the presence or absence of other non-brassica feeds in the diet. Anecdotally, risk of brassicas-associated bloat, ruminal acidosis, nitrate toxicity and SMCO toxicity appears positively associated with the proportional contribution of brassicas to the daily diet. The OPTIMUM dietary inclusion of brassicas will vary with class of stock. For example; milking cows should only be offered 35% of their diet as forage brassica to minimise risk of brassica milk taint. Dry cows are best offered up to 50-60% of their daily DM intake as brassicas; whilst young stock may adequately handle up to 80% of their daily DM intake as brassica, with the balance of diets delivered as pasture, silage, hay, straw or other supplements.

Is there evidence or history of breakouts over electric fences by cattle? 'Break outs' by hungry cattle over or through electric fences are a significant risk factor for brassicas-associated cases of ruminal acidosis, bloat and nitrate. Crops should be double fenced and adequate voltage on fences well maintained. Some dairy clients report apparent evidence of laminitic damage 2 to 3 months following breakouts on crop, indicating that for individual cattle, sub-clinical repeated episodes of brassica-associated ruminal acidosis may be an undiagnosed sequel to winter breakouts.

Order of feeding / daily routine. Are cattle offered supplements as the first feed of the day, or do they access the forage brassica crop first? The decision to feed either supplements (or pasture) before or after forage brassicas crops is a controversial one especially for summer-fed crop. Moving hungry cattle onto crop increases risk of bloat, ruminal acidosis, nitrate toxicity and choke but does improve utilisation of the crop. Conversely, 'full' cattle that are fed supplements first experience fewer health risks but utilisation of the crop can be reduced, due to 'full', content cattle roaming through the crop unnecessarily. During winter, offering some hay, straw and/or silage is recommended before shifting the break which allows the crop to thaw and prevents gorging by cattle on a new break. Feeding supplements first has the additional benefit of stopping cattle wandering which would otherwise lead to significant soil damage.

Consider recommending that during the first 10 to 14 days of brassicas grazing, cattle are 'filled up' on pasture or supplements first, then move them onto brassicas and accept that some wastage of crop is preferable to risk of nitrate toxicity or ruminal acidosis. Once cattle are better adapted after 10 to 14 days, the order of feeding can be reversed. Dry-cows are often moved from the milking platform direct to the brassica crop, removing the opportunity to slowly adjust animals from pasture to crop. In such cases crops can be 'heavy-rolled' to slow down animal intake, and offer as much alternative feeds, such as silage, hay or straw as the feed budget will allow.

Order of feeding for summer turnips to prevent milk taint. Brassica-fed milking cows may produce milk 'tainted' by volatile glucosinolates. Standard practice is for milking cows to access turnips or other brassica after the morning milking and to limit the intake of brassicas to less than 1/3 of the diet on a DM basis. Some cattle in some herds may be at increased risk of ruminal acidosis if hungry cattle access turnips immediately after milking. Risk is heightened by cattle 'drifting' onto the turnip crop as they leave the milking shed because the same dominant cattle will tend to access the crop *ad libitum*, first. By preference, all cattle should access some pasture and/or forage supplements before moving to the turnip crop, for example, consider the use of feeders on the main race. At least consider holding all cows back from the crop until milking is complete, such that all cattle can access the turnip crop face simultaneously.

Quantity of crop on offer. Underfeeding is a risk factor for condition loss / failure to perform and increases the likelihood for breakouts by hungry cattle over fences. Underfeeding is the single most important cause of brassica-fed cattle failing to meet performance expectations. Underfeeding is commonly caused by overestimating tonnage of crop on offer and/or underestimating wastage of crop (and supplements) during grazing. Over-estimating crop yield is often caused by incorrect measurements of fresh weight yield, over-estimation of DM percentage and over-estimation of the paddock area actually in crop.

Overfeeding is a risk factor for ruminal acidosis, bloat and PEM due to selection of leaf over stem by dominant cattle. Risk of SMCO toxicity increases with overfeeding due to the potential overconsumption of brassica by some cattle, relative to other non-brassica supplements. Overfeeding is undesirable for economic reasons due to the wastage of brassicas grown, increasing the cost cents per kgDM of feed *utilised* by the animal. The cost and time involved with preparing a paddock for regrassing is increased by overfeeding / poor crop utilisation due to the disking and reworking of uneaten bulbs and/or stems during seedbed preparation.

Nichol et al (2003) described a method for assessing DM yields of forage brassica crops to assist with the allocation of appropriate areas of forage crop per day. This process should be MANDATORY before any crop is grazed by cattle to minimise risk of over or under feeding problems.

Presence of leaf relative to stem (and bulb, if relevant). Leaf may be lost from both leafy and bulb crops due to moisture stress, disease and insect pressure, frosting or snow damage or simply as the crop becomes over mature.

Loss of leaf on rape and kale crops increases risk of poor performance due to an over predominance of poorer quality stem relative to leaf. Bulb crops with little or no leaf increases the intake of WSC relative to NDF with an increased risk of ruminal acidosis. Crude protein deficiency due to loss of leaf is a hypothetical risk for some stock classes, however practically this is rarely of significance.

Recent growth rates / DM production by the crop. Brassica-associated photosensitisation is more commonly seen in cattle on summer brassica crops when crops are low yielding and the crop is stressed by inadequate rainfall (Morton and Campbell, 1997). Wilting of crops may increase risk of nitrate accumulation in the plant, thus increasing risk of toxicity.

Presence of yellow flowers and/or seed pods. Flowers and seed pods increase the risk of nitrate and SMCO toxicity as concentrations of both compounds, as well as glucosinolates are concentrated in the flowers and seed pods (Prache, 1994). Flowering crops are typically of lower feed quality and support poorer feed conversion efficiencies than vegetative brassica crops. Anecdotal evidence would suggest that cattle can tolerate some the ingestion of some flowers and seed pods, provided brassicas deliver only part of the daily requirement for DM.

Presence of other non-brassica species within the crop including weed species. A wide range of common weed species may contribute to risk of animal health challenges for brassica crops, particularly if weeds contribute a substantial amount of DM to daily intake by cattle and/or if cattle are forced to clean up weed species. It is critical to ask about the presence of weeds in the crop and ideally to walk the crop yourself or arrange for someone with more agronomic expertise to check this for you. Examples may include the presence of redroot (*Amaranthus sp*) and fathen (*Chenopodium album*) as a potential cause of nitrate toxicity in cattle fed brassicas, or hemlock (*Conium maculatum*) along fence lines, contributing to cases of sudden death in brassica crops.

Break feeding. Are cattle well fenced or are they breaking through? Breakouts increase risk of ruminal acidosis, bloat, and nitrate. Is there sufficient face of crop (metres per cow) on offer to cattle or is there too much competition between cattle for access = greater between-animal variation in feed intakes and liveweight gains. An ideal target for adult cattle is around 600 mm per cow face access. Breaks should be long and narrow, rather than short and wide. As break width increases, utilisation will decline due to trampling of crop, leading to reduced DM intakes.

Changes in break feeding strategies weeks or months after cattle started grazing brassicas may induce animal health challenges. The accumulation of unwanted tonnages of forage brassica due to above average crop DM yields and/or low stocking rates can be problematic. Surplus forage brassica is challenging to remove often requiring more stock (often animals that have not previously been on crop) to remove the excess so that it can be re-cropped or sown into pasture, When additional stock are unavailable to consume the surplus, cattle are often 'opened up' onto large areas of brassica with the concurrent cessation of supplementary feeding. *Ad libitum* feeding may induce brassica-associated health problems not seen earlier when grazing was more tightly controlled. PEM was reported in 25% of kale-fed heifers following the cessation of break feeding and hay supplementation (Hill and Ebbett, 1997). No cases of PEM were seen during the preceding two months when hay was fed and electric fences were used to control crop allocation.

Supplements present. The high digestibility and low levels of NDF of brassicas necessitate the feeding of high NDF supplements or pasture as part of the diet (Keogh et al, 2009). Cattle should not be fed 100% of their daily DM demand as brassicas.

The ideal "brassica balancing" supplement is one that is characterised by a high physically effective NDF (peNDF), one which is clean and that is palatable to cattle. Typically part of the supplements should be a high quality silage or baleage, the balance as a high peNDF forage e.g. straw or a rougher meadow hay. Check the quality of these supplements, and make sure the cows are actual eating them. For example, cereal straw should be "clean and bright", blackened straw can lead to rejection by cattle or cause mycotic abortion. Note, 'ryegrass staggers' associated with silage or hay made from ryegrass infected with the standard (wild-type) ryegrass endophyte can occur if sufficient quantities are fed.

Low crude protein (CP) forage supplements may deliver insufficient protein if a bulb crop has lost significant leaf, however this is rarely of practical significance unless a stock class with a high requirement for protein (e.g. yearling cattle) are offered a low CP silage e.g. maize and cereal silage together with a leafless forage brassica.

Quantities of supplement on offer – do they tally relative to numbers of stock present and the planned per head per day feeding rates? Are there overt moulds or fungi present in silage, hay or straw? These may imply poor utilisation of supplements, increasingly likelihood of poor per head performance, as well as a greater risk for mycotic abortion and listeriosis. Farmers often clear silage pits towards the end of winter and offer this to late gestation dry cows. The feed quality of this silage is likely to be poor, and poses health risks due to silage contamination with fungi and soil.

Waste onions are occasionally fed to cattle, including those already ingesting forage brassicas. The concurrent feeding of onions and forage brassicas should be avoided because onions contain SMCO and SPCO (S-propenylcysteine sulphoxides, Parton, 2000) that are potentially haemolytic and may accentuate the effects of SMCO from forage brassicas.

Presence or absence of hedge or tree lines adjacent to crop. Consider the presence of macrocarpa trees and hedgelines when investigating cases of 'brassica-associated' cases of abortion. Note that the absence of shelter may contribute to poor feed conversion efficiency and increased risk of metabolic disease in heavily pregnant cattle during inclement weather.

Stock water

- **Availability of stock water and quality of the water.** All stock classes MUST access water when grazing forage brassicas. It is INCORRECT to presume that the high water concentration found in forage brassica will ameliorate demand by stock for water. Lack of water / problems of access by cattle to water whilst grazing forage brassicas will increase the risk of sub-optimal performance.
- **Water quality** – any issues with quality of water (would you put it in YOUR coffee?). Think through water quality issues, e.g. high sulphur accentuating risk of PEM on brassica crop or high nitrate concentrations accentuating risk of nitrate from the forage brassica crop.
- **Distance of water troughs from brassica break face** – too far will discourage some cattle from drinking = lower DM intakes and more variable animal productivity from brassica crops. During winter feeding, water should be kept up to the crop face, preventing damage to the soil with animals moving around the paddock in search of water.

Finding out more about the cattle

Define the stock class, age range and pregnancy status. For some brassicas-associated diseases including SMCO toxicity and nitrate, younger cattle and heavily in-calf cattle are at greater risk of disease than older, non-pregnant. Heifers that are cutting teeth are more prone to failure to adapt well to brassicas due to a reluctance to prehend and chew plants, and young cattle of shorter stature are less able to handle tall kale crops due to size disparity.

Vaccination history. For young cattle, a failure to vaccinate against the common clostridial diseases increases risk of deaths. Vaccination is mandatory for young cattle about to graze crop, with a second injection given at least 2 weeks before cattle access crop.

Evidence of clinical disease in the cattle. Knowledge of a current or developing clinical problem is critical to not only to pre-empt ongoing clinical problems in cattle on the crop, but also to assess the role for disease in the aetiology of sub-optimal performance. The absence of overt clinical disease does not rule out the presence of sub-clinical problems.

Cases of clinical disease observed. When did these cases apparently occur relative to the timeline of the cattle grazing the forage brassicas? Creating a timeline of events is critical to assist with the identification of possible causal and non-causal associations between aetiological agents and clinical cases of disease.

Were treatments initiated and what results were observed in response to treatments? Response by cattle to treatment does not offer a definitive diagnosis but can be useful in narrowing down probable causes of disease. Care is needed in some situations, e.g. response by ‘downer’ cattle to calcium may be a short term response to hypocalcaemia secondary to a primary disease agent, e.g. ruminal acidosis or nitrate.

Any cases of goitre in pregnant cattle on the crop? The detection of clinically goitrous calves aborted from or born to brassica-fed dairy cattle is a relatively rare outcome (Kearney, 2003) and varies with season. Cattle are less severely affected by goitrogens than ewes maintained on forage brassica crops pre-lambing. Kearney (2003) concluded that clinical abortions of goitrous calves were more commonly seen in heifers fed on brassica crops for more than 90 days, and more often reported on kale than swede or turnip crops. Anecdotal evidence supports the benefits of Flexidine in the prevention of goitrous calves born to cattle fed on brassica crops (Kearney, 2003).

Are there, or have there been prophylactic mineral treatments on offer to the cattle?

- **Absence of magnesium supplementation** may predispose some stock classes to hypomagnesaemia in heavily pregnant cattle on crop. Typically most springing cattle are removed from brassicas crops before calving, thus removing the class of pregnant cattle most susceptible to hypomagnesaemia, however best practice may involve supplementing 'far off' pregnant cattle on crop, beginning four weeks before planned start of calving.
- **Lack of copper, selenium, iodine supplementation** increases risk of deficiency, particularly if the trace mineral status is poor before cattle access crop. A primary copper deficiency induced by low concentrations of copper in forage brassica crops may be accentuated by dietary copper antagonists, including high concentrations of sulphur in the brassica plant and ingestion of soil during grazing, increasing the intake of molybdenum, iron, and sulphur. Typically prolonged exposure (greater than 3 months) to brassica-based diets is needed to induce overt clinical signs of copper deficiency, most typically in young cattle (Barry et al, 1981).

  Levels of selenium in brassica plants are typically low or nil and supplementation is usually required, as either daily oral supplementation with sodium selenate based preparations, or remediation of deficiencies using parenteral products when cattle are removed from brassicas. Note that the susceptibility of cattle to SMCO toxicity could hypothetically be increased by a concurrent deficiency of selenium.

  Brassicas are characterised by low levels of iodine and the presence of goitrogens in forage brassicas accentuates the potential for iodine deficiency in cattle grazing forage brassicas. Kearney (2003) gave an excellent practitioners overview of the role of iodine in forage brassica nutrition, including quantitative guidelines as to typical iodine supplementation rates for brassica-fed cattle.

Walking the forage brassica-fed herd: What to consider

Body condition score (BCS) – average and range. This is best repeated over time to gain relevance as to recent changes in condition score. Changes in BCS provide an indicator for probable level of feeding (or feed utilisation) and the probable successfulness of adaptation by cows to crop. A widening range of body condition scores over time can be suggestive of a proportion of cows failing to adapt well to crop. Consider issues such as social pressures of very large mobs, amount of crop face available per cow, and failure by rising two year olds to adequately adapt socially or that may be struggling due to the emergence of teeth. Utilise bodyweight data, if available, to validate the more subjective body condition score process.

Rumen score – average and range. Rumen score on a scale of 1 to 5 (1 is slab sided, 5 is extremely full rumen capacity) can provide an objective indictor for adequacy of feed on offer and for current, developing or previous challenges of rumen wellbeing / ruminal acidosis. Variable rumen fill may simply reflect the high intake of water associated with the low DM % of brassicas (Keogh et al, 2009). Note that rumen scoring is potentially confounded by timing of scoring relative to shifting of cattle onto new break or feeding out of supplements. The presence of bloat in some cattle may be suggestive of one or more of: Breakouts over fences, feeding off a frosted winter crop, presence of ruminal acidosis, overfeeding, or the presence of a very leafy, lush brassica crop.

Dung score – average and range on a scale of 1 to 5 where 1 is extremely liquid and 5 is dry, firm and 'horse dung' like. Subjectively appraise the dung for consistency, smell, colour, presence of undigested fibre, bubbles or mucus, and lumps of undigested brassica plant.

Cud chewing. This provides an indirect, subjective indicator for rumen well being. Absence of chewing or fewer than target chews / minute may be suggestive of but not diagnostic for ruminal acidosis. The appropriate use of cud chewing to assess rumen health can be challenged by time of appraisal, relative to feeding times.

General cattle behaviour. Changes in behaviour that deviate from normal may include hyperexcitability, suggestive of hypomagnesaemia, nervous form of ketosis, or PEM. Dull, depressed cattle may indicate ketosis, the over zealous supplementation of cattle with magnesium, or simply cattle that are depressed due to systemic disease from ruminal acidosis or mastitis. Consider PEM or rape blindness for any cattle that may appear poorly responsive due to apparent blindness.

Coat condition. This is an extremely subjective measure of cattle well being and care is required in interpreting general coat condition. Very rough coats may indicate a recent period of loss of body condition score or a selenium or copper deficit. Do not confuse rough coats with heavy winter coats with cattle on winter brassica.

Respiratory well being. Respiratory distress in individual cattle may indicate nitrate toxicity or acute interstitial pneumonia (tryptophan toxicity) or simply that cattle that have recently moved paddocks, or been recently yarded. Note that acute interstitial pneumonia is relatively uncommon in New Zealand.

Skin and Udder. Mud cover over the udder may highlight an increased risk for early dry period mastitis if recently dried off cows are on crop and are still leaking milk. For lactating cattle on forage brassicas, the presence of mud implies a greater risk of environmental mastitis and prevention strategies should be discussed with your client. Mitigation strategies may include pre as well as post milking teat spraying, and holding cattle on relatively clean areas before sending out onto crop – allowing additional time for teat end closure before exposing the teats to mud.

Bryan (1998) queried the presence of a brassica-associated allergen during the investigation of an usually high incidence of pruritis in herds grazing winter brassicas in Southland, however the author did not propose a causal association.

Vulva. Look for red vulval staining on individual cows, indicative of SMCO toxicity, evidence of a slip of membrane indicative of foetal loss caused by nitrate toxicity, mycotic abortion, neosporosis, leptosporosis or listeriosis.

Feet and legs. Look for evidence of footrot, or sole bruising due to wet muddy conditions. Lameness and bone fractures were reported in young angus steers grazing swedes for 3 months (Thompson and Cook, 1986) most likely due to an insufficient intake of phosphorus with a subsequent osteodystrophy. Despite the unusual calcium to phosphorus ratio of forage brassica crops, field reports of rickets in young cattle grazing forage brassicas are extremely rare.

Examining the individual forage brassica-fed animal

The summary table on the following page is not intended to replace your standard approach to the clinical examination of your patient, rather it is intended to highlight, on a system by system basis possible brassica-related conditions that should be specifically investigated. The examination should complement the collection of history about the animal and the herd, and ideally accompany a crop and herd walk to look for ‘flags’ of interest as discussed earlier.

Table 3. Clinical signs directly or indirectly associated with the feeding of forage brassicas

Clinical signs	**Possible causes related to the crop**	**Unrelated aetiological agents for consideration**
Typically (but not necessarily) during first 10 to 14 days		
Abortion	Stress of trucking, nitrate, mouldy silage or hay fed with crop	Neosporosis; Leptosporosis; Macrocarpa ingestion; Listeriosis, mycotic abortion
Diarrhoea	Ruminal acidosis, nitrate, high water content of crop	Salmonella or other bacterial enteritis, BVDV/mucosal disease, parasitic gastroenteritis
Distension of rumen / abdomen	Bloat – frothy and / or secondary to ruminal acidosis (free gas bloat) Oesophageal obstruction/ choke - turnips, small Swedes	Frothy bloat from lush N boosted pasture or legumes Vagal indigestion, choke, clostridial disease, displaced or impacted abomasum, caecal torsion, foetal hydrops (contour of abdomen should be observed from the rear to help differentiate between conditions) prior to auscultation and rectal examination
Neurological signs,	Polioencephalomalacia: staggering, blindness, ataxia, muscle twitching head pressing Nitrate toxicity: muscle tremors, weakness, stumbling gait, convulsions	Nervous form of ketosis; hypomagnesaemia; ryegrass staggers; Lead toxicity
Goitre in newborn calves	Primary iodine deficiency and / or conditioned deficiency due to presence of goitrogens	
Hypocuprosis, coat colour changes, diarrhoea in young cattle	Prolonged exposure to high sulphur, low copper status of forage brassicas, soil ingestion	Other differential diagnoses for scouring in young cattle
Hyposelenosis	Prolonged exposure to low selenium, high sulphur status of forage brassicas, possibly compounded by vitamin E deficiency	Other differential diagnoses for ill thrift
Lameness	Ruminal acidosis, nitrate, phosphorus related osteodystrophy (rickets; young cattle only)	Footrot, chronic lameness (e.g. WLD from milking platform), stones trapped between claws under muddy conditions, osteodystrophy from vitamin D deficiency
Loss of body condition score	Insufficient DM on offer, failure to allow for wastage of crop during grazing, poor grazing management, sub-clinical disease that limits appetite, high quality forage driving milksolids production in lactating cattle.	Multiple management and sub-clinical disease issues to consider
Red water	Kale anaemia (SMCO toxicity)	Copper toxicity, Hypophosphataemia; Leptospirosis; Onion toxicity; MCF, Bracken fern toxicity,
Photosensitisation	Primary photosensitisation agent in some brassicas	Facial eczema, Spring eczema, storksbill or St John Wort, Ngaio toxicity, algae in water supply
Pneumonia	Acute interstitial pneumonia (acute pulmonary emphysema and odema, Tryptophan toxicity or 'fog fever')	Pneumonic pasturellosis, viral interstitial pneumonia, IBR, verminous pneumonia (Dictyocaulus), allergic rhinitis, aspiration pneumonia
Staggering, agonal gasping, colic, brown mucous membranes,	Nitrate toxicity. May be during first few days on crop or later, if the crop is flowering	
Sudden death	Nitrate toxicity, ruminal acidosis, SMCO toxicity, clostridial disease, choke, PEM	Copper toxicity, cyanide toxicity, acute enteritis,Type 2 ostertagiosis, lightening strike, plant toxicities (e.g. Hemlock), monensin toxicity,

Table 4. Some clinical signs to consider when examining cattle fed on brassicas

Clinical examination of the individual cow or heifer	**Rationale to investigation with specific regard to brassica-associated disease**	**Common differential diagnoses to consider**
General appearance and demeanour	Dull, unresponsive = range of brassica-associated disease including PEM Hyper-reactive = nervous ketosis secondary to other primary disease, hypomagnesaemia for cattle in late pregnancy	
Rectal temperature	Hypothermia or hyperthermia with SMCO; Hypothermia with ‘downer’ cow due to range of conditions; Hyperthermia with excessive muscular activity associated with PEM	Increased with stress, viral or bacterial infections, recent handling e.g. running cattle into yards
Eye	Apparent blindness / absence of menace reflex, dorsal strabismus, nystagmus with PEM A separate and possibly unrelated condition ‘rape blindness’ is reported, associated with the high sulphur content of brassicas. Eyes appear normal, some response to light and pupils may or may not be dilated.	Blindness due to injury to optic nerve, other causes of ischaemic or metabolic lesions of the cerebral cortex, ketosis, secondary to ruminal acidosis, lead poisoning
Respiratory rate	Increased rate and mild hyperpnea with SMCO associated anaemia Increased rate and severe dyspnea with acute interstitial pneumonia and nitrate. Mouth breathing and subcutaneous emphysema around the thorax may be seen with acute interstitial pneumonia.	Stress and / or exercise associated with yarding Overconditioned cattle have increased RR relative to moderately conditioned cattle Pneumonia: IBR, Salmonella
Heart rate	Tachycardia: Ruminal acidosis and SMCO induced anaemia	Increased HR with stress of handling and yarding
Left abdomen: Rumen	Hypomotility, ruminal acidosis; Bloat	Hypomotility, hypocalcaemia; Frothy bloat; Vagal indigestion
Reproductive tract	Abortion: Nitrate or mycotic and secondary sequalae	Abortion due to other reasons: Neosporosis, leptosporosis, BVD, listeriosis
Skin and udder	Brassica-associated photosensitisation due to an unknown primary photosensitisation agent	Other causes of primary or secondary photosensitisation – sporidesmin toxicity, Ngaio, St Johns Wort toxicity

Table 4*(continued)*. Some clinical signs to consider when examining cattle fed on brassicas

Clinical examination of the individual cow or heifer	**Rationale to investigation with specific regard to brassica-associated disease**	**Common differential diagnoses to consider**
Rectal examination (abdominal and pelvic cavities, contents of rectum)	Contents of rectum dry – constipation secondary to milk fever High faecal moisture– ruminal acidosis, nitrate toxicity, high water content of brassicas	Ruminal acidosis from supplementary feeds (cereal grains and silages with high starch contents)
Mucous membranes	Pale brown or grey – Nitrate toxicity Pale and slow CRT – SMCO induced anaemia Jaundice	Pale – hypophosphataemia, copper toxicity, chronic hypomagnesaemia, onion toxicity, leptospirosis, malignant catarrhal fever, bracken fern toxicity, anaemia secondary to acute bacterial infection, 'Taranaki anaemia', sporidesmin toxicity
Urine sample	Haemoglobinuria associated with SMCO toxicity – haemoglobinuria is seen when blood haemoglobin concentration is below 60g/L; Frequent urination and dribbling with nitrate	
Blood haematology profile	**SMCO:** Red blood cell count, haemoglobin concentration, haematocrit and leucocyte count reduced – nadir is 3 to 5 weeks after cattle start on crop. Haematocrit may be as low as 35% of normal values. Heinz Erlich bodies present up to 100% of RBCs and precedes anaemia. Heinz bodies can appear a few days to 3 weeks after cattle start on brassica crops, peak numbers are 10 to 30 days after cattle start on crop. Macrocytic anaemia **Nitrate** (chronic exposure): Increased PCV and haemoglobin; Dark chocolate colouration to blood (NOT in all cases)	
Blood chemistry profile	**SMCO:** Hypocalcaemia and hypophosphataemia; Icterus (both pre and intra-hepatic) **PEM:** Blood thiamine, not very reliable and less relevant if PEM mediated by high dietary sulphur; Erythrocyte transketolase activity decreased and thiamin pyrophosphate effect increased (hard to interpret) **Ruminal acidosis:** Terminal stages; increased haematocrit, increased blood lactate and phosphate, hypocalcaemia. **Nitrate:** Methaemoglobin useful but difficult to handle, usually rely on post-mortem results and feed analysis for diagnosis	

Table 5. Brassica-related changes on post mortem to consider when investigating death of cattle on forage brassica crops

Post Mortem findings: Brassica related disease	**Gross pathology findings**	**Diagnostic aids**
Nitrate toxicity	Blood – dark chocolate, coffee or dark red brown (absence does not rule out nitrate toxicity) GIT mucosa may be congested and haemorrhagic Cardiac haemorrhages and pulmonary congestion may be seen	Urine, blood or aqueous humour to demonstate presence of nitrate / nitrite. Aqueous humour is of value up to 24 hours after death, blood only a few hours. Submit feed tests for nitrate analysis to laboratory.
PEM	Brain: Cerebral oedema, with evidence of compression, yellow discolouration of the dorsal and cortical gyri. Cerebellum may be pushed back into the foramen magnum. Rumen: PEM may confer an abnormal hydrogen sulphur smell.	Fluorescence under UV light and histolopathological examination of the brain to demonstrate bilateral laminar necrosis. Samples of forage brassica for full feed test analysis including sulphur concentration
SMCO toxicity	General pallor and jaundice; Bladder: Haemoglobinuria; Blood: Thin and watery; Renal darkened colouration; Liver: Accentuated lobular appearance; Spleen enlargement (peracute cases)	Submit histopathology – non-specific changes to liver associated with hypoxia; Collect bloods from other less severely affected cattle to look for changes consistent with haemolytic anaemia and presence of Heinz-Ehrlich bodies; SMCO levels in forage
Goitre	Goitrous calves born to or aborted from heavily in calf cows	Gross evidence of thyroid enlargement, confirm on histopathology.
Rumen acidosis	Thin, liquid rumen contents, epithelium peels away; Abomasitis, enteritis; Histopath on rumen: severe haemorrhagic necrosis and infiltration by fungal mycelia; fungal hepatitis, terminal ischaemic nephrosis	Rumen contents pH < 5.0 and certainly < 4.5 (test sample within 1 hour of death)
Acute interstitial pneumonia	Very rare. Both lungs are firm, heavy and wet. Foam is in the larger airways and the lungs do not collapse readily when incised.	Confirm diagnosis with histopath

Summarising 'Best Practice' for cattle on forage brassicas

An opportunity for the practice

Become involved with your clients forage brassica **planning**, including discussions with your clients agronomist to better understand why, how and when crops are being planned.

Involve yourself with your clients planning well before the crop is going to be grazed off. Proactive involvement could include one or more of the following:

- Feed budget to help define feed supply and demand, including crop cuts to define amounts of feed on offer
- Opportunities to balance the crop with the more appropriate supplement (s) that may be on hand,
- Strategies that will help cattle gradually adapt to crop
- Development of a time line that permits maximum returns for the client from the crop and includes your proactive involvement every step of the way including checking mineral status of the herd well before they go onto crop.

  Most of the planning should aim to maximise animal performance on the crop through excellent crop utilisation, nutritional balancing and feeding levels that match well the feed demand for that particular stock class. Strategies that aim to mitigate risk of the brassica-associated animal health challenges are a lesser but nonetheless important part of the planning process.

The basic steps of planning include some or all of the following:

- Feed budget to define if there is adequate crop (and pasture and/or supplements) on hand to fully feed the cattle as intended. At the very least, defining numbers of 'cow days' at a given feeding level per cow per day can provide a short term, partial look at quantities of feed on offer. MOST CASES OF POOR PERFORMANCE ON CROP ARE CASES OF SIMPLE UNDERFEEDING DUE TO POOR OR INAPPROPRIATE PLANNING
- Define the tonnage of crop on hand (as described by Nichol et al 2003) - train one of your RATs to do this or recruit a professional organisation that will do this for the client. Arrange for brassica forage samples to be tested for nitrate before stock graze the crop if growing conditions and fertiliser history are suggestive for nitrate toxicity.
- Discuss break-feeding plans with the client, including developing the appropriate square metres per cow per day based on the per hectare tonnage of crop on offer.
- Ensure that a copper, selenium and iodine mineral supplementation has been developed for the cattle, and a magnesium plan is in place for lactating and heavily pregnant cattle.
- Suggest a couple of proactive drop in visits to view the cattle during the first couple of weeks on the crop to help identify sub-clinical problems that may be limiting animal performance.
- For larger dairy businesses, offer a training seminar for staff, covering off the above topics, as well as signs to look for in cattle that may be underperforming or showing signs of disease on crop.

Conclusions

Forage brassicas are an extremely valuable component of many New Zealand dairy farms and runoffs. More than 300,000 ha of forage brassicas are grown annually and almost all crops are successfully and cost-effectively converted into liveweight gain and milksolids.

Occasionally, a dairy practitioner is asked to investigate a case of cattle "failing to meet expectations of animal performance" on a brassica crop and in these instances, it is appropriate to undertake an investigation of the interface between crop and animal. In almost all cases it is inappropriate to simply examine and treat apparent cases of clinical disease in the absence of a more thorough investigation of the whole herds performance on the forage brassica crop. Importantly, easy as it may be, don't be tempted to automatically blame a clinical problem of ill thrift or disease on the crop, it is your job to undertake an impartial investigation of the problem, remembering to consider all non-crop associated aetiologies that may present with similar signs as crop related conditions.

Providing a "fence at the top of the cliff" is preferable to providing "the ambulance at the bottom" for almost all cases of nutritionally mediated disease, and brassica-associated challenges are no exception. By evolving a basic understanding of brassica crops and the best ways that they should be managed will allow you to become more proactively involved in your clients dairy business as well as developing professional satisfaction that comes with a more holistic involvement in the farm system.

Develop a network of people around you to assist in areas of your dairy clients business in which you may feel a little out of your depth (none of us can and never will know it all). Most of us received minimal agronomy training at vet school and realistically we're not going to retrain now as fully fledged agronomists. Learn to "know what we don't know" and gather likeminded individuals around you who possess a complementary skills set. Chances are that they will be just as keen to connect with you to share ideas and complement each other when working with clients.

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