MEAT & LIVESTOCK AUSTRALIA

On farm

Review of Hydroponic Fodder Production for Beef Cattle

Project number NBP.332

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ABSTRACT

On the surface, the concept of putting one kilogram of grain into a hydroponic system and producing 6 to 10 kilograms of lush green sprouts, independent of weather and at any time of year, is appealing. Though it seems like growing a lot of feed, the increase in fresh weight is due to water and most often there is a reduction in dry matter weight compared with the initial grain. Hydroponically sprouting grain is less a case of growing feed and more a case of buying in grain and spending additional, sizeable quantities of time and money to change its quality and reduce its dry matter weight. The economics and application of such a production system should be carefully examined.

This report evaluates the economics of producing cereal sprouts for commercial cattle production through a hydroponic system. It looks at aspects of sprouts dry matter content and nutrient quality as well as provides methods of costing and comparing sprouts with other supplements.

EXECUTIVE SUMMARY

Profitable use of sprouting grain as a feed source for commercial cattle production appears unlikely. Although hydroponically sprouted grain is a highly nutritious feed, it has major limitations for profitable use in commercial cattle operations, including its high cost of production (cost of capital, depreciation, labour, running costs), scale of operation, handling of very high moisture feed and risk of mould.

Mould is a common problem that increases labour and costs, reduces animal performance and sometimes results in stock deaths.

A problem that people may have in evaluating the cost of sprouts is failing to account for its high moisture content, labour input and capital costs. Therefore many people think it is much cheaper than it really is. It is best to evaluate supplements on a dry matter basis and examples are given in this report. Sprouts have been found to cost from two to five times the cost of dry matter compared with the original grain. Ultimately, it is the performance relative to the cost that determines profitability.

There are many unsubstantiated claims of exceptional live weight performance due to hydroponic sprouts. Tudor et al. (2003) recorded higher than expected performance over 48 days and concluded that further rigorous research was required. The performance potential of sprouts as a supplement to dry pasture remains largely unknown.

Hydroponic sprouts may have profitable application in intensive, small-scale livestock situations with high value outputs, where land and alternative feed costs are high, and where the quality changes (eg less starch, more lysine, vitamins, etc) due to sprouting are advantageous to the particular livestock. Such quality improvements may be more applicable to horses and humans than to commercial cattle. Sprouted legumes have been used to prevent scurvy in humans (Leitch 1939). For horses, sprouts provide high energy and protein, low starch, no dust and a useful supplement of vitamin E and biotin (Cuddeford 1989). Ruminants synthesise many of their own vitamins in the rumen. Cattle are also less efficient at using high quality feeds than horses or monogastrics such as pigs and people.

Full feeding for commercial cattle production with sprouts is inappropriate due to its high moisture content, high cost and scale of operation. As with any supplementary feeding, the cost and performance of sprouts should be compared with other feeds.

The future of hydroponic sprouts in commercial cattle production depends on:

1. The cost of nutrients and performance supplied by sprouts relative to other feed supplements; and
2. Understanding the real cost and value of sprouts in animal production.

MAIN RESEARCH REPORT

Background

Sprouting grains for human consumption has been used for centuries in Asian countries to improve food value. Hydroponics and sprouting cereals for livestock fodder has a shorter history. In 1699 an English scientist, Woodward attempted to grow plants in various sources of water (Withrow and Withrow 1948 as cited in Myers 1974). In the mid 1800s, the French chemist Jean Boussingault verified nutritional requirements of plants grown without soil and by 1860 the techniques of "nutriculture" were being perfected by Sachs and Knop working independently in England (Hoagland and Arnon 1938 as cited in Myers 1974). About this time European farmers also began sprouting cereal grasses to feed to dairy cows during winter. In the 1920s and early 1930s Dr W. F. Gericke developed procedures to grow plants in nutrient solution on a large scale (Butler and Oebker 1962 as cited in Myers 1974).

In 1939 Leitch reviewed a range of experiments using sprouted fodder for dairy cows, beef cattle, calves, pigs and poultry. The introduction to Leitch's thesis commences "The present lively interest in sprouted fodder has arisen from the commercial exploitation of processes of water culture of plants to produce stock fodder". Leitch referred to five commercial hydroponic fodder systems. Two British commercial systems, "Cabinet Culture" (also called "Crop-a-day") and "The Sprout Process", two German patents and interestingly an electrically heated cabinet in Australia called "Vitaplant" which was marketed by "British Cultivations, Ltd." In the 1950s fodder sprouting chambers had moved from Europe to the USA.

From the early 1970s a range of units were designed and manufactured in Europe and the USA. One Irish company manufactured a machine to produce hydroponic barley grass.

In 1973 in South Africa, D. A. Harris (1973) estimated that "no more than 400 units of all types of fodder sprouting chambers are in use in South Africa" and also raised the question of the economics of such a production system. Meanwhile in 1974 in Arizona, John Myers commented, "Thus it is that we find nothing but contradictory and conflicting research reports in a literature search today" (Myers 1974).

Fodder sprouting chambers have been used in Britain, Europe, Canada, USA, Mexico, Ireland, South Africa, India, Russia, New Zealand, Australia and no doubt many more countries.

In Australia in 1992, 1997 and 2003 journalists reported that 'The Fodder Factory' was the answer to drought for livestock producers. In March 2003 in Western Australia Tudor et al. (2003) found conflicting results feeding cattle with sprouted barley.

Today a range of commercial hydroponic systems are marketed in Australia for sprouting cereal grains for livestock production (Table 1).

Table 1 Some commercial hydroponic fodder systems in Australia

States in which the businesses are based			
NSW	QLD	VIC	WA
1. Fodder Factory 2. Green Feed Solutions 3. Hydroponic Greenfeed 4. Rotating Fodder Machine 5. The Charles Feed Shed	6. Automatic Paddock 7. Greenhouse Fodder Systems 8. Opti Grass 9. Simple Shed 10. The Fodder Wheel	11. Livestock Fodder Shed	12. Auto Grass

Project objectives

1. Independent review of the advantages and disadvantages of growing hydroponic feed for beef cattle under Australian conditions and production regimes compared to conventional feeding regimes, including:
   - nutritional value;
   - economics;
   - infrastructure requirements; and
   - labour requirements.

2. Identification of issues and research needed to be undertaken to evaluate growing hydroponic feed for beef cattle under Australian conditions and production regimes.

3. Information and reference database for use by red meat producers, scientists, extension staff and others to make more informed decisions regarding the use of hydroponic fodder as an alternative feed source compared to conventional methods.

4. This information may also inform the MLA Feed Stuff Consultancy currently underway.

Methodology

1. Literature review
2. Informal interviews - phone and/or face-to-face (where practical) with key representatives from the following groups of hydroponic fodder stakeholders, including:
   - suppliers;
   - producers currently growing hydroponic fodder for feeding beef cattle or other ruminants;
   - nutritionists; and
   - others, e.g. extension staff.

3. Analysis of the information gathered from points 1 and 2 above in terms of the nutritional, economic, infrastructure and labour advantages and disadvantages of growing and feeding hydroponic fodder for beef cattle compared to comparable conventional feeding regimes (e.g. paddock feeding whole barley grain).

4. Identify issues and opportunities for further research.

5. Peer review results of points 1-4 with beef cattle producers, husbandry officers and nutritionists.

Success in achieving objectives

An extensive literature review was conducted, however not a lot of current information was available. One recent Australian paper (Tudor et al. 2003) recorded a period of higher than expected performance when steers fed hay were supplemented with barley sprouts. They concluded that further work was needed under rigorous research conditions to better evaluate the performance potential of sprouts and the reasons for the response. Without fully understanding the performance of sprouts, it is difficult to calculate the economics conclusively. Methods for calculating the cost of hydroponic fodder are included in the report so that producers can use them to do their own figures. This report clarifies the dry matter and nutrient changes that occur with sprouting. It also provides a method for costing dry matter and nutrients from sprouts and some examples of economics. The report confirms that while sprouts are highly nutritious they are expensive.

Impact on Meat and Livestock industry

Hydroponic fodder has been advertised and perceived by some producers as a solution to drought. Hydroponic fodder production systems are potentially very high capital, operating and lifestyle investments. Some producers were having trouble evaluating the cost-benefits for their business. This report provides independent information and tools to evaluate the cost and nutrient value of hydroponic sprouts to assist producers' decision making to minimise the risk of unprofitable and/or unsuitable investments.

How hydroponic fodder systems work

The sprouting process

Producing sprouts involves soaking the grain, most commonly barley, in water until fully saturated, followed by draining and placing it in trays or troughs for sprouting, usually for 5 to 8 days. The grain is kept moist during this period. Pre-soaking is important as there is a rapid uptake of water which facilitates the metabolism of reserve material and the utilisation of these reserves for growth and development (Thomas and Reddy 1962 as cited in Morgan et al. 1992). Grain is often soaked or washed with a sterilising solution to help minimise the risk of mould.

The yield and quality of sprouts produced is influenced by many factors such as soaking time, grain quality, grain variety and treatments, temperature, humidity, nutrient supply, depth and density of grain in troughs and the incidence of mould. To achieve maximum yield and nutritional benefits of sprouts the grain should be clean, sound, free from broken or infested seeds, untreated and viable. Cereal seeds germinate equally well under dark or light conditions (Whyte 1973, Bartlett 1917 and Miller 1978 as cited in Chavan and Kadam 1989).

Domestic or household sprout production does not require special equipment and containers such as plates, bowls or pans will do. There are many different commercial sprout production systems and versions of controlled atmosphere sheds using heating and air conditioning available. They are usually constructed on a slab of concrete and require access to electricity and water as well as a storage tank for nutrients in solution. Grain storage and handling equipment and often nutrients and sterilising agents are also required.

Regarding the growth process, Scott (2003) from the Nerang Hydroponic Centre web site (www.hydrocentre.com.au) comments that, "in 24 hours they sprout a root, green shoots day 2 and 3, by 5 days you can early harvest, 7 days is about max before they slow down and behave more like slow growing grasses. High levels of light are not necessary, but cool temperatures are. I recommend shade."

Hygiene is essential. In between crops, the trays must be cleaned, often with chlorine based cleaning solutions, to minimise the risk of mould.

Labour required

Labour requirements in running a shed range from labour intensive through to fully automatic. Specific activities in growing sprouts vary with different systems. An example of activities involved is given on the Greenfeed Technologies Pty Ltd web site (http://www.rdaquaponics.com.au/12403.html) where labour involved:

- Loading the grain into and filling the soak tank;
- Making up the nutrient solution;
- Transferring the grain to the trays and loading the trays onto the shelves;
- Checking fodder growth daily;
- Removing the trays from the shelves and emptying them into a container;
- Washing, rinsing and sterilising the trays and cleaning the growing chamber; and
- Feeding the green feed to the animals.

According to commercial companies 1 kg of grain will produce from 6 to 9 kg of sprouts. Most of this increase in weight is water. Feeding out requires handling and transporting heavy slabs of sprouts that are mostly water. At a further cost some sheds have conveyer belts to move the sprouts from the shed into the back of a vehicle to alleviate some of the heavy handling.

Time required

Suggested daily labour requirements to operate a system vary from 2 – 4 hours, for example:

- The Fodder Factory suggests 2 hours for a unit producing up to 1000 kg sprouts/day, i.e. approximately 150 to 200 kg dry matter (DM) sprouts/day.
- Greenfeed Technologies Pty Ltd suggest 3 to 3.5 hours.
- Producers using Green Feed Solutions series 180 producing up to 1500 kg/day comment that, "once a routine was found then the time it takes two of us is approximately one and a half hours, i.e. 3 hours work. That is, to wash and reload the 180 trays with grain and shelve them again" (Interview with Rex and Jean Young 28/11/02).
- The Rotating Fodder Machine web site (www.abhydroponics.com.au/8.html) quotes approximately 4 hours for a unit producing up to 2000 kg sprouts/day.
- The Hydrocentre web site cautions farmers that, "…you usually spend more time operating one than advertised, especially when inexperienced and some failure might occur with mould if everything is not clean."
- A producer's comment on the Hydrocentre web site is, "The fodder companies of some of these sheds put the labour down at 2 hours a day, which is a load of bull***. You have to spend a lot more time than that, to get good results …"
- Myers (1974) states that, "Even the most advanced system on the market today requires an average of four man hours to produce a ton of grass which will contain 200 to 320 lbs (91 – 145 kg) of dry matter."

Dry matter changes with sprouting

During soaking and germination, seeds lose dry matter (DM) as they use their own energy reserves for growth. Sprouts can regain some DM weight with the uptake of minerals and effective photosynthesis however in the short growing cycle there is most commonly a DM loss ranging from 7% to 47%. Within the literature reviewed for this report there were no substantiated examples of DM gains above the original grain DM input.

An independent study by the Department of Horticulture, University College Dublin in 1986 (Morgan et al. 1992) concluded that increased crop DM content over a short growing cycle is not possible.

Many factors affect the yield of sprouts in particular irrigation, water quality and pH, grain preparation, grain quality and variety, seeding density, temperature and growing duration. Hygiene is important to reduce the risk of mould. Soaking period, nutrients and light have some influence.

Seed soaking and germination

During soaking and germination seeds lose dry matter (DM). Chavan and Kadam (1989) state that the original dry weight of the seed decreases during soaking and subsequent sprouting processes due to leaching of materials and oxidation of substances from the seed.

When seeds are soaked, solutes leak out of them. Leakage is fastest at the start of imbibition (water uptake) and comes to a halt after about one day (Simon 1984 as cited in Chung et al. 1989). Solutes that leak include proteins, amino acids, sugars, organic acids, and inorganic ions.

During germination DM is lost due to the increased metabolic activity of sprouting seeds. The energy for this metabolic activity is derived by partial degradation and oxidation of starch (Chavan and Kadam 1989).

Mineral uptake

Morgan et al. (1992) found that the ash and protein content of sprouts increased from day 4 corresponding with the extension of the radicle (root), which allows mineral uptake. The absorption of nitrates facilitates the metabolism of nitrogenous compounds from carbohydrate reserves, thus increasing crude protein levels.

Table 2 The dry matter, ash and crude protein contents of seed and 4, 6 and 8-day old barley grass mats

	Dry matter (% of input)	Ash (g/kg DM)	Crude protein (% DM)
Original seed	100	21	10.1
4 day old	96	22	10.8
6 day old	91	31	13.7
8 day old	84	53	14.9

Source: Morgan et al. (1992).

It is worth noting that roughly half of the increase in percentage crude protein on a DM basis in Table 2 is due simply to the reduction in DM, which concentrates the weight of protein present.

Photosynthesis

Light is not required to sprout cereal grains. Some light in the second half of the sprouting period encourages some photosynthesis and greening of the sprouts.

If the seedlings are grown without light or too low a light intensity, photosynthesis is non-existent or minimal (Hillier and Perry 1969 and Bidwell 1974 as cited in Peer and Leeson 1985a) and seedlings must rely on their starch and fat reserves to meet their energy demand. Where sprouts are stacked inside a shed many sprouts may be heavily shaded.

Morgan et al. (1992) found little difference between treatments in DM content when grass was provided with 1000 lux from day 2, 4, 6 or 8. Grass supplied with light from day 8 appeared unattractively yellow whilst the highest light level caused a decrease in grass height, probably due to reduced etiolation[1]. Two days illumination was required to green the grass.

O'Sullivan (1982) as cited in Morgan et al. (1992) reported increased losses of DM, where no light was provided. He found that the rate of decrease of DM content slowed down after day 4 in lighted experiments, when leaves began photosynthesising. In agreement with Morgan et al. (1992), lighting prior to day 3 was of little significance.

However, Wagner (1984) as cited in Morgan et al. (1992), suggests that photosynthesis is not important for the metabolism of the seedlings until the end of day 5, when the chloroplasts are activated. Working with oats, Trubey et al. (1969) as cited in Morgan et al. (1992) found that light did not have a significant effect on DM content. Losses continued to increase from a value of 5.2% after 3 days to 12.3% after 6 days, probably reflecting the losses due to respiration and the negligible amount of photosynthesis by young seedlings at the low light intensity (800 lux).

Dry matter production claims

From a purely mathematical perspective the total dry matter (DM) produced by sprouts depends on the yield of sprouts from each kilogram of grain used and the DM of the sprouts. For example, if 1 kg of grain 'as fed' produces 8 kg of fresh sprouts and assuming 90% DM in the grain and

[1]Etiolation is a phenomenon where stems of plants raised in the dark elongate much more rapidly than normal. It is a mechanism that increases the probability of the plant reaching the light.

10% DM in the sprouts then 0.9 kg of grain DM results in 0.8 kg of sprouts DM or an 11% DM loss. This is represented in Table 3.

Table 3 Dry matter production in grain and sprouts

	Grain	x 8 yield	Sprouts
As fed	1 kg	⇐	8 kg
Dry matter %	↓ x 90%		↓ x 10%
Dry matter	0.9 kg		0.8 kg

Further examples of the effect of sprouts yield and DM percentage on dry weight change are given in Table 4.

Table 4 Percentage DM change as influenced by sprout yield and DM, assuming the initial grain was 90% DM

	Sprouts yield per unit input of grain				
DM	6	7	8	9	10
6%	-60%	-53%	-47%	-40%	-33%
8%	-47%	-38%	-29%	-20%	-11%
10%	-33%	-22%	-11%	0%	11%
12%	-20%	-7%	7%	20%	33%
14%	-7%	9%	24%	40%	56%
16%	7%	24%	42%	60%	78%
18%	20%	40%	60%	80%	100%
20%	33%	56%	78%	100%	122%

Various hydroponic fodder companies advertise yields of 6 – 10 times (i.e. 1 kg grain produces 6 to 10 kg sprouts) and DM percentages from 6.4 – 20%. Yields of up to 8-fold and dry matters up to 15% are common in commercial advertisements (Table 5) while trial yields range from 5 to 8-fold. The impact of yields and dry matters in this range, upon percentage DM change, is indicated in the shaded box in Table 4.

Table 5 Approximate yields and DM percentages of fresh sprouts from 1 kg of grain

	Approx. yield of wet sprouts from 1 kg grain in approximately 7 days	DM %
Fodder Factory	7 – 9.6	15.43
Green Feed Solutions	8.5	6.2 - 16
Hydroponic Greenfeed	6 - 8	-
Rotating Fodder Machine	6 – 7.5	6.4
The Charles Feed Shed	8 - 10	-
Automatic Paddock	9	-
Greenhouse Fodder Systems	-	-
Opti Grass	-	11
Simple Shed	8 – 9	12.30 - 16
The Fodder Wheel	-	-
Livestock Fodder Shed	7 – 8.5	-
Auto Grass (Tudor et al. 2003)	8	8 – 16.5 (av. 11.9)
Magic Meadow (1974 trial, Arizona)	6.2	-
Peer and Leeson (1985a)	5.7	-
Hillier and Perry (1969)	5.5	-
Mansbridge and Gooch (1985) in Cuddeford (1989)	5	-

Source: Compiled from company web sites, brochures and trial results.

At one extreme a claim of 10-fold yield of sprouts at 16% DM in a 7-day growth cycle equates to 78% increase in DM. In contrast a 6 times yield of sprouts at 6% DM equates to a 60% reduction in DM.

An Irish company suggested their hydroponic barley grass unit produced 20% DM increases in an 8-day production cycle. Independent tests found a 24% loss in DM (Flynn and O'Kiely 1986 as cited in Morgan et al. 1992). As a result, the Department of Horticulture, University College Dublin was commissioned in 1986 to examine the components of production and to determine the possibility of achieving an increase in DM during the short growth cycle. As a source of viable seed they used the barley cultivar Triumph, which provided in excess of 80% germination after one hour of pre-soaking. They performed a range of experiments analysing the effects of soaking period, temperature, aeration during soaking, seed disinfestation, growing temperature, light level and duration, irrigation techniques and frequency, nutrition, seeding rate on DM and also assessed feed value and digestibility. Effect of cultivar, water quality, humidity or a range of irrigation approaches was not studied. Details are given in Appendix A however their overall summary was that:

"Increased crop dry matter content over the growing cycle is not possible.

The principle factors affecting dry matter are seed preparation, seeding density, irrigation and growing cycle duration. Irrigation is the most important and the key to successful commercial designs. Lighting is required only for grass greening at the end of the cycle.

Using optimum methods and conditions a dry matter recovery of over 90% is achievable. Analyses indicated little loss in feed value during growth, but the production technology is difficult to justify.

They also suggest that *"the greatest potential market for hydroponic barely grass growing machines would be the bloodstock industry, where feed 'quality' rather than cost is a prime requirement."*

Dry matter changes with sprouting

Peer and Leeson (1985a), Hillier and Perry (1969) and Chung et al. (1989) reported dry matter (DM) losses ranging from 9.4 – 18% with sprouting cereals from 5 to 7 days.

Peer and Leeson (1985a) hydroponically sprouted barley grain in light, without nutrients, at 21ºC for 1-7 days. Fresh weight increased 5.7-fold after 7 days. During sprouting the weights of DM, starch and gross energy decreased markedly. Dry matter reduced linearly from 1000 g to 817 g in 7 days, an 18% reduction.

Hillier and Perry (1969) hydroponically sprouted oats in light, without nutrients at 21ºC for 6 days. Fresh weight increased 5.5 fold after 6 days. 100 g of oat seeds (89.7% DM) yielded an average of 550 g of sprouts (13.4% DM), which is equivalent to 89.7 g to 73.7 g DM, a 17.8 % reduction in DM.

Chung et al. (1989) measured a 9.4% decrease in DM of sprouted barely seeds over 5 days in room light, without nutrients, at 22ºC.

The germination of wheat for 5 to 7 days resulted in a 17% loss of total DM (McConnell 1977 as cited in Chavan and Kadam 1989) while Yocum (1925) as cited in Chavan and Kadam (1989) observed a 25% loss in DM of wheat after 12 days of sprouting. During sprouting for 8 days, oats lost 17% dry weight (Bartlett 1917 as cited in Chavan and Kadam 1989).

Flynn et al. (1986) as cited in Morgan et al. (1992) found a 24% loss in DM in barley in an 8-day production cycle.

Mansbridge and Gooch (1985) as cited in Cuddeford (1989) demonstrated a mean increase in fresh weight yield of 500% and a mean decrease of DM yield of 25% in barley grass grown over an 8-day cycle. Growth trials at the Royal School of Veterinary Studies have shown mean DM losses of 20% by day 5 and 23% on day 8 of an 8-day growth cycle (Cuddeford 1989).

Tudor et al. (2003) reports a yield increase of approximately 8 times where 9 kg of barley grain produced about 71.5 kg of sprouts in 6 days. With average dry matters of grain at 94.6% and sprouts at 11.9% this suggests no overall change in DM weight, for example:

- 9.0 kg grain x 94.6 % DM = 8.5 kg DM
- 71.5 kg sprouts x 11.9 % DM = 8.5 kg DM

One producer comment on the Hydrocentre web site states that "The shed has been operating for nearly 5 months, 25 tonnes of barley seed kept it going for over 4 months with a weekly output of about 7 tonnes green matter and root mass, stock eat the lot." In 5 months this is roughly 152.5 tonnes of sprouts from 25 tonnes of grain which is approximately a 6.1-fold yield.

Morgan et al. (1992) sprouted grain in light with a nutrient solution for 8 days at 21ºC and 27ºC. The seeds lost weight to day 6 and then regained some weight. Dry matter loss by day 8 at 21ºC was 18% and at 27ºC was 23.6% as shown in Figure 1. Improved irrigation methods reduced DM losses to as low as 7 to 9%.

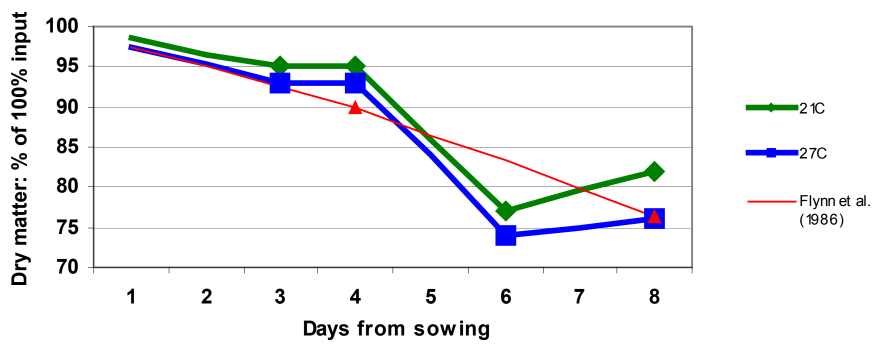


Figure 1 Change in dry matter content of barley grass during an 8-day growth cycle grown at 21^{0}C and 27^{0}C (Morgan et al. 1992)

A summary of Morgan et al. (1992) findings is listed below (detailed summary in Appendix A):

- 4 hours soaking gave 88% germination. Prolonged soaking reduced rates below 60%.
- Seed soaked at 23ºC appeared to germinate more rapidly than if soaked at 12ºC or 30ºC.
- Aeration of the solution did not improve the percent germination after a 4-hour soak.
- 1-hour treatment in 0.1% hypochlorite reduced fungal contamination without adversely affecting germination percentage.
- Sprouts grown at 21ºC lost 18% DM by day 8 and at 27ºC the loss was 23.6% DM.
- Light intensity ranging from 1000 to 9000 lux appeared to have little effect on DM content.
- Light duration had little effect on DM content. Two days light is needed to green the grass.
- Higher irrigation frequency increased DM conservation from 86% up to 91% of input.
- Improved irrigation techniques were able to offset the temperature effect and reduce DM losses to 7 to 9 % by day seven.
- Provision of nutrients had little effect on DM growth to 7 days.

- As seed density increased from 2.5 to 5 to 7.5 kg/m² there was a reduction in DM recovery and increased contamination by micro-organisms. Massantini et al. (1980) as cited in Morgan et al. (1992) concludes that a seeding rate of 4 kg/m² is the most efficient for seedling growth.

Nutrient quality of barley grain and sprouts

This section looks at the nutrient content of grain and sprouts and the changes that occur with sprouting.

Processed grain and grain sprouts are both highly digestible, nutritious feeds. The energy in grain is largely starch and sprouting converts much of the starch to sugars. Sprouting also increases fibre levels.

Chavan and Kadam (1989) state that, *"Sprouting grains causes increased activities of hydrolytic enzymes, improvements in the contents of total proteins, fat, certain essential amino acids, total sugars, B-group vitamins, and a decrease in dry matter, starch and anti-nutrients. The increased contents of protein, fat, fibre and total ash are only apparent and attributable to the disappearance of starch. However, improvements in amino acid composition, B-group vitamins, sugars, protein and starch digestibilities, and decrease in phytates and protease inhibitors are the metabolic effects of sprouting process. However, the overall nutritional improvement upon sprouting is of smaller magnitude and not often accounted for in animal feeding experiments."*

Nutrients in cereal grain and sprouts

Table 6 (over page) shows that sprouts are much wetter than the other feeds listed. The metabolisable energy (ME) levels of sprouts on a DM basis are similar to grain and cottonseed meal, for example around 10 to 13 megajoules (MJ). Lucerne has lower levels of ME due to its extra fibre. For the sprout samples listed in Table 6, crude protein (CP) ranges from 14 to 24.9%. Barley grain CP is given as 13.5%, lucerne 18% and cottonseed meal at 44% is 1.8 – 3 times higher in CP than sprouts, grain and lucerne. Both sprouts and grain are low in calcium and require additional calcium in the diet to correct the Ca:P ratio to between 1:1 to 2:1 required by cattle.

Table 6 Comparison of nutrients in cereal sprouts, cereal grain, cottonseed meal, rye grass and lucerne hay

	Oat Grass (6 day)	Barley grass	Barley grass	Barley grass	Barley grass	Barley grass	Barley grass	Barley grass	Barley grass	Barley grass	Barley grain	Oat grain	Cottonseed meal	Perennial rye grass	Lucerne hay#
	Hillier & Perry (1969)	Pandey & Pathak (1991)	Reddy et al. (1991)	Grigor'ev et al. (1986)	Green Feed Solutions	Automatic Paddock	Simple Shed	Fodder Factory	Opti Grow	Auto Grass	NRC (1984)	Hillier & Perry (1969)	NRC (1984)	NRC (1984)	NRC (1984)
Dry matter (%)	13.4	14.15	14.6	12.62	6.9	-	16	15.43	11	11.9	88	89.7	93	27	90
Metabolisable energy (MJME/kg DM)	-	-	-	-	8.7	12	11.4	11.8	12	11.7	12.72	-	11.8	10.3	9
Total Digestible Nutrient %	-	-	-	-	-	76		78.4	-	-	84	-	78	68	60
Nitrogen Free Extract %	48.9	-	68.85	63.22	-	-	61.3	-	-	-	-	69.5	-	-	-
Crude Protein %	20.7	14.69	11.38	16.4	24.9	23.3	16.5	17.3	14	19.7	13.5	12.3	44	10.4	18
Crude Fibre %	21.2	-	7.35	7.35	-	-	15.2	-	-	-	5.7	10.1	12.8	23.2	23
Acid detergent fibre %	-	-	-	-	28.2	-	19	15	18	-	7	-	20	-	35
Ash %	4.3	4.3	3.15	3.44	-	-	3.6	-	3	4.6	2.6	3.2	6.6	8.6	9.6
Ether extract %	4.9	3.18	9.27	4.45	-	-	3.4	-	-	-	-	4.9	-	2.7	-
Macro Elements (%DM)															
Calcium	-	-	-	-	-	-	-	0.07	0.13	0.16	0.05	-	0.21	0.55	1.41
Phosphorus	-	-	-	-	-	-	-	0.30	0.31	0.30	0.38	-	1.16	0.27	0.24
Ca:P ratio	-	-	-	-	-	-	-	0.23	0.42	0.54	0.13	-	0.18	2.04	5.88
Sulphur	-	-	-	-	-	-	-		0.16	0.22	0.17	-	0.43	0.3	0.28
Potassium	-	-	-	-	-	-	-	0.56	0.48	0.60	0.47	-	1.45	1.91	1.71
Sodium	-	-	-	-	-	-	-	0.1	0.03	0.21	0.03	-	0.05		0.12
Magnesium	-	-	-	-	-	-	-	0.4	0.12	0.25	0.15	-	0.58	0.35	0.31
Trace Elements (mg/kg)															
Iron	-	-	-	-	-	-	-	168	81	121	85	-	197	-	134
Zinc	-	-	-	-	-	-	-	32	34	21	19	-	69	-	23
Manganese	-	-	-	-	-	-	-	21	27	21	18	-	24	-	28
Copper	-	-	-	-	-	-	-	8	11	6	9	-	20	13	14
Cobalt	-	-	-	-	-	-	-	-	0.2	-	0.1	-	0.17	0.06	0.36
Selenium	-	-	-	-	-	-	-	-	0.9	-	0.22	-	-	-	-

Early bloom

- not recorded

Nutritional value of barley grain

Starch is the major energy source in barley. The 1984 National Research Council (NRC) tables list barley grain at 12.7 MJ ME/kg DM and crude protein (CP) at 13.5%. As with all feeds these values can vary significantly. The protein content of most barley ranges from 7.5 to 17% on a dry matter (DM) basis with 75% of that protein being digestible (Boyles et al. at http://beef.osu.edu/library/barley.html).

It is important to process grain, eg crack or roll, to improve its digestibility. Feedlot finishing diets using grain sorghum, corn, barley and wheat had digestibility values of 72%, 83%, 84% and 88% respectively (Oltjen et al. 1967 as cited by Boyles et al. at http://beef.osu.edu/library/barley.html). It is estimated that only 60% of the starch in whole, unprocessed grains is digested.

The 1984 NRC tables list crude fibre values of 5.7 to 7.1% for barley. The primary mineral deficiency in barley is calcium, although potassium should also be evaluated. Barley is low in carotene (vitamin A), vitamin D, E, thiamine and niacin. Among the amino acids essential to man, lysine is the first limiting in all cereal grains, followed by tryptophan (Chavan and Kadam 1989).

Grain rations are extensively used in feedlot finishing in Australia with over 600,000 cattle on feed mostly destined for the Japanese and domestic markets. Both profits and losses on grain-based diets are common depending on cattle prices, costs and performance. Grain feeding is expensive and importantly most feedlot cattle are under contract to specific markets. High performances are achieved with daily liveweight gains exceeding 1.5 kg and feed conversion ratios greater than 7:1 (kg DM feed to liveweight gain) being common. Grain achieves very high performance however the highly digestible starch can also cause acidosis and liver damage if introduced to cattle too quickly.

Nutrient changes with sprouting grain

Soaking grain increases its moisture content and enzyme activity. These enzymes breakdown storage compounds into more simple and digestible fractions for example, starch to sugars, proteins to amino acids and lipids to free fatty acids. There is an overall reduction in dry matter (DM) and total energy. Total weight of protein stays similar, however due to DM loss, the protein percentage increases giving an apparent increase in protein. There is an increase in fibre and some vitamins and a reduction in antinutritional compounds.

Chavan and Kadam (1989) state that *"the metabolic activity of resting seeds increases as soon as they are hydrated during soaking. Complex biochemical changes occur during hydration and subsequent sprouting in various parts of the seed. The reserve chemical constituents, such as protein, starch and lipids, are broken down by enzymes into simple compounds that are used to make new compounds or transported to other parts of the growing seedling."* Cuddeford (1989) comments that dry barley grains contain up to 650 g starch/kgDM and that starch is the raw material that supports the growth of the plant.

"Among the carbohydrates, α-amylase is the main starch-hydrolysing enzyme and barley develops higher α- and β- amylase activities than other cereal grains, which is why it is the preferred grain for malting. Amylase and maltase activity during sprouting of cereal grains results in a gradual decrease in starch with a concomitant increase in reducing and non-reducing sugars, which is available to the developing embryo. If no external nutrients are added, only water and oxygen are consumed by sprouting seeds" (Chavan and Kadam 1989).

"Under optimum conditions of moisture, oxygen and warmth, the sugars will be used for cell wall synthesis and provide energy for growth. The grain fuels its own growth process with a subsequent respiratory loss of carbon. The accumulation of carbon through photosynthesis is very small because the light intensity in hydroponic units is usually too low and furthermore, in the immature plant, photosynthetic processes are not very efficient" (Cuddeford 1989). The

desirable nutritional changes that occur during sprouting are mainly due to the breakdown of complex compounds into a more simple form, transformation into essential constituents, and breakdown of nutritionally undesirable constituents (Chavan and Kadam 1989).

"An increase in proteolytic activity during sprouting is desirable for nutritional improvement of cereals because it leads to hydrolysis of prolamins and the liberated amino acids such as glutamic and proline are converted to limiting amino acids such as lysine. Compared to carbohydrates and proteins, the lipids are present in relatively small amounts in cereal grains. An increase in lipase activity has been reported in barley" (MacLeod and White 1962 as cited by Chavan and Kadam 1989). Increased lipolytic activity during germination and sprouting causes hydrolysis of triacylglycerols to glycerol and constituent fatty acids.

Lorenz (1980) states that the sprouting of grains causes increased enzyme activity, a loss of total DM, an increase in total protein, a change in amino acid composition, a decrease in starch, increases in sugars, a slight increase in crude fat and crude fibre, and slightly higher amounts of certain vitamins and minerals. Most of the increases in nutrients are not true increases, they simply reflect the loss of DM, mainly in the form of carbohydrates, due to respiration during sprouting. As total carbohydrates decreases, the percentage of other nutrients increases.

Cuddeford (1989) states that, "*the effect of time on nutrient proportions of sprouted barley is clearly seen in Table 7 (adapted by Cuddeford 1989 based on data obtained by Peer and Leeson 1985a.). A loss of dry matter occurs caused by the energy reserve in the endosperm fuelling the growth process. Protein, which is not used for growth, increases in percentage terms but in absolute terms remains fairly static; this also generally applies to the other nutrients. The exception is fibre, a major constituent of cell walls, which increases both in percentage and real terms with the synthesis of structural carbohydrates, such as cellulose and hemicellulose"*. Chung et al. (1989) found that the fibre content increased from 3.75% in unsprouted barley seed to 6% in 5-day sprouts. The growing conditions and barley variety can have a large effect on the composition of the grass at any particular stage of development, so grass produced from different hydroponic units will almost certainly vary in composition even if harvested at the same age (Cuddeford 1989).

Table 7 Nutrient weights and proportions of barley sprouted over a 7-day period

	Time (days)							
	0	1	2	3	4	5	6	7
Dry matter (g)	1026	1008	996	957	902	885	867	839
Dry matter (%)	100	100	100	100	100	100	100	100
Dry matter loss (%)	-	1.7	2.9	6.7	12.0	13.7	15.5	18.2
Crude fibre (g)	55.6	56.8	59.6	55.8	66.8	86.7	94.5	119
Crude fibre (% of DM)	5.4	5.6	5.9	5.8	7.4	9.7	10.8	14.1
Crude fibre gain (%)	-	2.1	7.1	3.5	20.1	55.9	69.9	114
Crude protein (g)	131	128	130	131	121	123	122	130
Crude protein (% of DM)	12.7	12.7	13.0	13.6	13.4	13.9	14.0	15.5
Crude protein loss (%)	-	-2.2	-0.7	0.0	-7.6	-6.1	-6.8	-0.7

Source: Adapted by Cuddeford (1989) based on data obtained by Peer and Leeson (1985a).

The trace minerals present in barley grass will reflect those that were originally present in the barley grain and would be present in slightly higher proportions because of starch losses (Cuddeford 1989).

Digestibility and metabolisable energy of sprouts

Grain and grain sprouts both have high digestibility and metabolisable energy (ME). There is conflicting evidence that sprouting improves or reduces DM digestibility.

Morgan et al. (1992) measured digestibility of barley grain and sprouts and suggested that the digestibility appeared to be at a maximum in 4-day old grass mats whether measured in terms of organic matter, dry matter (DM) or estimated *in vivo*, i.e. in the live animal (Table 8).

Table 8 The digestibility of barley sprouts of different ages

	Organic matter (%)	Dry matter (%)	In vivo* (%)
Grain seed	88.8	89.9	83.9
4-day old	91.8	92.2	85.8
6-day old	87.9	88.9	82.1
8-day old	88.4	89.0	82.6

* Estimated according to Dowman et al. (1982) as cited by Morgan (1992).

Morgan et al. (1992) states, *"Other researchers (Flynn et al. 1986 and Peer and Leeson 1985a) reported more significant losses in dry matter digestibility, which declined progressively during a 7 to 8-day growth cycle. In agreement with Peer and Leeson (1985a) digestibility of 4-day old sprouts was superior to whole barley. Flynn and O'Kiely (1986) recorded an 8.6% reduction in digestibility of 8-day old sprouts, probably due to increasing fibre content with age. In feeding trials (Peer and Leeson 1985a) pigs fed on 4-day old sprouts gained significantly less weight than those fed barley grain. These trials indicated few positive effects due to sprouting and it was concluded that sprouted barley was inferior to whole barley in feed value."*

Mansbridge and Gooch (1985) as cited by Cuddeford (1989) reported in vitro digestibility of 8-day sprouts to be 0.73 and of 6-day sprouts to be between 0.74 and 0.72. Also in Cuddeford (1989) in vivo digestibility of barely sprouts in adult sheep was shown by Grigor'ev et al. (1986) to be 0.73 and 0.76 by Mansbridge and Gooch (1985). These later researchers assessed the ME of 8-day barley sprouts at 12.2 MJ/kg DM.

Morgan et al. (1992) estimated ME content assuming a digestible organic matter value of 17 MJME/kgDM (Table 9).

Table 9 Estimated metabolisable energy content of barley grass root mats of different ages

	Complete mat (MJME/kgDM)	Root portion only (MJME/kgDM)
Grain seed	10.7	10.7
4-day old	11.0	10.6
6-day old	10.4	9.4
8-day old	10.1	8.4

Source: Morgan et al. (1992).

Morgan et al. (1992) state *"The apparent increase in the complete mat on day 4 is probably related to the increase in digestibility."* There were losses in energy beyond day 4, exceeding 20% in the root portion. Peer and Leeson (1985a) determined the apparent ME concentration in sprouted and unsprouted barley fed to cockerels. The energy content decreased significantly with duration of sprouting. They were able to relate this loss to increases in fibre, which poultry have a limited ability to digest, and continued loss of starch, catabolised to soluble sugars for use in respiration and cell wall synthesis.

Tudor et al. (2003) found steers performed better than expected on a sprouts and restricted hay diet and questioned whether sprouts may actually have higher ME than is being measured by current methods.

Changes in protein due to sprouting

A review by Chavan and Kadam (1989) found that some reports indicated an increase in protein, others a decrease in protein, while a few indicated non-significant differences due to sprouting cereals. The increase in protein content has been attributed to loss in dry weight, particularly carbohydrates, through respiration during germination. Higher germination temperature and longer sprouting time means greater losses in dry weight and increases in protein content. Thus, the increase in protein is not true, but only apparent. This effect is well demonstrated in Table 7 (Peer and Leeson 1985a). Longer soaking periods were also found to reduce protein attributable to the loss of low molecular weight nitrogenous compounds during soaking and rinsing of the seeds. Simon (1984) as cited by Chung et al. (1989), found the leakage of solutes to be fastest at the start of imbibation and coming to a halt after about one day. Solutes that leaked included proteins, amino acids, sugars, organic acids, and inorganic ions. Hwang and Bushuk (1973) as cited by Chavan and Kadam (1989) observed a decrease in water-soluble proteins when wheat seeds were soaked at 10ºC for 2 days prior to sprouting. Similarly, Bhatty (1969) as cited by Chavan and Kadam (1989) observed a decrease in soluble protein of barley grains after prolonged soaking until the second day of germination. Losses were attributed to solubilization and leaching of proteins by the germinating embryo during the early germination period when there is little proteolytic activity developed in the seed.

Morgan et al. (1992) found that changes in the ash and protein contents occur rapidly from day 4 corresponding with the extension of the radicle (root), which allows mineral uptake. The absorption of nitrates facilitates the metabolism of nitrogenous compounds from carbohydrate reserves, thus increasing the levels of crude protein (CP). Grass was grown in a controlled environment chamber at 21ºC and 5,000 lux illumination for 16 hours daily. Samples of 4, 6 and 8-day-old grass, as well as the seed, were analysed for DM, ash and CP contents. The DM content of grass ‘mats’ decreased with age. Total grams of CP were the same in the seed and day 4 sprouts and then increased by 24% in 6 and 8 day old sprouts. On a DM basis this increase represented 48%, half of which was apparent due to a 16% loss in DM by day 8.

In agreement with Flynn et al. (1986) as cited by Morgan et al. (1992), the CP content increases progressively with age, reaching a maximum of 48% on day 8. These increases are due partly to the absorption of nitrogen from the nutrients solution and to the concentration of nitrogenous compounds in a reduced mass of DM. When Flynn et al. (1986) calculated the weights of CP at the beginning and end of an 8-day cycle they found that the recovered weights of CP and true protein had actually decreased significantly, i.e. by 7% and 24% respectively. Chung et al. (1989) found an initial depression in protein content by the second day of sprouting, followed by a return to pre-germination protein levels with the same trend observed in the ash (minerals) content.

Although the net change in total protein content is usually non-significant, very complex qualitative changes are reported to occur during soaking and sprouting of seeds. The storage proteins of cereal seeds are partially hydrolysed by proteolytic enzymes, which is evidenced by an increase in water-soluble proteins and free amino acids (Nielson et al. 1978 and Pathirana et al. 1983 as cited by Chavan and Kadam 1989). In wheat the water soluble proteins were found to increase sixfold after 10 days of sprouting.

The storage proteins of cereal grains are classified as albumins (water soluble), globulins (salt soluble), prolamins (alcohol soluble), glutelins (acid or alkali soluble) and residue or insoluble proteins (Osborne and Mendel 1914, Nagy et al. 1941 as cited by Chavan and Kadam 1989). The prolamins and glutelins together with residue proteins constitute more than 80% of the total seed proteins (Kent-Jones and Amos 1967 cited in Chavan and Kadam 1989). These protein fractions, particularly prolamin, are known to be deficient in lysine and are inversely correlated with the seed protein content (Kent-Jones and Amos 1967, Salunkhe et al. 1984 as cited in Chavan and Kadam 1989). Hence, the conversion of this fraction into albumins and globulins during sprouting may improve the quality of cereal proteins. Many studies have shown an increase in lysine with sprouting (Chavan and Kadam 1989) with the suggested mechanism being the degradation of prolamins into lower peptides and free amino acids to supply the amino groups, which are possibly used through transamination to synthesize lysine. The benefit directly to the ruminant animal would be questionable since bacteria in the rumen degrade the majority of highly digestible nutrients.

Vitamins

According to Chavan and Kadam (1989) most reports agree that sprouting treatment of cereal grains generally improves their vitamin value. However the quantitative increase in each vitamin may be small and its practical significance in meeting the nutritional requirements of cereal-based diets is difficult to evaluate in feeding trials.

Certain vitamins such as α-tocopherol (vitamin E) and β-carotene (vitamin A precursor) are produced during the growth process (Cuddeford 1989).

Table 10 Vitamin analysis based on single 6-day grass samples (mg/kg DM)

	Barley GRAIN	Barley GRASS
Vitamin E	7.4	62.4
Beta – carotene	4.1	42.7
Biotin	0.16	1.15
Free Folic Acid	0.12	1.05

Source: Cuddeford (1989).

In cattle, most vitamin requirements are met by synthesis by micro-organisms in the rumen, supplies in natural feedstuffs, and synthesis in tissues (NRC 1984). The National Research Council (1984) also states that, *"colostrum is rich in vitamins, providing immediate protection to the newborn calf. The ability to synthesise B vitamins and vitamin K in the rumen develops rapidly when solid feed is introduced into the diet. Vitamin D is synthesised by animals exposed to direct sunlight and is found in large amounts in sun-cured forages. High quality forages contain large amounts of vitamin A precursors and vitamin E. Vitamin A is the vitamin most likely to be of practical importance in feeding cattle. The liver can store large amounts of vitamin A. The duration of protection afforded by liver stores can vary from none to perhaps a year or longer, however it is seldom safe to expect more than 2 to 4 months of protection from stored vitamin A. Vitamin E is an antioxidant and has been widely used to protect and to facilitate the uptake and storage of vitamin A. Normal diets apparently supply adequate amounts for adult cattle. Even diets very low in vitamin E did not affect growth, reproduction, or lactation when fed for four generations."*

Changes in antinutritional factors

Phytic acid occurs primarily in the seed coats and germ of plant seeds. It forms insoluble or nearly insoluble compounds with minerals including Ca, Fe, Mg and Zn. Diets high in phytic acid and poor in these minerals produces mineral deficiency symptoms in experimental animals (Gontzea and Sutzescu 1958 as cited in Chavan and Kadam 1989). The sprouting of cereals has been reported to decrease the levels of phytic acid.

Polyphenols and tannins usually present in the testa layer of seeds of certain cereals like sorghum, barley and millet, have been recognised as antinutritional factors. These are known to inhibit several hydrolytic enzymes, such as trypsin, chymotrypsin, amylases, cellulases and β-galactosidase (Salunkhe et al. 1982 as cited in Chavan and Kadam 1989). In addition they bind with proteins and form tannin-protein complexes, thus making protein unavailable. Detrimental effects of polyphenols and tannins on the availability of minerals and vitamins have been reported (Salunkhe et al. 1982 and Chavan et al. 1981 as cited in Chavan and Kadam 1989). On reviewing the literature, Chavan and Kadam (1989), concluded that sprouting treatment does not decrease the tannin content of grain, but favours the formation of complexes between testa tannins and endosperm proteins. The problem of tannin however is not significant in low tannin types and other cereals that do not contain appreciable amounts of tannins.

Livestock performance from sprouts

There have been many trials conducted by researchers throughout the world on livestock performance from sprouts. These trials have been conducted with dairy cattle, beef cattle, pigs and poultry. The majority of these trials have found no advantage to feeding sprouts compared to other conventional livestock feeds. The results of reviews by Leitch (1939) and Myers (1974) are summarised in Tables 11 and 12 on the following page. A more detailed summary of these reviews is available in Appendix B. Of thirty-three trials reviewed by Leitch and Myers, twenty-one indicate no advantage or a disadvantage in feeding sprouts to livestock.

The trials that Leitch (1939) reviewed do not simulate the likely circumstances and conditions where beef producers would use the system in Australia. In Australia sprouts are more likely be used as a low level supplement (eg 1 – 1.5 kgDM/head/day) to dry pasture.

Tudor et al. (2003) conducted the most recent trial of livestock performance from sprouts under Australian conditions. A summary of these results as well as other trials conducted worldwide since 1974 is included in this section.

Most of the trials on livestock performance from hydroponic sprouts show no advantage to including them in the diet, especially when it replaces highly nutritious feeds such as grain. From a theoretical perspective performance improvements occur if the supplement supplies the primary limiting nutrient(s) or improve feed use efficiency such as the situation that Tudor et al. (2003) experienced with steers on protein deficient hay.

Thomas and Reddy (1962) as cited in Myers (1974) summarise this perspective after their dairy experiments when they concluded, *"The different response of these two groups of cows indicates that feeding sprouted oats will not increase milk production in cows that are already receiving sufficient energy, but it may increase milk production in cows that are not receiving a high level of nutrients. This could explain some of the results observed on farms."* After noting that sprouted oats cost over four times as much as the original oats, they continued: *"This high cost plus (1) loss in nutrients during sprouting, (2) the decreased digestibility of sprouted oats and (3) no observed increase in milk production when sprouted oats were added to an adequate ration indicate that this feed has no justification for being in any modern dairy ration."*

Hydroponic sprouts are highly nutritious however the challenge to their use is finding circumstances where their benefits outweigh their costs. Cuddeford (1989) describes some possible advantages of hydroponic sprouts for horses such as reduced starch and dust. Myers (1974) refers to subjectively observed health benefits in feedlot cattle receiving hydroponic barley grass but also states *"it was recognised from the beginning that hydroponically grown grass was not the cheapest method of putting weight on cattle."*

Mould – reduced performance and deaths

Myers (1974) found that mouldy sprouts reduced liveweight performance. In April 2003 the Queensland Department of Primary warned people through the Australian Broadcasting Corporation rural news to take care with hydroponic grass after 4 cases of cattle deaths in Queensland occurred due to the fungus *Aspergillus clavatus* and reports of sheep deaths in NSW thought to be of the same cause. Kellerman et al. (1984) recorded that of 16 dairy cattle that were fed maize sprouts infested with the mould *Aspergillus clavatus*, 8 cattle were affected, 5 of which died.

Table 11 Summary of trial outcomes involving feeding sprouts to livestock as reviewed by Leitch (1939)

Year	Author	Class / Age	Sprouts fed (kg)	Advantage	No advantage	Disadvantage
1935	National Institute for Research in Dairying (Reading, England)	Lactating dairy cows	+ sprouts from 6 lb maize	-	√	-
1935	Henke (Hawaii)	Dairy cows & heifers	NA	-	√	-
1936	Davis & Hathaway	Dairy cows & heifers	+ 6 lb sprouted oats/hd/day	-	√	-
1936-38	Paterson (Scotland)[2]	Bullocks	+ sprouts of equivalent DM to 10, 20 & 30 lb Swedes	√	-	-
1937	Schmidt and Kliesch (Berlin, Germany)	Dairy cows	+ 1.8 kg sprout fodder	-	√	-
1937	Visser (Bloemfontein, South Africa)	Dairy cows	NA	√[3]	-	-
1937	Bostock & Brown (Hawkesbury College NSW)	Dairy cows	NA	-	-	√
1937	Fishwick ((Wye, England)	Pigs	+ 1 lb sprouted barley	-	√	-
1937	Schmidt & Kliesch (Berlin, Germany)	Pigs	350 g barley grain replaced by sprouts from 350 g barley	-	√	-
1938	Schmidt, Kliesch & Giersberg (Dahlem, Germany)	Pigs	Two trials with sprouts replacing barley grain	-	√	√
1938	Schmidt, Kliesch & Giersberg (Koppehof, Germany)	Pigs	450 g grain supplement compared with 1.5 kg sprouts	-	-	√
1938	Bartlett et al. (Reading, England)	Lactating dairy cows	+ sprouts from 4 lb maize	-	√	-
1938	Vickers, Tinley & Bryant (Wye, England)	Lactating dairy cows	+ 10 lb sprouted maize	-	√	-
1938	Tinley & Bryant (Wye, England)	Lactating dairy cows	+ 10 lb sprout fodder	-	√	-
1938	McCandlish & Struthers (Scotland)	Bullocks 21 mths	+ 6.15 lb sprouted maize	√	-	-
1938	Schmidt, Kliesch & Giersberg (Berlin, Germany)	Bullocks	+ 4.1, 2.9 & 0.7 kg sprouted barley	-	√	-
1939	McCandlish (Scotland)	Calves 3 wks	NA	√ At lower feeding levels	-	√ At higher feeding levels

2 Three experiments in total, 2 published in 1936 and 1 in 1938

3 Unsubstantiated

Table 12 Summary of trail outcomes involving feeding sprouts to dairy and beef cattle as reviewed by Myers (1974)

Year	Author	Class / Age	Sprouts fed (kg)	Advantage	No advantage	Disadvantage
1936	Kohler, Elvehjem & Hart	Dairy cows	NA	√	-	-
1956	Williams	Dairy cows	+ 20 lbs of sprouts	-	√	-
1961	Thomas	Dairy cows	NA	-	√	√ Economics
1961	Appleman	Dairy cows	NA	-	√	√ Economics
1962	Thomas & Reddy	Dairy cows	NA	-	√	-
1962	Height	Dairy cows	NA	-	√	√ Economics
1963	McFate[4]	Beef steers	+ oat grass from 5 lb grain	-	√	√ Economics
1965	Anonymous cited in Myers 1974	Beef steers	+ 12 lb oat grass/hd/day	√	-	-
1966	Nelson & Gay	Dairy cows	NA	-	√	√ Economics
1966	Floretin & Floretin (France)	Dairy cows	NA	√	-	-
1968	Robinson	Crossbred steers	NA	√	-	-

[4] Results uncertain as both advantages and disadvantages recorded.

Review of more recent trials

(Improvement) Tudor et al. (2003) measured intake and liveweight change in 17 Droughtmaster steers that received low quality hay and barley sprouts over 70 days. During the first 48 days cattle ate 1.9 kgDM/head/day of sprouts (15.4 kg wet weight) and 3.1 kgDM/head/day of poor quality hay and gained 1.01 kg/head/day. Energy intake was 47 MJME/head/day, which was considered by nutrition standards to only be sufficient for low weight gains of up to 200g/head/day. This high performance could not be explained by energy and protein intakes. During the next 22 days sprouts were restricted to 1.6 kgDM/head/day (13 kg wet weight) and ad lib hay intake was 7.8 kgDM/head/day. Energy intake increased to 74 MJME/head/day and cattle gained 0.41 kg/head/day, which conformed to nutrition standards. More details are in appendix B.

(No advantage) Hillier and Perry (1969) fed cattle with four levels of supplemental oat sprouts (0, 0.63, 0.95, 1.26 kg DM) on both low and high-energy diets. They found no effect on digestibility of DM, protein, fibre, ether extract, nitrogen free extract or energy.

(Improvement) In their review of literature, Hillier and Perry (1969) found growth responses for poultry (Scott et al. 1951, Scott 1951, Scott and Jensen 1952, Slinger et al. 1952) and also increased gains for cattle when sprouted corn was added to the ration (Patterson 1937 and McCandlish 1939).

(No advantage) Two other trials showed no significant effect on ration digestibility with the addition of sprouted corn to the ration. (McCandlish and Struthers 1938, Thomas and Reddy 1962 as cited in Hillier and Perry 1969).

(Disadvantage) Peer and Leeson (1985a) as cited in Morgan et al. (1992) found that pigs fed 4-day-old sprouts gained significantly less weight than those fed barley grain.

(No advantage) In India, Pandey and Pathak (1991) fed five crossbred (*Bos taurus x Bos indicus*) cows (3-4 years old and 350 – 410 kg liveweight) ad lib on artificially grown barley fodder during their 3rd to 5th month of their second lactation. Voluntary intake of fresh sprouts was 50.38 kg/day or 7.13 kgDM. The mean dry matter intake was 1.93% of liveweight and milk yield was 9.13 kg/day. They concluded that DM intake was a limiting factor for sole feeding and for high milk yielding cows supplementation of adequate concentrate was necessary.

(No advantage) In India, Reddy et al. (1991) conducted 2 experiments with 8 crossbred (On gole x Holstein) cows. In both experiments there was no significant difference in DM intakes, milk yields or quality. The first experiment used 8 cows (5-6 years old and 340 – 350 kg liveweight) in their 2nd and 3rd lactation and producing 7-8 kg milk/day. Half received a concentrate mix plus ad lib paddy straw. The other half received the same ration except half the concentrate mix was replaced by 20 kg of fresh 8-day-old barley sprouts. The second experiment used 8 cows (5-6 years old and 350 – 370 kg liveweight) in their 2nd and 3rd lactation and producing 5-6 kg milk/day. Half received a concentrate mix plus ad lib paddy straw. The other half received the same ration except 25% of the concentrate mix was replaced by 10 kg of fresh 8-day-old barley sprouts. Comparing these two experiments the cattle receiving 20 kg of sprouts had higher DM intakes as a percentage of liveweight (3.14%) compared with the cows that received 10 kg of sprouts (2.6%).

(Improvement) In Russia, Grigor'ev et al. (1986) fed two groups of 8 cows, at the same stage of lactation, for 101 days on mixed feeds based on maize silage. Replacing 50% of the maize silage with 18 kg of hydroponic barley grass increased milk yield by 8.7% although milk fat was depressed.

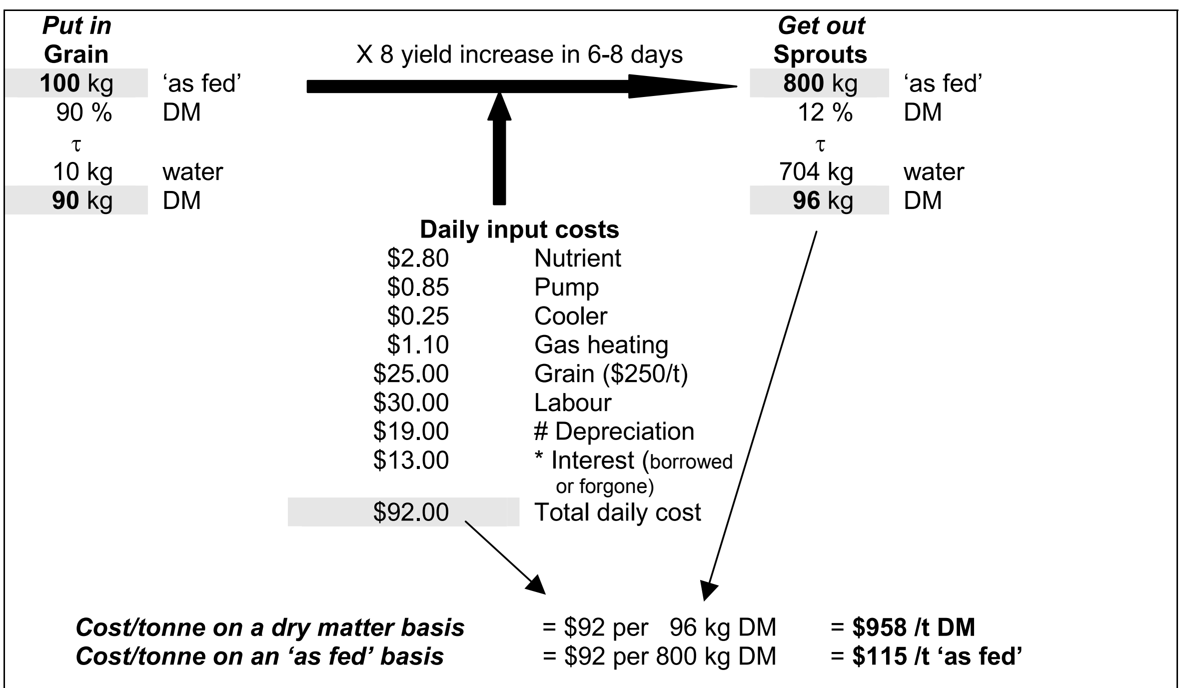
Costing dry matter, energy and protein in grain and sprouts

Cost of dry matter

One approach to evaluate the economics of sprouts is to start by costing the dry matter (DM) in and out of the system. The same can be done for energy, crude protein (CP) and performance potential. Once the cost of supplement is known, then actual or budgeted animal performance can be used to estimate likely profit or loss with supplementation. Costs to consider include:

1. Grain;
2. Infrastructure, e.g. hydroponic shed, construction, equipment, concrete slab, tanks, silo and augers;
3. Depreciation;
4. Interest on money invested;
5. Labour;
6. Running costs, e.g. electricity, gas, nutrients and sterilising agents;
7. Repairs, maintenance and unexpected technical problems; and
8. Risks, e.g. sourcing good grain, germination failures, grain and livestock performance losses due to mould and resale value.

Many of these factors are represented in the example in Figure 2 for a shed using 100 kg of grain to turnoff 800 kg of sprouts each day at 12% DM. It is assumed that $70,000 was borrowed at 7% interest and depreciated at 10% over 10 years. The daily costs for nutrient, pump, cooler and gas heating is based on figures from the Fodder Factory web site and relate to producing less than 1 tonne of sprouts per day. Grain is costed in at $250/t. Other costs such as water and grain treatments, sterilising agents, repairs and maintenance are not included.



Capital Costs		
	*Invest/borrow	# Depreciation
$ invested	$70,000.00	$70,000.00
Interest rate	7%	10%
$ per year	$4,900.00	$7,000.00
$ per day	$13.00	$19.00

Figure 2 Costing sprouts production

Given the assumptions in Figure 2, then it costs $92.00 to produce 96 kgDM/day (or 800 kg wet feed). This is the same as **$958** for 1 tonne of DM and is 3.4 times more expensive per kilogram of DM than the original grain. The original grain price used going in was $250/tonne as fed. Allowing for 10% moisture this equates to **$278/**tonne of DM. If the grain cost was increased to $300 to allow for cracking and a feedlot concentrate, sprouts would still cost greater than 3 times for DM. Different yields and dry matters would significantly affect the cost of production. The cost of the nutrient is a guide only, as the performance relative to cost better determines its value as a supplement.

Cost of energy

The cost of energy and protein in grain and sprouts can be calculated in the same way. Energy is measured in megajoules (MJ) of metabolisable energy (ME) and protein as percent crude protein (CP).

Table 13 Costing the energy and protein in grain and sprouts

	Grain in	**Fodder out**		
$/t DM	**$278**	**$958**	3.4	times cost
Energy MJ ME/kg DM	**12.7**	**11.8**		
= Cents/MJ ME	**2.19**	**8.12**	3.7	times cost
Crude protein CP% DM	**11**	**17.3**		
= $/kg CP DM	$2.53	$5.54	2.2	times cost
Hypothetical feed conversion ratio	**7**	**5**		
= Feed cost / kg live weight	$1.94	$4.79	2.5	times cost

Given the assumptions in Table 6, the energy in the sprouts is 3.7 times more expensive than in the original grain and the protein is 2.2 times more expensive. Assuming that it takes 5 kg of sprouts DM for 1 kg of liveweight gain and 7 kg for grain then the sprouts are 2.5 times more expensive per kilogram of liveweight gain. The final feed conversion comparison is probably fair for comparing feedlot rations however this is misleading for sprouts as they are used as a supplement to improve the overall conversion of the total diet.

In the 1930s Leitch recorded that Hawkesbury College stated that 1 tonne of fodder, costing between £10 and £11, would provide "green" feed for 100 pigs for 11 days, while the same number could be fed over an equal period with green barley and lucerne for £1 to £1 10S (ie sprouts were ~10 times more expensive).

Appleman (1961) as cited in Myers (1974) found that *"Hydroponic oat grass may be 2.1 times more costly than rolled oats or 3.8 times more costly than rolled barley in terms of food energy …"* He concluded that *" … with our ample supplies of forage and feed grains in this country, it appears that hydroponic grass is not an economical way to produce livestock feed."* Concurrently, an Extension Service researcher at the University of California (Height 1962) determined the cost of hydroponic barley grass to be 5.4 times that of rolled barley. In that study, Height philosophised that:

Contrary to a relatively few expressed opinions, it is not the mystic qualities of a feed stuff that puts pounds of gains on beef, hogs, sheep and pounds of milk in the tank from a dairy cow. It is simply an ample supply of net energy balanced with enough protein, vitamins, and minerals to allow the supplied energy to do its job… These are not merely statements but are sound facts borne out by many thousands of feed lots and dairies over the nations that are getting phenomenal production results based upon the foregoing facts. This knowledge was developed through thousands upon thousands of research hours and feeding trials conducted by competent scientists in both industry and universities throughout the world.

The figures will vary with different scales of operation, costs and production performance. Based on available information the sprouts production figures used in Figure 2 and Table 14 appear to be for a good sprout production scenario and with costs at the lower end. Technical problems as well as mould are common. These problems can quickly and dramatically escalate costs.

For a best case scenario, i.e. if it was possible to achieve 10-fold sprout production with 20% DM in the sprouts, and using the same low cost structure as in Figure 2, would result in DM at $463/tonne DM or 1.7 times more expensive than the original grain DM.

Conversely, for a more likely scenario of 6-fold sprout production and 10% DM in the sprouts, and using the same low cost structure as above, this would result in DM at $1,545/tonne or 5.6 times more expensive than the original grain DM.

A worse case scenario would be mould and the costs of lost feed, animal performance, cleaning and starting again. The questions and answers listed on the Hydrocentre website (www.hydrocentre.com.au) suggest that mould is a common problem. Some examples are given in appendix D. A cost comparison of sprouts with various other feeds for energy and protein are given in the Table 15 over page.

Comparing supplement costs

Table 14 A comparison of supplements for cost of dry matter, energy and protein

Feed	Wet Price		DM%		Price	Energy			Crude Protein		
	$/t as fed				$/t DM	MJME/kgDM	MJME/kg as fed	c/MJME	CP% (DM)	CP% as fed	$/kg CP
Pasture	**$35**	÷	**75%**	=	$47	**7.5**	5.6	0.62	**7.5**	5.6	0.62
Molasses + 8% Urea	**$200**	÷	**77%**	=	$260	**10.5**	8.1	2.47	**30.0**	23.1	0.87
Grain	**$300**	÷	**90%**	=	$333	**11**	9.9	3.03	**10.0**	9.0	3.33
Copra	**$380**	÷	**92%**	=	$413	**12.5**	11.5	3.30	**22.0**	20.2	1.88
Cottonseed meal	**$500**	÷	**92%**	=	$543	**12.0**	11.0	4.53	**43.0**	39.6	1.26
Lucerne	**$400**	÷	**90%**	=	$444	**9.5**	8.6	4.68	**17.0**	15.3	2.61
Barley sprouts	**$70**	÷	**12%**	=	$583	**11.8**	1.4	4.94	**17.0**	2.0	3.43
Barley sprouts	**$115**	÷	**12%**	=	$958	**11.8**	1.4	8.12	**17.0**	2.0	5.64

The supplements in Table 15 are sorted in order of cheapest to most expensive energy (cents per megajoule) on a DM basis. Sprouts have been entered at $70 and $115 per tonne 'as fed' to represent a range. Given the assumptions in **bold**, sprouts at $70 and $115 per tonne on a wet matter basis is the most expensive feed for both energy and protein. Although prices change this process can be used with new prices or different feeds. These figures are only a guide and can sometimes be misleading as it is also essential to consider how well livestock respond to the supplement to better determine its value. A rough comparison can be made assuming the additional response due to supplementation as shown in Table 16. A proper analysis requires full details of cattle performance, prices, costs and time frames.

Table 15 Hypothetical comparison of barley sprouts and copra based on cattle performance

Feed	Price	Amount fed out			Supplies		Cost as fed	Response			Cost of gain
	$/t as fed	kg as fed	DM%	kg (DM)	Energy (MJ ME)	CP (g)	c/day	Gain/day (g)	Days	Gain kg	$/kg gain
Copra	$380	0.75	92%	0.690	8.6	152	28.5	**250**	100	25	$1.14
Barley sprouts	$115	7.5	12%	0.900	10.6	153	86.3	**400**	100	40	$2.16
Barley sprouts	$115	13.5	12%	1.620	19.1	275	155.3	**1000**	100	100	$1.55

Given the assumptions in Tables 15 and 16 this shows that 750 g of copra supplies similar protein and energy as 7.5 kg as fed of sprouts. The responses in bold are purely hypothetical to see the impact on the cost of liveweight gain.

Claims: feed supply versus animal demands

There are many claims regarding animal performance on sprouts. Two examples are:
1. 'One tonne of feed is enough to feed 100 head of cattle with an average weight gain of 1.7 kg/day'
2. 'The dry matter intake of sprouts as a percentage of body weight is 3.4%'

Claim 1: '1 tonne of feed is enough to feed 100 head of cattle with an average weight gain of 1.7 kg/day'

An average daily liveweight gain in a feedlot of 1.7 kg would be considered very good, on fresh oats or rye grass this would be exceptional. This claim suggests that just 10 kg of fresh cereal grain sprouts/head/day produces such gains. An analysis of this shows that:

= **1000 kg** fresh sprouts per **100 head** gives **1.7 kg** liveweight gain
= 10 kg fresh sprouts per **1 head**

Assuming that 12% of the sprouts is DM or 88% is water, then

= feeding **1.2 kg** DM sprouts/head/day gives **1.7 kg** liveweight gain
= **0.7 kg** feed per **1** kg liveweight gain.
= **0.7:1** feed conversion

Since it is not possible for an animal eating 0.7 kg of feed to gain 1 kg liveweight, additional feed intake is required. To gain 1.5 kg/day a 300 kg steer would require approximately 112 MJME/day and 875 g protein/day. If it can be assumed that sprouts contain 12 MJME/kgDM and 23.3% protein, 1.2 kg sprouts DM will provide 14.4 MJME and 280 g protein, a deficit of 97.6 MJME and 595 g protein.

A 300 kg steer on high quality feed will eat approximately 3% of its liveweight, i.e. 9 kgDM/day. If sprouts make up 1.2 kg of this feed then the animal has a capacity to eat an extra 7.8 kg of feed. To meet the nutrient requirements to gain 1.5 kg/day this 7.8 kg of feed would have to contain 12.5 MJME/kg and 7.6% protein. From this it can be seen that sprouts make up only a small proportion of the diet.

Claim 2: 'The dry matter intake of sprouts as a percentage of body weight is 3.4%'

Using a 400 kg steer for example, it would have a DM intake of 3.4% x 400 = 13.6 kgDM/day. If this were supplied only by sprouts (assuming the sprouts are 12% DM) the animal would need to eat 113 kg of fresh sprouts, of which 99.4 kg is water and 13.6 kg is dry matter.. At $70/tonne on a wet basis, excluding capital and labour costs, this would cost $7.91/head/day or at $115/t it would cost $13. Pandey and Pathak (1991) found that 3 – 4 year old, 350 to 410 kg dairy heifers fed barley sprouts ad libitum only ate 1.93% of their liveweight in DM per day.

Feedlot scenario

Using the assumptions below and pricing sprouts at only $70/t 'as fed', full feeding results in a loss of $124 after accounting for feed costs alone and ignoring infrastructure, labour, freight, treatments, interest, etc.

Live weight gain:	1.7 kg x 100 days	= 170 kg	
Exit value:	570 kg x $1.90		= $1083
Entry value:	400 kg x $1.40		= $ 560
Increase in value			= $ 523
Daily dry matter intake:	2.3% x 485 kg	= 11.1 kg DM	
Daily fresh matter intake:	11.1 kg DM ÷ 12% DM	= 92.5 kg fresh/day	
Total fresh feed intake:	92.5 kg/day x 100 d	= 9,250 kg	
Feed cost:	9,250 kg x $70/tonne		= $ 647
Loss:			= ($ 124)

If the feed cost $100/t fresh this would result in a $402 loss.

Whole farm economic comparisons

To further evaluate the value of commercial hydroponics systems for beef cattle the following comparison looks at the whole farm economics on a simplified steer growing enterprise. The figures used are estimates. The calculations are in Appendix C to assist producers make decisions based on their circumstances.

The comparisons are:
1. No change
2. Buy fodder shed
3. Protein supplement

Assumptions:

- A supplementation rate of around 10 kg fresh sprouts per head per day seems common practice and for this reason a comparison was based on 75 head as this is approximately the number of cattle a hydroponic unit producing approximately 800 kg of sprouts can supplement.

- The scenario assumes that cash was available to invest in and operate a hydroponic shed all year. (An alternative approach could be to borrow for the shed.) The ‘No Change’ and ‘Protein supplement’ options invested this cash elsewhere for growth and income.

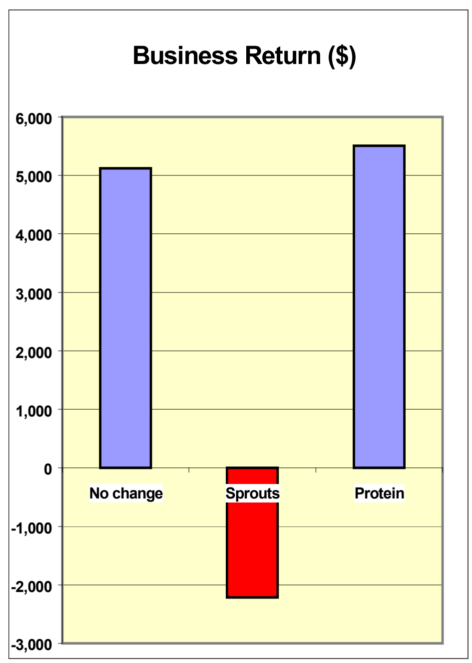
- It was assumed that cattle supplemented with sprouts were able to achieve 1 kg daily weight gain for the entire year. It is not known if this is possible but is based on the weight gain achieved over a short period of time by Tudor et al. (2003). In comparison, the ‘No Change’ scenario assumes an average daily gain of 340 g/head and the ‘Protein supplement’ scenario of 420 g/head/day. The protein scenario is based on investing $0.12/head/day in “dry lick” for four months and then changing to $0.20/head/day in vegetable protein meal for a further 2 months during the year. Steers are priced in at $1.40/kg liveweight. The steers fed sprouts are sold at $1.70 while steers for the other two options are sold at $1.45/kg liveweight. Additional assumptions are given on the next page.

The assumptions include:

	No Change	Sprouts	Protein supplement
$ Invested in hydroponics shed	-	$76,000	-
Supplementation period (months)	-	12	6
Number of steers (head)	75	75	75
Weight in (kg)	180	180	180
Average Daily Gain (ADG) (kg/head/day)	0.340	1.0	0.420
Annual liveweight gain (kg/head/year)	124	365	153
Weight out (kg)	304	545	333
Price in ($/kg liveweight)	1.40	1.40	1.40
Price out ($/kg liveweight)	1.45	1.70	1.45
Supplement rate 'as fed' (kg/hd/day)	-	10.67	-
Supplement rate DM (kg/hd/day)	-	1.28	-
Grain price ($/t)	-	250	-
Sprout yield per 1 kg grain input (kg)	-	8.0	-
Sprout DM (%)	-	12%	-
Protein dry lick for 4 months ($/head)	-	-	$14.40 ($0.12/h/day)
Protein meal for 2 months ($/head)	-	-	$12.00 ($0.20/h/d)

The summary of results is:

	No Change	Sprouts	Protein supplement
ADG (kg/hd/day)	0.340	1.000	0.420
Assets	303,000	303,000	303,000
Liabilities	0	0	0
Equity	303,000	303,000	303,000
Income	47,270	69,488	46,224
Variable cost	21,347	45,303	23,916
Gross margin	21,923	24,185	22,308
Fixed cost	16,800	26,400	16,800
Operating profit	5,123	-2,215	5,508
Interest	0	0	0
Business return	5,123	-2,215	5,508
Return on equity	1.69%	-0.73%	1.82%



The sprouts option has the highest income but also much higher variable and fixed costs resulting in a loss of $2,215 and being $7,338 worse than the 'no change' option. In this case $76,000 was spent on a shed and associated equipment and grain was priced at $250/t. There are situations where a shed producing less than 1 tonne of sprouts daily costs around $120,000 and grain priced up to $400/t. In this case the loss would be approximately $12,000 or $17,000 worse than the 'no change' option. The shed is also a depreciating item while other investments can provide both income and capital growth. The shed is a daily commitment of several hours of work.

Things to consider before investing in sprout production

The following is a list of things that anyone thinking about investing in growing sprouts should consider:

- Cash outlay
- Opportunity cost of interest forgone
- Depreciation (and resale value)
- Hours labour
- Number of head to feed
- Risks, breakdowns, problems
- Water access and quality
- Mould
- Time to learn new enterprise and research and overcome problems
- Lifestyle impact
- Grain cost, availability, quality and germination
- Grain storage and handling
- Sprouts handling (80-90% water)
- Cost of dry matter
- Alternatives (eg adjusting stock numbers, supplements, extra land, production feeding, etc – some alternatives may be far easier and more profitable).

It is important that individuals estimate if it can be profitable for them. A major stumbling block in people's evaluations is not factoring in the high moisture content, labour, interest and depreciation into their calculations. An example is given in Figure 2 on page 28. Conflicting data on performance also makes it difficult to evaluate. The information collated in this report suggests that for the majority of commercial Australian beef producers the use of hydroponics to produce sprouted fodder is not profitable.

Future work

1. Economics aside, sprouts have shown instances of significant performance improvements, however it is uncertain if these results are repeatable. Tudor et al. (2003) had intriguing results using hydroponic fodder as a supplement to steers on low protein hay. Over a 48-day period steers on restricted hay intake given 1.8 kg DM of barley sprouts produced 1 kg/head/day liveweight gains and 5:1 feed conversions. The same cattle for a further 22 days given 1.5 kg of sprouts DM and ad lib hay gained 0.41 kg with a 22.8:1 feed conversion ratio. More work is needed to confirm if the exceptional performance was due to sprouts and if so why the performance was so much higher in the first 48-day period. It would be valuable to understand which circumstances lead to high performance responses.

   Taking economics into consideration, if sprouts cost 2 – 5 times the original grain DM, could similar results be achieved with feeding grain or protein meals at a similar cost and without having the large capital outlay and daily workload of a hydroponic shed? For example, assuming sprouts cost $120/t as fed, it would be possible to feed almost 5 kg of a protein meal or grain ration at $380/t for a similar cost as 1.8 kg DM sprouts. With more conventional supplements, McLennan (2003) pers. comm. has found substantial liveweight performances in penned weaner cattle fed hay and supplemented with protein meals between 0.5 to 1% of liveweight. To better evaluate the supplementation potential of sprouts under Australian conditions, compared to conventional supplements, requires further rigorous, independent research.

2. Morgan et al. (1992) found dramatic reductions in DM loss with improved irrigation techniques. They concluded that DM gains in a short growth cycle (eg 6-8 days) are not possible. Claims of 10-fold sprout yields and 15-20% dry matters would theoretically produce significant DM gains. If further research is done on sprouts it would be worthwhile evaluating the productivity of current hydroponic systems to determine if DM gains are possible as well as the economics.

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Appendices

Appendix A: Summary of the paper "Limiting Factors in Hydroponic Barley Grass Production" Morgan et al. 1992

In 1986 the Department of Horticulture, University College Dublin was commissioned to examine the components of sprouts production and to determine the possibility of achieving an increase in dry matter during an 8 day growth cycle.

A range of experiments were conducted to examine the effect of pre-soaking, aeration during soaking, chemical seed treatments to reduce mould, growing temperature, water temperature, light level and duration, irrigation techniques, irrigation frequency, nutrients and seeding rate. A laboratory assessment of feed value was also made. Experiments were carried out in a range of environments including germination cabinets, laboratory, walk-in growing rooms and controlled environment cabinets, as considered appropriate.

Pre-soaking treatment

Soaking time: Germination rates were assessed for three days for cultivar Triumph barley seeds that were soaked between 1 to 24 hours at 21ºC and then placed on moist filter paper in petri dishes at 24 ºC. Soaking periods of 1 – 4 hours resulted in germination rates in excess of 80% with a 4-hour soak giving 88% germination. Prolonging the soaking period resulted in germination rates below 60%.

Pre-soaking water temperatures: Water temperatures of 12ºC, 23ºC and 30ºC during 4 hours of soaking made little difference on germination percentage after 72 hours, but seed soaked at 23ºC appeared to germinate more rapidly.

Aeration during soaking: Following either 4 or 24 hours soaking with or without aeration, seeds were assessed for germination after three days in petri dishes at 24ºC. Aeration of the solution did not improve the % germination after a 4-hour soak. The reduced % germination normally found when soaking is done for more than four hours (eg 24 hours) was prevented where aeration was provided.

Chemical seed treatments: Initial chemical treatments to reduce mould also reduced germination and growth. A further test found that 1-hour treatment in 1% 'domestos' (equivalent to 0.1% hypochlorite) was effective in reducing contamination without adversely affecting germination percentage.

Growing temperature: Dry matter (DM) losses were measured over 8 days at two growing temperatures, 21ºC and 27ºC. From day 3 the sprouts received balanced nutrient feed and light for 16 hours daily. Dry matter loss was gradual to day 4, after which it began to drop rapidly. DM appeared to increase after six days. Sprouts grown at 21ºC lost 18% DM by day 8 and at 27ºC the loss was 23.6%.

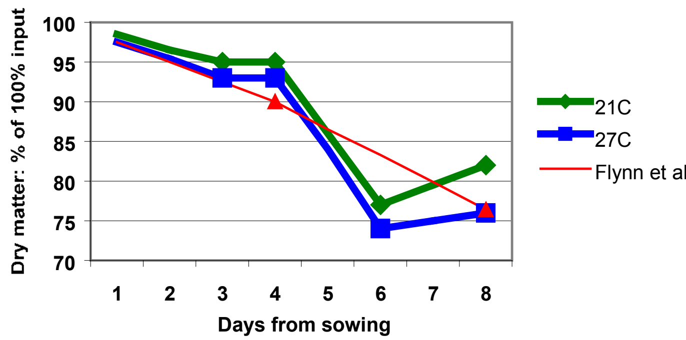

Figure 3 Dry matter content of barley grass during eight-day growth cycle

Light level: Soaked seed was grown at 24ºC at illumination levels using warm white fluorescent tubes ranging from 1000 to 9000 lux for 16 hours daily from the third day. DM content was measured at the end of day 8. Illuminance level appeared to have little effect on DM content, suggesting that increasing light intensity in production units is not likely to give a significant, or cost effective improvement in the DM of output grass.

Table 16 Influence of illuminance level on dry matter content of barley grass

Illuminance (lux)	DM as % of input
1,000	73.3
3,000	73.3
5,000	76.1
9,000	75.6

Light duration: Grass was provided with 1000 lux from day 2, 4, 6 or 8. There was little difference between treatments in DM content. Grass supplied with light from day 8 appeared unattractively yellow. The highest light level caused a decrease in grass height, probably due to reduced etiolation. A minimum of 2 days illumination is required to give satisfactory greening of the grass.

O'Sullivan (1982) as cited in Morgan et al. (1992) reported increased losses of DM, where no light was provided. He found that the rate of decrease of DM content slowed down after the fourth day in lighted experiments, when leaves began photosynthesising. In agreement with Morgan et al. (1992), lighting prior to day 3 was of little significance.

Wagner (1984) as cited in Morgan et al. (1992), however, suggests that photosynthesis is not important for the metabolism of the seedlings until the end of the fifth day, when the chloroplasts are activated. Working with oats Trubey et al. (1969) as cited in Morgan et al. (1992) found that light did not have a significant effect on DM content. Losses continued to drop from a value of 5.2% after three das to 12.3% after six days, probably reflecting the losses due to respiration and the negligible amount of photosynthesis by young seedlings at the low light intensity (800 lux).

Table 17 Influence of illuminance level on dry matter content on barley grass

Lighting from day	DM as % of input
2	74.4
4	76.1
6	76.1
8	75.9

Irrigation techniques: *"The principal secret to successful barley grass production lies in the provision of optimum irrigation."* Morgan et al. (1992).

These experiments evaluated flood irrigation however many commercial systems use sprays. Trays were automatically watered by pumps via capillary drip tubes and controlled by time clock. One set of trays allowed water to escape within 15 minutes of pump switch off and the second set drained more slowly within 30 minutes. Pumps were switched on for 30 minutes, four times daily and the maximum water depth was 10 mm. Trays with 15 minute water escape time retained greater DM and produced more healthy looking grass and with more vigorous and thicker and firmer root mass. The 30-minute water escape time sprouts showed signs of waterlogging.

Table 18 Dry matter content of barley grass from flooded trays with different water escape times (8-day cycle)

Water escape time (min)	DM (% of input)
15	83
30	77

Three more experiments produced better results in terms of DM retention and grass of excellent quality and vigorous root mass. Water depth ever exceeded 5 mm. Seeds were irrigated for 15 minutes 3 times in the first 24 hours and then six times on subsequent days. Light was supplied at 4000 lux for 16 hours daily from the sixth day.

Table 19 Dry matter content of barley grass grown in automatically irrigated units

Experiment	Growth Cycle (days)	DM (% of input)
1	8	90
2	7	84
3	7	83

Irrigation frequency: higher irrigation frequency increased DM conservation from 86 up to 91% of input. Two regimes were compared:

1. Irrigation every four hours during the entire seven-day growth cycle.
2. Irrigation every four hours for days 1-3. For days 4-7 irrigation was increased to once every two hours during the light phase, but remained at one every four hours during the dark phase.

Light was supplied at 4000 lux for 16 hours daily from the start of day 4.

Table 20 Influence of irrigation frequency on dry matter of barley grass grown with automatic irrigation

Irrigation frequency	DM (% of input)
Every 4 hours	86
Every 4 hours on days 1-3, then every 2 hours during light phase and every 4 hours during dark phase	91

A re-examination of light and temperature requirements with automatic irrigation: Using the improved irrigation frequency from the previous experiment, grass was grown at with a photoperiod of 16 hours from day 3, combined with either 5,000 or 10,000 lux. Three temperatures, 17º, 21º and 25ºC were assessed at an illuminance of 10,000 lux from day 3 and DM was assessed on day 7. The data confirmed that illuminance level has little influence on DM changes, confirming earlier results. Improved irrigation appeared to offset the affect of temperature on DM. There was little difference between temperature levels, with the 17ºC regime conserving slightly more DM. However the leaves of the grass harvested at 17ºC were not fully developed when harvested. Massantini and Magnani (1980) as cited in Morgan et al. (1992) likewise recorded a lower leaf/root ratio at 15ºC, together with improved DM conservation.

Table 21 The influence of light and temperature levels on dry matter of barley grass grown with automatic irrigation

Treatment	DM (% of input)
5,000 lux	92
10,000 lux	93
17ºC	93
21ºC	92
25ºC	91

Nutrition: Sprouts were supplied with water only (EC 150 *u*S) and compared with two levels of nutrient solution (EC 500 *u*S, EC 1,000 *u*S) which were supplied from day 3. There was little difference between treatments after seven days growth.

Table 22 Influence of nutrient solution concentration on dry matter content of barley grass

EC (*u*S)	DM (% of input)
150 (tap water)	83
500	82
1,000	84

Trubey et al. (1969) as cited in Morgan (1992) reckoned that the small improvement in the nutrient content of the sprouts did not justify the added expense of using nutrient solution rather than water. Massantini et al. (1980) as cited in Morgan (1992) reported a positive response to added nutrient solution, which was temperature related. Leaf growth rate was increased by 31.5% at 27ºC with nutrient solution, compared with water. No data are provided for DM content.

Seeding rate: Trays were sown with the equivalent of 2.5, 5 and 7.5 kg/m² of seed and were provided with nutrients at 500uS and irrigated and illuminated as previously described. DM was assessed at 7 days. There was a reduction in DM recovery as seed density increased.

Table 23 Effect of seeding rate on dry matter content of barley grass

Seeding rate (kg/ m²)	DM (% of input)
2.5	83
5.0	79
7.5	71

At the highest rate of 7.5 kg/m² the root mat became so thick that anaerobic conditions occurred within it towards the end of the growing cycle and the mat began to heat. The grass in these trays was severely affected by contaminating micro-organisms. Morgan et al. (1992) states that most commercial units recommend seeding rates of 6-8 kg/m². Massantini et al. (1980) as cited in Morgan et al. (1992) reported total dry weight increasing with seeding rates up to 5 kg/m². However, they showed that leaf/root ratios were constant with seeding rates up to 4 kg/m², after which they fell rapidly. On the basis of total dry weight / seed weigh ratio, Massantini et al. (1980) as cited in Morgan et al. (1992) concludes that a seeding rate of 4 kg/m² is the most efficient for seedling growth, generally confirming the present results.

Appendix B: Reviews of livestock performance trials using sprouts

This section includes a summary of literature reviews by Leitch (1939) and Myers (1974) regarding livestock performance from sprouts.

Early Work – Leitch 1939

Leitch (1939) reviewed experiments which involved feeding sprouted grain to dairy cows, beef cattle, calves, pigs and chickens. Most of the experiments that Leitch reviewed observed no advantage over conventional diets in terms of livestock performance. It is interesting that Leitch's introduction in 1939 began *"The present lively interest in sprouted fodder has arisen from commercial exploitation of processes of water culture of plants to produce stock fodder."*

The following is a summary of Leitch's key findings.

Effect on weight gain

Dairy cows

(No advantage) At Reading, England, Bartlett et al. (1938) incorporated maize sprouts into dairy cow diets. From three trials it was impossible to draw any conclusion other than that sprout fodder appeared to be as good as the fodder it replaced and that it possesses/ed no special feed value.

(No advantage) The conclusion to a further 8 tests by Bartlett et al. (1938) was that feeding sprouted maize showed no advantage in either milk yield or quality.

(No advantage) Tinley and Bryant (1938) at Wye (England) abandoned one experiment with dairy cows due to scouring which was particularly bad in the cows that received maize sprouts. In another experiment the difference in milk yield between the sprout-fed and control groups was not significantly different.

(No advantage) In Berlin reported that sprout patentees claimed milk yield increases of 8 to 9 kg/head/day and a 3% increase in fat content from feeding sprouted fodder. However, when 0.5 kg of crushed barley was replaced by the quantity of sprouts grown from 0.5 kg of barley seed the only result was *"a considerable increase in the cost of the ration"*.

(No advantage) Bostock and Brown (1937) at Hawkesbury College, New South Wales, reported that, *"Sprouted fodder was unpalatable to dairy cows but they might acquire a taste for it".*

Beef cattle

(Improvement) In 6 experiments at the West Scotland College of Agriculture in Auchincruive by Paterson (1936, 1937 and 1938) there was on average a 183 g/day live weight gain advantage in bullocks when sprouts replaced an equivalent dry matter of swedes.

(No advantage) Two trials by Schmidt et al. (1938) in Berlin resulted in no differences in live weight gain when bullocks received 1 kg/day of crushed barley or the equivalent (seed weight) of sprouted barley in the diet. They recognised that in feeding the sprout grown from a quantity of barley equivalent to that displaced, there was a reduction in total dry matter and protein.

Calves

(Disadvantage) At the West Scotland College of Agriculture McCandlish (1939) found that calf growth was less when sprouted maize replaced flaked maize at an equivalent weight of dry matter. Higher allowances of sprouts reduced growth. A similar trend was apparent in their earlier bullock trials where sprouts replaced swedes.

Pigs

(No advantage) Fishwick (1939) at Wye added sprouted barley to the daily ration of fattening pigs. The amounts of sprouted barely required to produce 1 lb. of surplus weight was calculated to be from 7.22 – 8 lb. The conclusion was that there was no evidence that sprouted barley had any “accessory” food value when fed as a supplement to a normal meal ration. A preliminary trial with weaner pigs showed no special feed value.

(No advantage)) In Berlin, Schmidt and Kliesch (1937) found that when 350 g of crushed barley was replaced with sprout fodder from 350 g of barley there was no difference in live weight gain of fattening pigs. At the request of the firm supplying the sprout apparatus and nutrient solution, 1.5 kg of sprouts was used to replace the control supplement of 700 g of crushed barely and 200 g of fish meal/head/day. Daily gains in the sprout-supplemented group dropped 32% from 644 g to 437g.

(No advantage) In two more experiments at Dahlem Station by Schmidt et al. (1937) one group of pigs had 300 g of barley replaced by 1175 grams of sprouted fodder with no difference in performance, however when sprouts were the only protein supplement, performance was lower. In the second trial barley alone was fed, one group receiving the equivalent of 300 g barely as sprouted fodder. No advantage was evident in weight gain or food utilisation.

(No advantage) At Koppehof Station by Schmidt and Kliesch (1937) pigs on a basal diet of steamed potatoes received either 450 g of crushed barley or 1.5 kg sprout fodder. The crushed barely group gained 373 g daily compared with 243 g for the sprout group and they also used protein and starch more efficiently.

All three of these early pig experiments showed no evidence of any special properties of sprouted fodder. There was no advantage when the sprouts replaced similar amounts of grain. An advantage was seen when sprouts replaced Swedes.

Effect on reproduction

(No advantage) In Hawaii, a trial by Henke (1935) using ‘shy breeder’ cows showed no reproductive advantage when given a daily supplement of sprouted oats from 2 lb (0.9 kg) of dry seed to a diet that already had abundant green feed.

(No advantage) In a group of similarly selected ‘shy breeder’ sows the treatment of sprouted oats equivalent to 1 lb (0.454 kg) of dry seed daily showed no advantage (Henke 1935).

(No advantage) "*Mass observations were made of the breeding efficiency of the whole herd, to which about 6 lb (2.72 kg) of sprouted oats per head was fed daily between years 1926 and 1931. Results during this period were substantially the same as during the preceding and following 5-year periods*" (Davis and Hathaway 1936).

Leitch’s summary of feeding experiments

From three centres controlled experiments on dairy cows are reported. These show no special advantage in sprouted fodder for milk production, but indicate that it may replace an equivalent amount of silage or kale in short period trials (1 to 3 months).

Tests on beef cattle in which sprouted barley replaced the equivalent weight of seed in the concentrate ration showed no improvement in rate or economy of live weight gain. Trials on a much larger scale at one centre in which sprouted maize replaced an equivalent (dry matter) amount of swedes, showed highly significant increases in rate of live weight gain, and gave excellent quality of beef.

A single experiment with calves showed that sprouted maize was of less value for growth than flaked maize and that growth was less on a higher than on a lower allowance of sprout.

Three centres report negative results with pigs.

Observations on the effect of feeding germinated oats to cows and sows suffering from "temporary sterility" are discussed. Controlled experiments show no benefit from this treatment, either in number of animals conceiving during the term of the experiments or in the number of services per conception.

Experiments with laying hens show a balance of evidence that germinated grain or seedlings of a few day's growth, added to rations without green food or with hay meal in winter and spring, improves egg yield, fertility and hatchability. When the ration contains fresh green food no benefit is found from feeding germinated grain.

Myers 1974 literature research

Effect on weight gain

Dairy cattle

(No advantage) Williams (1956) supplemented two sets of lactating identical twin cows (Holsteins and Guernseys) for 30 days with 20 lb of 6-day-old hydroponic oats grass. There was no change in milk production or fat percentage.

(No advantage) Thomas and Reddy (1962) used a double reversal trial on 14 dairy cows over a 12-week period and compared four different types of hydroponic growth chambers for cost. They concluded that, *"The different response of these two groups of cows indicates that feeding sprouted oats will not increase milk production in cows that are already receiving sufficient energy, but it may increase milk production in cows that are not receiving a high level of nutrients. This could explain some of the results observed on farms."* After noting that sprouted oats cost over four times as much as the original oats, they continued: *"This high cost plus (1) loss in nutrients during sprouting, (2) the decreased digestibility of sprouted oats and (3) no observed increase in milk production when sprouted oats were added to an adequate ration indicate that this feed has no justification for being in any modern dairy ration."*

Beef cattle

(No advantage) McFate (1963) feed 3 pens of 10 beef cattle with an average starting live weight of 342 kg. The control group A received 2.27 kg of crushed oats plus 2.27 kg of corn and 1 kg of hay per 100 kg live weight. The second group B received oat grass grown from 2.27 kg of oats plus corn and hay as for group A. Group C was the same as group B except they were allowed nearly as much as they could eat of corn each day. After 98 days the average daily gain for groups A and B was 535 grams and group C was 463 grams. The cost per kilogram liveweight gain was $0.65, $1.25 and $1.52 for groups A, B and C respectively.

Table 24 Summary of results from experiments by McFate (1963)

	A	**B**	**C**
Feed intake			
Crushed oats	2.27 kg		
Oats sprouts		Sprouts from 2.27 kg oats	Sprouts from 2.27 kg oats
Corn	2.27 kg	2.27 kg	Near ad lib
Hay	1 kg / 100 kg	1 kg / 100 kg	1 kg / 100 kg
Average daily gain	535 g	535 g	463 g
Cost: $/ kg gain	$0.65	$1.25	$1.52

Source: Myers (1974).

(Advantage) Work by Perry et al. (1965) as cited in Myers (1974) found that supplementation with hydroponic fodder gave 7.5% improved weight gains on 23% less feed consumption in 250 kg cattle on a corn grain and corn cob diet. Ten steers had ad lib intake of the below ration and another ten steers has the same ration plus 5.44 kg of hydroponic sprouts per head per day.

Table 25 Basal diet and performance of steers with or without a sprout supplement

Ration	
Ground shelled corn	47.6%
Ground corn cobs	47.8%
Soybean meal	4%
Dicalcium phosphate	0.6%

	10 steers	**10 steers + 5.44 kg sprouts**
Entry liveweight (kg)	249	249
Average daily gain (kg)	0.962	1.03
Feed conversion ratio	11.4	8.7

Source: Myers 1974.

(No advantage) In Arizona, Myers (1974) feed 7 steers ad lib on a feedlot ration and another 7 steers on the same ration plus ad lib 7-day-old hydroponic barley grass. No attempt was made to determine economic feasibility and he states *"it was recognised from the beginning that hydroponically grown grass was not the cheapest method of putting weight on cattle."*

Table 26 Live weight gains and feed conversions of feedlot steers with or without barley grass

	7 steers	**7 steers + barley grass**
Ration	Ad lib feedlot ration	Ad lib feedlot ration + ad lib barley grass
Entry liveweight (kg)	185	186
Days	85	85
Average daily gain (kg/head/day)	1.33	1.32
Feed conversion range	4.45 to 5.87	4.45 to 5.4

Source: Myers (1974).

After 85 days the average daily liveweight gain for the control group was 1.33 kg/head and for the barley grass group 1.32 kg/head. Daily fresh grass intake started at 5.44 kg/head and built up to 34 kg/head. Two outbreaks of mould resulted in intakes reducing to 7.7 kg/head and complete refusal. When the grass was clean and fresh it seemed to stimulate growth and when mouldy it reduced average daily gains. Cattle receiving the grass showed easier transitions in feedlot rations from Purina Starter 2 to Purina Conditioning Ration to Purina Cattle Chow Complete.

Improvements were made to prevent mould and a second trial was run for 70 days using Arizona Feeds Cattle Rations. The first 56 days was on a 30% concentrate ration with 12.5% crude protein and the last 14 days on a 90% concentrate ration plus 12.5% crude protein. To minimise mould they increased chlorine during seed soak, increased shed cleaning using chlorine and changed planting technique for better shed circulation. To feed the grass they also changed from steel drums to wooden troughs to keep the grass cooler and fresher.

Table 27 Liveweight gains and feed intakes of feedlot steers with or without barley grass (Period 1: 56 days)

	6 steers	**7 steers + barley grass**
Ration	Ad lib 30% concentrate ration	Ad lib 30% concentrate ration + ad lib barley sprouts
Entry liveweight (kg)	~ 317	~ 317
Days	56	56
Average daily gain (kg/head/day)	0.953	1.18
Daily ration intake (kg/head 'as fed')	9.84	10.12
Daily grass intake (kg/head 'as fed')		12.93

Source: Myers (1974).

The treated group averaged an extra 230 g liveweight gain per day. Assuming the barley grass costs $100/t then 12.93 kg of grass costs $1.29.

Cattle then switched from the 30% concentrate ration to a 90% concentrate ration also with 12.5% crude protein for 14 days.

Table 28 Liveweight gains of feedlot steers with or without barley grass (Period 2: 14 days)

	6 steers	**7 steers + sprouts**
Ration	Ad lib 90% concentrate ration, 12.5% CP	Ad lib 90% concentrate ration, 12.5% CP + ad lib barley sprouts
Days	14	14
Average daily gain (kg/head/day)	1.13	1.21

Source: Myers (1974).

Myers (1974) concluded *"it was apparent now that whether or not the test animals received hydroponic grass was not the critical determinant in their performance."*

In terms of visual appearance it was considered that general appearance of the grass fed animals was better than the control group. They shed their winter coats earlier and the new coat was slicker, shinier and generally cleaner than the control animals' coats. The grass fed animals were more active and playful at all times.

Myers (1974) also observed *" it is infeasible to feed only hydroponic grass to fattening steers regardless of the economics involved. Animals fed grass and concentrate free choice consumed 50% more grass than those fed grass only."*

Trials using sprouted-in-the-head grain

The following three trials used grain that sprouted in the head due to wet conditions before it could be harvested.

(Disadvantage) Bull and Petersen (1969) ran two trials with pigs and chickens using wheat that had sprouted in the head prior to harvesting. In forty weanling pigs the average daily gain was not affected by feeding sprouted grain either as the sole source of wheat or in various combinations with normal wheat; however the efficiency was decreased with increasing amounts of sprouted wheat in the ration (3.68, 3.83, 3.95 and 3.99 kg of feed/kg of gain for groups fed 0, 33.3, 66.6 and 100% sprouted wheat respectively).

(No advantage) One hundred and fifty White Leghorn cockerel chicks were allotted to five different rations composed of 61% wheat with the following percentages of sprouted wheat, 0, 25, 50, 75 and 100%. Neither rate of gain nor feed efficiency were altered by substituting all or pare the normal wheat with the sprouted grain (Bull and Petersen 1969)

(No advantage) Farlin et al. (1971) ran a 140-day feeding trial to evaluate the nutritive value of wheat containing 60% sprouted kernels. Groups of 10 yearling steers received diets where the wheat fraction was 100, 66.6, 33.3 or 0% sprouted wheat. Substitution of sprouted wheat for nonsprouted wheat in the diet had no effect on liveweight gain, carcass weight, grade, cutability, loin eye area, marbling, fat cover, kidney fat, or incidence of abscessed liver. To the untrained observer, much of the grain appeared to be normal because the sprouts were just beginning to appear. Since the dry matter of the sprouted wheat was 92% no storage problems were encountered. The nutritional value of wheat containing very long sprouts may be different as loss of long sprouts might affect the feeding value.

Research by Tudor et al. (2003)

(Improvement) Work by Tudor et al. (2003) on a property in the Gascoyne Pilbara region of Western Australia involved 17 Droughtmaster steers (15 – 18 months old and averaging 330 kg liveweight) which received low quality hay and barley sprouts over 70 days. Over the first 48 days cattle ate 1.9 kgDM/head/day of sprouts (15.4 kg wet weight) and 3.1 kgDM/head/day of poor quality hay and gained 1.01 kg/head/day. Energy intake was 47 MJME/head/day, which was considered by nutrition standards to only be sufficient for low weight gains of up to 200g/head/day. This high performance could not be explained by energy and protein intakes. During the next 22 days sprouts were restricted to 1.6 kgDM/head/day (13 kg wet weight) and ad lib hay intake was 7.8 kgDM/head/day. Energy intake increased to 74 MJME/head/day and cattle gained 0.41 kg/head/day, which conformed to nutrition standards. Average daily gain for the 70 days was 0.814 kg/head. Two animals died from unknown causes and there was no suggestion of fungal growth on the sprouts. A conclusion was that one or more experiments should be conducted at a research station where individual intakes can be measured and all aspects closely monitored to better measure and understand why the animals performed so well on the restricted diet during the first 48 days compared with the following 22 days.

The following is a hypothetical example of the economics for the 70-day trial by Tudor et al. (2003). It assumes the sprouts and hay cost $120/tonne as fed, i.e. $0.12/kg. The $120/t for sprouts includes capital, labour, operating and grain costs.

Table 29 Feed costs, cattle performance and return for 70 days

Feed cost	Days	kg (wet)	$/kg	Total
Sprouts	48	15.4	0.12	$88.70
Hay	48	3.4	0.12	$19.58
Sprouts	22	13	0.12	$34.32
Hay	22	8	0.12	$21.12
				$163.73

	Kg	Price	$	
Start	330	$1.50	$495	
Finish	387	$1.80	$697	
Liveweight gain	57		$202	Extra value
Days	70		$164	Feed cost
ADG (kg/hd/d)	0.814		**$38**	

Returns during the first 48 days were far superior to the last 22 days. During the first period the steers averaged 1 kg/head/day liveweight gain with a 5:1 DM feed conversion. During the second period cattle ate more feed and gained 0.41 kg/head/day with a DM feed conversion ratio of 22.8:1.

Appendix C: Whole farm economic comparison

Original – Grow steers, invest cash, no supplements

This example is for 75 head of steers with an average daily gain (ADG) of 0.34 kg.

Land	150 ha	3 ha/AE	50 AE	
Adult equivalents (AE) run	75 hd	0.75 AE/hd	56 AE	
ASSETS				
Land		150 ha	$800/ha	$120,000
Steers		75 hd	$252/hd	$18,900
Vehicles and equipment				$30,000
Cash				$32,000
Cash invested				$102,100
TOTAL ASSETS				$303,000
LIABILITIES				$0
EQUITY (assets – liabilities)			100%	**$303,000**
PROFITABILITY				
Cattle income				
Steers	75 hd	304 kg	$1.45/kg	$33,060
Investment – income	5%			$5,105
Investment - capital gain	5%			$5,105
				$47,270
Cattle variable costs				
Livestock purchases	75 hd	180 kg/hd	$1.40/kg	$18,900
Commission on sales	4%			$1,322
Transport in and out		150 km	$5/km	$750
Vaccines, drenches, etc.		75 hd	$5/hd	$375
				$21,347
Cattle gross margin				**$21,923**
FIXED COSTS (overheads)				
Rates, insurance, administration, etc				$3,800
Repairs and maintenance				$3,000
Depreciation		$30,000 @	10%	$3,000
Fuel and power				$2,000
Management allowance				$5,000
				$16,800
OPERATING RETURN				**$5,123**
Percent Return On Assets				**1.69%**
Interest on liability		-	8%	-
BUSINESS RETURN				**$5,123**
Percent return on equity				**1.69%**

Sprouts – Buy shed, feed sprouts for 12 months

This example is for 75 growing steers with an average daily gain (ADG) of 1 kg.

Land	150 ha	3 hd/ha	50 AE	
AE run	75 hd	0.85 AE/hd	64 AE	
ASSETS				
Land		150 ha	$800/ha	$120,000
Steers		75 hd	$252/hd	$18,900
Vehicles and equipment				$30,000
Cash				$58,100
Hydroponic equip and shed			$60,000	
Installation			$1,000	
Silos			$2,500	
Slab			$2,500	
Augers			$7,500	
Tanks			$2,500	
Total hydroponic system				$76,000
TOTAL ASSETS				**$303,000**
LIABILITIES				-
EQUITY (assets-liabilities)			100%	**$303,000**
PROFITABILITY				
Cattle income				
Steers	75 hd	545 kg	$1.70/kg	**$69,488**
Cattle variable costs				
Livestock purchases	180 kg	75 hd	$1.40/kg	$18,900
Commission on sales	4%			$2,780
Transport in and out		150 km	$5/km	$750
Wages		365 days	$30/day	$10,950
Vaccines, drenches, etc		75 hd	$5/hd	$375
Feed out	3 km/day	365 days	$0.52/day	$569
Hydroponics - fertiliser, etc		365 days	$5.08/day	$1,854
Grain	$0.25/kg	100 kg/day	365 days	$9,125
				$45,303
Cattle gross margin				**$24,185**
FIXED COSTS (overheads)				
Rates, insurance, administration, etc				$3,800
Repairs and maintenance				$5,000
Depreciation		$106,000 @	10%	$10,600
Fuel and power				$2,000
Management allowance				$5,000
				$26,400
OPERATING RETURN				**-$2,215**
Percent return on assets				**-0.73%**
Interest on liability	8%	-		-
BUSINESS RETURN				**-$2,215**
Percent return on equity				**-0.73%**

Protein supplement – Supplement for 6 months, invest cash

This example is for 75 growing steers with an average daily gain (ADG) of 0.42 kg.

Land	150 ha	3 ha/AE	50 AE	
AE run	75 hd	0.75 AE/hd	56 AE	
ASSETS				
Land		150 ha	$800/ha	$120,000
Steers		75 hd	$252/hd	$18,900
Vehicles and equipment				$30,000
Cash			-	$34,000
Cash - invested			-	$100,100
TOTAL ASSETS				**$303,000**
LIABILITIES				-
EQUITY (assets-liabilities)			100%	**$303,000**
PROFITABILITY				
Cattle income				
Steers	75 hd	333 kg	$1.45/kg	$36,214
Investment - income	5%			$5,005
Investment - capital gain	5%			$5,005
				$46,224
Cattle variable costs				
Livestock purchases	180 kg	75 hd	$1.40/kg	$18,900
Commission on sales	4%			$2,050
Transport in and out		150 km	5	$750
Wages - feed out		45 days	$10/day	$450
Vaccines, drenches, etc		75	5	$375
Hydroponics – fertiliser, etc		-	-	-
Urea lick	$0.12/hd/day	75 hd	120 days	$1,080
Meal	$0.40/kg	38 kg/day	60 days	$912
				$23,916
Cattle gross margin				**$22,308**
FIXED COSTS (overheads)				
Rates, insurance, administration, etc				$3,800
Repairs and maintenance				$3,000
Depreciation		$30,000 @	10%	$3,000
Fuel and power				$2,000
Management allowance				$5,000
				$16,800
OPERATING RETURN				**$5,508**
Percent Return On Assets				**1.82%**
Interest on liability	8%	-		-
BUSINESS RETURN				**$5,508**
Percent Return On Equity				**1.82%**

Appendix D: Other considerations and common problems

To get a feel for potential problems it is highly recommended to read the questions and answers posted on the Hydrocentre website (www.hydrocentre.com.au). Some examples of comments from this site include:

- Mould is number 1 problem, humid days don't help, but up to now we haven't had a lot of them (p.8 Q&A Hydrocentre).

- I grew some hydroponic barley fodder last October with amazing results but the cattle wouldn't look at it. Took a bit of a nibble and headed back to the barley straw!

- Just as I think the mould is under control, up it crops again, maybe it's the wet weather we have had lately.

- Mould comes off the seed, and can come from the water. Water can be sterilized with UV, Ozone, Hydrogen Peroxide, and most popular is Pythoff (Monochloramine). Standing tanks can be sterilized with Chlorine/Bleach. The chlorine/bleach must be eliminated before contact with plants by aeration or Hydrogen peroxide. pH of 6-7 is safe in all Hydroponics. EC 1.4 (This is a CF14 or 700-980ppm depending on your meter) I would think about 0.8 to 1.6 is fine. Look at your growth compared to humidity and temperature. High EC slows growth, but increases weight. You may find high EC linked to heavy growth and slow growth which could be linked to mould in dense growth. The EC is linked to the transpiration rate (Its sweating of moisture to allow further uptake of liquid) which is reliant on the environment. Raise the temperature for example; there is a higher transpiration (think sweating) and you have to lower the EC to get a similar result. Increase the airflow over the fodder and the transpiration goes up. Because of the environment, every green fodder grower will get slightly different results even if using the same EC/CF.

- We have been using Pythoff, and it is keeping the mould under control, we soak the grain for at least an hour, let it drain for about 2 hours, then put it in the trays. We also treat supply tank, and flush racks when empty. Still get a bit of mould at 7-8 days, but this doesn't affect growth.

- We are only just starting into fodder production of barley (3 tonnes per day) and have encountered mould problems. Some of the equipment has pumped with questionable efficiency. We are starting over with pre-treating seed. What dosage of calcium hyperchloride would you recommend to address the problem, both through tray washer and overhead sprinklers? Is this the most effective/efficient product to use, as we are feeding 7-8 day old shoots to dairy and beef cattle?

- Bore water may be too saline. Have it checked for suitability first with a water test.

- I have a fodder shed. You mentioned monochloramine, could this be used in the supply tank (5000 gal) And its cost. This shed produces over a 1000 kg a day, works on bore water, the only trouble I have is calcium build up and it is blocking nozels, plus I am getting fungus on 7th & 8th days.

- I have recently installed a fodder factory. I have encountered problems with mould. The addition of sulphur to the nutrient tank has seemed to deal with black mould but lately we have gotten a severe problem with a white mould. This is worse in humid weather associated with the rain we have been having lately. The cows seem to eat it without harm but it stops growth and badly affects production. I am wondering if there is anything I can add to the nutrient tank, like peroxide, that will help with this problem, and if so what quantities are safe to use. My nutrient tank is 27,000 litres. I have noted the advice on presoaking the seed in a 1% peroxide solution but am reluctant to do this because of the difficulty in spreading wet seed in the trays. Do you have any suggestions on this?

Answer: Humidity has a lot to do with the problem. Try to air condition the area or use fans to keep humidity down. If mould is in the air from spores, maybe have your fan intakes come in from a higher point like through the roof, not near the ground where mould often lives.

The seed is often the source of the mould. I highly recommend washing some seed thoroughly and see if trays washed produce low or no mould. Try also some sterilizing of the seed as well, use hydrogen peroxide or Monochloramine, and compare that too. I think it is worth the effort, once you get used to it.

Sometimes the source is our hands. Don't touch the seed. EVER. Use gloves. Do not disturb the seed once it has been placed into the trays.

Sometimes the source is the water supply. Sterilize the water and test that theory on a few trays.

I seem to think that Fodder growing is not as low a labour activity as the sales people try to make it sound. It is not excessive but washing and cleaning is very important.

I also think that air conditioners make it much easier, as long as they are not blowing up. Make it a good model with too much power. Good Luck – Scott.

http://www.peterdoyleconsultancy.com.au/fodder-installation.html

Not Included But Required:

- Site Preparation including hole for nutrient tank (as per plans supplied by LFS)
- Nutrient Tank to be put in ground.
- Concrete Slab (as per plans supplied by LFS)
- Power & Water to site
- Electrical Wiring
- Freight - $1.50 per km from Albury to Charters Towers (One Way Cost)
- Crane to lift off Hydroponic Channel (unless you have a couple of fork lifts)
- 14 crates approx 300kg each. 4mt long x .7mt wide x .6mt high for each crate.
- Ortho Phosphoric Acid (Used to bring down the pH) - Costs $95 for a 20lt drum which lasts about 6 weeks.
- Sporekill (Agricultural Disinfectant used to kill any potential spores) - Costs $134 for 5lt container. Last approx 12 months. 20mls per 1000lts added to nutrient tank once a week.
- Accommodation including overnight stay to and from job. Will stay at homesteads or such like
- Travel Expenses – Petrol

Not Included But Optional:

- Chlorine - Wash down channels - Costs $24 for a 20lt drum (Very very mild solution when washing channel) We don't use chlorine when washing our channel, just plain water.
- Silo - Measured in cubic metres. Some example of silos and capacity. 18 tonne of Barley needs a 26m3 silo, 7.1 tonne of Barley needs a 10.2m3 silo.
- Available Silo sizes vary depending on manufacturer but approx 1.444m3 silo space per tonne of Barley is required.
- Colourbond Option (Required by some Councils) - $1800 ex GST on LFS 1
- Extra Nutrient - 1-6 Batches - $161 ex GST per batch plus Freight from Childers
- 7-14 Batches - $132 ex GST per batch plus Freight from Childers
- 15 or more Batches - $125 ex GST per batch 5 plus Freight from Childers

Administrative Details Report

MLA funded this report from June to October 2003 to the value of $10,000.