DIRECTIONS FOR SUSTAINABLE AND PROFITABLE GAINS IN THE AUSTRALIAN GRAINS INDUSTRY

2002 Australian Nuffield Farming Scholar

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EXECUTIVE SUMMARY

The concept of sustainability in Australia is too often viewed as a goal that is independent to achieving profitability gains in modern day food production. In the Australian grains industry if we look at the main environmental problems of salinity, soil erosion and nitrate leaching, it is obvious that economic benefits are to be derived from keeping the soil productive, keeping the soil in the system and optimising nitrogen conversion into grain yield. Whilst these are very real concerns in a world of cheap oil, they are secondary to the inevitable negative impact of rising energy costs in the future.

Vast amounts of energy are required to produce nitrogenous fertilizers. It takes the energy from roughly one litre of oil to produce one kilogram of urea. One must therefore appreciate that inflation in the cost of consuming energy, will directly inflate the price of nitrogenous fertilizers and impact tremendously on the profitability of producing nitrogen hungry crops such as wheat and canola in Australia.

Organic production is expanding but at the expense of volume in the global food chain and some like myself would also argue weakening future global food security. The organic movement seems to be ignorant of the fact that replacing chemical inputs like pesticides with diesel and steel in complex repetitious cultivation is not a move towards a sustainable future. It is more realistically the energy cost of producing that will likely shape the future evolution of agriculture and horticulture worldwide. The general impact being that production systems will need to focus more on the ability of leguminous crop species to suffice nitrogen needs.

Poor returns from growing grain legumes in Australia have lead to a dominance of cereal crops. Going forward this is a dangerous situation as research funding is directed away from leguminous crops such as lupins that need to ultimately dominate southern cropping zones. The energy cost associated with producing legumes is significantly lower than those crops like cereals requiring large amounts of fertilizer. Being the legume most greatly suited to Australia's predominantly acid soils, the lupin must be principally focussed on by plant breeders, grain growers, marketers and end users alike. Breeding higher percentages of oil into the crop remains the number one priority for industry to increase commodity value.

Australia's dependence on high risk markets in the Middle East to consume our cereal bounty would be reduced with the development of a profitable leguminous oilseed. Preferential marketing is better enabled with high valued grains particularly one containing both protein and oil, able to be assimilated into any known food culture. A recent problem with a false karnal bunt contamination claim in Pakistan serves to highlight this need for Australia to move marketing focus away from a region which is at best never stable. Asian opportunities need to be targeted given our significant freight advantage over our competitors which will only increase in time with the rising cost of transport and shipping traffic particularly between Australia and China.

The concept of perenniality in grain crops also warrants investment by industry. The economic benefits to any cropping business where two, three or more years' harvests can be taken from one years establishment cost are potentially very significant. The cost of machinery is significant and growing for all grains enterprises. Perennial crops with their deep and robust root systems also enable farmers to optimise inputs. Increased water and nutrient use efficiencies can be realised and energy investment is also able to be reduced significantly. This is where the future of crop production lies essentially. Breeding for crops that require less labour and input units for they are either able to do the work themselves or only remove those fertiliser elements that can be biologically produced. Some terrific examples in the area of transgenics exist reducing labour and input components, eg Bollgard cotton.

A cropping option exists that allows grain growers the ability produce oil and protein without fertilizer inputs. The sandalwood is a unique native tree crop highly adapted to Australia's harsh conditions. The tree produces nuts which are high in oil (60%) and protein (18%) making it an attractive proposition to the southern grain belt. It requires no fertilizer inputs and will be an important crop in the future.

Those opposed to the technology of transgenics turn their backs on science and at a time when the challenges faced by global food producers are largely unrealised given the current availability of cheap energy. Transgenic technology can offer ways in which to preserve and protect in the medium term the food culture we all love to indulge in. This will be through allowing agricultural production to reduce its dependence on fossil fuels for productivity and profitability.

ACKNOWLEDGEMENTS

2003 has been an exciting year full of learning both on and off the farm. An opportunity made possible by the Australian Nuffield Farming Scholars Association. For this I am truly indebted to this collective group which provides an unbelievable forum in which to cultivate many crops of thought. I look forward to joining the ranks of Nuffield and providing the support necessary to foster the development of new scholars and forward the goals of this industry leading organisation.

I would also like to thank my sponsor in Landmark AWB and in particular David Coombes. I was afforded confidence in my ability to identify areas of importance to the grains industry and for this I am hopeful I have generated value, not only for this industry, but also for Landmark AWB.

I am also extremely grateful for the work my parents put into the year whilst I was away and must congratulate them on their efforts in producing some of the best crops our farm has ever seen. I could not have had this experience without their strong support and ability to make the farm continue as though I was still there.

Finally I would like to dedicate this report to the late Harry Perkins whom I only briefly knew but whose passion for Nuffield inspired me to strive to achieve the most I could out of the experience. It will be hard to forget that proud grandfatherly smile that was unavoidable to ignore from behind the podium and microphone.

STUDY GOAL

The primary goal of this study was to identify technologies, new crops and/or agronomic practises that have the realistic potential and ability to be adopted by the Australian grains industry in order to concurrently increase profitability and better environmental parameters within and around the production system. It was also an important goal to better understand agriculture and if and how it will cope in the future with rising energy costs.

INTRODUCTION

The future role of the grains industry in the Australian landscape is going to face increased pressures from two distinct yet related areas in its goal to survive and flourish. Competing in the global marketplace has always and will continue, at an ever increasing rate, to drive the need to find more cost efficiencies in production. Our massive environmental problems (namely salinity and soil erosion) will have to be meaningfully addressed if government intervention is to be avoided and more importantly, access to affluent foreign markets is maintained.

Macroeconomic Factors Affecting the Viability of the Grains Industry

Aside from upward trends in currency values, the greatest medium to long term risk to the cost structure of all grain producing enterprises around the world is the inevitable ***rising cost of energy***. Fertilizer prices are intrinsically linked to the global oil price which then determines the price of gas. Most people would be surprised to learn that fertilizer accounts for the vast majority of energy invested into any cropping and for that matter food production system, even those involving conventional tillage practices. The energy equivalent from burning one litre of oil is required to produce one kilogram of urea, a common source of nitrogen for crops.

Given that fossil fuels such as natural gas are a non-renewable resource and the massive, yearly, global energy investment into nitrogenous fertilizer production, it is unlikely that such a comparatively cheap source of energy will be found as a replacement. This is especially the case where competition for energy will preferentially direct it to markets generating higher margins for oil and gas companies. Already this can be seen in the United States where anhydrous ammonia and urea prices have recently significantly appreciated as a result of significant volumes of gas being preferentially used for domestic household energy consumption. A similar situation will be faced by the New Zealand dairy industry when the Maui gas fields begin to show signs of exhaustion. Pressure exists globally on gas reserves with massive demand coming from China whose hunger will only continue to increase.

Variability and Unpredictability in Weather Patterns

Long term forecasts for Australia's climate as a result of global warming indicate trends towards declining rainfall averages, more extreme rainfall events, higher evaporation rates and increased susceptibility to frosts (as a result of higher carbon dioxide concentrations in the atmosphere). The consequences of all the trends for grain production are higher risk associated with planting decisions and indeed individual crop selections, increased cost in managing environmental issues such as soil erosion, and the capacity to be able to evolve management systems suited to potentially new seasonal conditions.

So what does this mean for agriculture and grain production in Australia going into the future? Quite simply it highlights the need for our industry to reduce our reliance on fossil fuel derived energy. How can industry effectively use less diesel, less fertilizer and less pesticide in yearly production yet still generate margins similar or even better than current profitabilities?

Environmental Problems Eroding Profitability and Sustainability

The single greatest environmental threat to the long term profitability of grain production in Australia is undoubtedly dry land salinity. There are however many other significant environmental challenges which industry will need to address to maintain productivity. These are in areas such as soil erosion, acidity, sodicity and pesticide resistance in weeds, insects and diseases.

Failure to utilize any tools available to help increase profitability and sustainability will translate to cost burdens that industry and, where the environment is concerned, society will have to bear in the future. This means that farmers, researchers, end users, consumers and political institutions should be open to evaluating the potential for all management options.

ENVIRONMENTAL ASSURANCE & DEVELOPING FOOD CULTURES

Developing Sustainable Food Culture

The development of food culture in Australia has been an evolutionary process generally following popular trends worldwide. Food culture is a function of economics, regional agricultural enterprises, consumable natural resources, taste, tradition, fashion, health issues and increasingly environmental considerations.

In India the culture of food revolves around grain legumes and rice. Pulses such as chickpeas, lentils, and cowpeas are cheap sources of protein being legumes, particularly when compared to meat, dairy and egg products. They store well and do not require refrigeration even in such a harsh environment. Poor economic conditions in the farming sector have favoured legume production where some farmers cannot afford fertilizer. Sweden on the other hand has a highly refined food culture centring on fish, meat, berries and dairy products. The wilderness of Sweden is home to a wide range of indigenous berries with unique tastes and nutritional benefits and its vast number of fresh water lakes are brimming with fish. Consumers are extremely affluent and large disposable incomes allow regular indulgence of expensive tastes like cheese. Swedish agriculture has traditionally focussed and continues to focus strongly on dairying to complement cropping enterprises.

It is important to understand how food culture, whilst shaped in some part by agriculture, is also able to strongly influence the nature of agricultural systems. The growing taste and demand for wine in Western Australia and the world in the 1990s resulted in the conversion of a large number of traditional beef and dairy areas across to grape and wine production. This presents problems for agriculture when prevailing tastes encourage agricultural enterprises not ‘friendly’ to the environmental parameters.

It is obvious in Australian food culture that very few consumers understand the significance of their food choices in determining land use in agriculture. Clearly this deficiency needs to be addressed in order for agricultural systems to develop that are more suited to the Australian landscape.

Clear attempts to achieve change in food cultures exist in the Baltic Sea region where huge nutrient loads from agriculture threaten the very habitability of this body of water by marine species. A project known as BERAS (Baltic Ecological Recycling Agriculture and Society) headed by Artur Gransted of the Biodynamic Research Institute in Sweden, has been initiated to try and achieve just this. Its basic aim is to promote more sustainable food supply systems and lifestyles in the Baltic region. Only in its early stages, the project will face some challenging issues. Particularly if it is found that ecological (organic) producers are found to contribute equally as damaging levels of nutrients to the catchment of the Baltic Sea. The general logistical demand of implementing a research program involving a number of different countries will be challenging.

In any case, the same opportunity exists here in Australia, where the environmental problems facing agriculture are numerous and their nature is extremely serious. Food from farms whose production has enhanced environmental parameters needs to be actively promoted amongst prevailing food cultures. This will then lead to economic opportunities in the agricultural sector significant enough to encourage more sustainable land use. Export opportunities in Europe will be created where food cultures are already developing in such a manner.

KRAV – Ecological Certification in Sweden

The KRAV system of organic certification in Sweden provides an excellent example of both the benefits of certification and also the complexities involved in implementing such a system of assurance. Widespread recognition of KRAV as the ecological or organic standard in Sweden exists amongst the majority of consumers. Processors and value adding enterprises are also firmly of the opinion that the logo helps to realise significant price premiums dependent on the nature of the product. One comment from a food manufacturer was that 'KRAV certified produce simply walks out the door'.

Whilst the majority of Swedish consumers could be seen to be more sensitive to the production environment of food products, they still fundamentally lack a broader understanding of the complexities involved in agricultural production. This is a problem that manifests itself all around the developed world and needs to be addressed if we as a society are to bias purchasing decisions in favour of more environmentally considerate production.

LEAF – Linking Environment And Farming

LEAF is an English charity which 'works to encourage farmers to take up more environmentally responsible farming practises or Integrated Farm Management (IFM). LEAF also promotes the benefits of IFM to consumers and raises awareness of the way many farmers are responding to current concerns.'

This innovative organisation is actively engaging in the process of developing food culture in the UK through implementation of extension campaigns. Demonstration farms are set up throughout the country to enable farmers, environmentalists, consumer groups and schools to learn first hand about the efforts of LEAF certified farms. Products containing the LEAF label of assurance can now be found in most major supermarkets.

The same opportunity exists in Australia to help try and bridge the ever widening gap between rural and urban cultures. It is of utmost importance that consumers possess a basic understanding of the problems created by farming systems so they understand the importance of their purchasing decisions.

ORGANIC AGRICULTURE – IS IT REALLY MORE SUSTAINABLE THAN CONVENTIONAL AGRICULTURE?

Many Claims Made!

‘There are people that wonder how organic production will feed the world. Today people are starving due to social and economic conditions – not because of a too small food production. The solution is found in political and economic change and not in agricultural methods. … Organic agriculture, as we know it today, is the most sustainable kind of agriculture. Nevertheless, also in organics, there are a lot of improvements to be made’ Gunnar Rundgren, CEO, Grolink.

‘Organic agriculture is an agricultural system that promotes environmentally, socially and economically sound production of food, fibre and timber etc. … Organic agriculture significantly reduces external inputs by avoiding the use of chemo-synthetic fertilizers, pesticides and pharmaceuticals. Instead it works with nature to increase both agricultural yields and disease resistance.’ International Federation of Organic Agriculture Movements (IFOAM).

Some Benefits Obvious, Others Very Dubious

No one can argue with the organic movement that pesticide usage is a negative part of economically sound agronomy with conventional food production systems. Agricultural production without the use of pesticides is probably the only true way to guarantee foods are free of chemical residues. Insecticides are broadly speaking very unselective in the insect species they have efficacy on. This results in the death of many beneficial insect species when they are applied. Their effects on the water cycle and other parts of the food chain including our own are also significant.

The organic movement fails to recognize the significant effect rising energy costs will have on the world’s food security as oil and gas reserves are eroded. In its mission to reduce chemical inputs, many organic agricultural and horticultural production systems have switched to techniques inherently increasingly reliant on fossil fuels. Cultivation is considered an acceptable means of achieving weed control and also increasing soil fertility. Yet in vast areas of the world, increased cultivation leads to far higher levels of soil erosion via wind and water. Forecasted climate change will only exacerbate these losses of a non renewable resource and vital substrate for life. What are we without our topsoil? Extreme weather after vigorous cultivation will lead to erosion in any soil type, in any country.

Nutrition in many broad acre organic cropping systems generally relies on leguminous plants, usually pasture species to build soil fertility for cereal crops. This may take two to three years with the assumption being that this nitrogen remains in the soil. In particular in Europe where high rainfall patterns prevail, it is hard to believe significant levels of nitrogen would not be leached. Some recent evidence in Sweden has been found to suggest organics is perhaps even more of a contributor to eutrophication problems as conventional systems.

Non-Pesticide versus Pesticide Production

A recent 4 year trial conducted by Landbo Centrum in central Zealand, Denmark made a comparison of a non-pesticide versus pesticide dependent cropping system. A number of interesting conclusions were drawn from this project. Inter-row tine harrowing as a means of weed control in the non-pesticide system resulted in only 'satisfactory' weed control. Obtaining a satisfactory level of control became increasingly problematic as seed banks and subsequent weed burdens increased over the duration of the trial, clearly threatening the long term sustainability of the system. On average for the four crops trialled, 25% of grain yield was lost in the non-pesticide trial. Levels of surplus nitrogen were far greater in the non-pesticide production systems and fuel consumption increased by 33%. If Denmark's 1.4 million hectares of equivalent cropping area converted to the non-pesticide system of production, the economy would suffer a loss of DKK 2.9 billion per year or around AU$700 million, a significant cost to any economy. The saying 'it is hard to be green when you are in the red' would certainly hold weight in this situation.

Genetic Modification will be the Key to Sustainable Cropping Systems

There is no doubting that genetic modification of crops will be essential to ensure food security in this world at some point in the future. Not only through modification for herbicide tolerance, which arguably translates to gains in sustainability, but for systems of production that will inherently require far less energy investment. Organic fertilizers are bulky and deliver far lower concentrations of nutrients being far more expensive than other fertilizer sources. Producing macronutrients such as nitrogen where they are needed must be the ultimate goal for all production systems, because transportation requires energy. Increased nitrogen levels will need to be produced by legumes and their associative nitrogen fixing bacterial species. Such bacteria have been the basis for life since the beginning of evolution and their real importance will begin to be comprehended as this millennium ages.

Plants will need to be able to cope with the changing nature of soil chemistry, eg acidification, salinisation, sodicity, aluminium toxicity. This is possible with transgenic technology. Is it sustainable for Sri Lanka to supply lime to agricultural soils that has been mined from their coastal reef ecosystems? It is more environmentally sound to alter plants to be able to cope with acidity or even biochemically remediate it. 70 million hectares of wasteland in India cannot continue to remain agriculturally and environmentally inert in the future with over one billion people to be fed and the number rising. Novel perennial plants are needed to drop water tables and allow yearly rainfall to then leach salt levels back below the growing zone of crops. Are we that presumptuous to think these plants can be created overnight? We have the cheapest energy now we will ever have, so let us begin to use it to produce the technology we will need to cope with higher production cost burdens.

Food for Thought

40% of the genes found in a potato plant are also found in a toad. Why do we as a society baulk at the notion of using foreign genes in food crops? What science tells us about genes is that they are transferable naturally amongst species if selection pressure is applied. Science also tells us that when DNA enters the digestive system of all animals, it is broken down into its various amino acid components. What science exists to even begin to make us suspicious that transgenic DNA could pose a danger to health?

It is the chemicals that DNA encodes for the production of which can lead to the presence of anti-nutritional factors and health risks, not the DNA itself. This means that the application of transgenic technology will have to be assessed on a case by case basis. There may very well be some bad applications for this technology. As a society, we can be precious and pursue ideology that appears to be going against science, or we can be judicious and prepare for the future, a future where food security will become a real issue particularly in developing countries, where large populations continue to grow larger.

IMPORTANCE OF GRAIN LEGUMES

Soybean Steaks and Soybean Sausages?

A visit to your local supermarket in most western European and Scandinavian countries allows you to find a whole range of plant and mushroom based meat substitutes for vegetarians, and dairy substitutes for those with intolerance to dairy products. Whilst expensive in relative terms to meat, these substitutes particularly those derived from legumes like soybeans will become increasingly important to the food culture of the world in the future. Prices do not reflect the true production costs of these food items and are more likely to be premium priced against meat because of their small vegan target market. For example, you will pay 38,90 Kronor in Sweden for 300g of soybean sausages. Assuming 5SEK=AU$1, this equates to around $24/kg, well above normal prices for sausages. Similarly for soybean ice cream, 15,50 Swedish Kronor (AU$4.10/kg) would be paid for a 750ml tub. In the United States, meat alternatives such as turkey and hamburger that are predominantly soy, have grown into a US$500 million annual market. Many burgers now contain two 'almost' beef patties and in fact unless stated as 100% beef, burger patties can contain up to 30% soy protein in North America.

Figure1. 100% soy sausages (absolutely no meat) and 100% soy icecream (absolutely no milk) from a supermarket in Sweden.

Rising energy costs over time affecting the price of artificial nitrogenous fertilizers, refrigeration and processing costs, particularly with milk, will place increasing pressure on the cost of meat and dairy products. Legumes such as soybean are currently the cheapest sources of protein in the world of food and this will become even more the case with their production costs virtually independent of nitrogenous fertilizers and cold storage requirements until after the point of manufacture. Broader scale adoption of transgenic technology in legume crops is likely to, in fact, provide down side price risk to these sources of dietary protein.

Dairy Substitutes

The soybean is already a significant competitor as a substitute to milk and dairy products. Soymilk sales in the US grew from US$100 million in 1995 to US$500 million in 2000. Predictions in the US alone for the next 3-5 years suggest soymilk sales could exceed US$1 billion. Soy bean milk and yoghurt has a differing taste to similar dairy products which could be seen to discourage substitution. Soybean ice cream on the other hand is almost identical in taste and texture to ice cream made using dairy components. Substitution in this area is most likely discouraged by a lack of consumer awareness as to taste and also past experiences with trying soybean milk or yoghurt. What is important here is that soy substitutes are increasingly improving in taste.

The problem the dairy industry has is the huge energy cost it bears in the processing of a highly perishable commodity into protein and milk fat components that can be cheaply stored, not to mention the reliance to a large extent on nitrogenous fertilizers to fuel pasture growth or cereal feed grain production. Nutritionally, dairy products are less desirable than the benefits offered by soymilk substitutes. Soybeans on the other hand are easily stored in ambient temperatures, quite often without risk of insect attack. Milk production in Australia is also highly dependent on water for pasture irrigation where grain is not the main food source, which may place pressure on returns into the future. This would be more as a result of governmental regulation on practises such as flood irrigation.

Australia Needs a Profitable Legume – Enter the LUPIN

The current problem for the Australian grains industry is that there is no one legume that is as profitable as growing cereals or canola. Lupins are the most widely grown legume due to large areas of poorer, acidic soil types throughout the southern grain belts. Most gross margins are exceedingly poor and in some cases even negative because of low yields and weak commodity values stemming from end uses predominantly in the feed sector. The area planted to lupins in Australia has steadily been declining also due to increased production risks in low rainfall areas. The most immediate priority for the lupin industry must surely be to target human consumption markets where soybeans are used.

Lupin prices only appear to spike in extreme seasons when drought impacts significantly on nation wide yields. It is interesting to consider how lupin prices seem to be a function of the size of the Australian crop, which has ranged from nearly 2 million tonnes down to 300,000 and has seen prices range from $150-300/tonne. The world soybean crop is forecast to hit 220 million tonnes for the current 2003-04 season. You could be sure that if world production figures for soybean were out by 1.7 million tonnes, it would not translate to a huge difference in grower returns. It clearly highlights the need for our lupin industry to target high valued niche markets. It is crazy to think that the lupin industry should continue to be satisfied with low valued feed markets where competition is fierce.

Priorities for Lupin Breeders

The great irony is that the world soybean crop, which has around double the world economic value of lupins on a per tonne basis is approximately 65% genetically modified. The case against genetic modification of lupins is fickle and laughable. The lupin industry suffers economic damage every year from the *Heliothis* caterpillar yet multi-gene resistance is available against this pest, such as in the Australian cotton industry with the Bollgard® variety.

Nutritionally, soy has big advantages over lupins, which contribute to its price premium. Lupin seed is lower in oil than soybean having 6-9% as opposed to 18%. It would be highly desirable for this percentage to be increased in lupins to open up new marketing possibilities in the future. The pearl lupin (*Lupinus mutabilis*) has a seed oil percentage that is similar to soy yet agronomically performs poorly when compared to the narrow leaf lupin (*Lupinus angustifolius*). The most immediate way to increase oil levels in narrow leaf lupins may be through interspecific hybridisation with the pearl lupin. It must be highlighted that it is the oil component of the soy bean which currently contributes greatly to the value of that grain.

The newest 'bad fats' known as trans fatty acids are produced when oils such as soy oil are hydrogenated, an industrial process which makes the oil more stable and able to be used at high temperatures for frying and baking. Legislation is enacted which will force food manufacturers in the US to identify the levels of trans fats in their product by the year 2006. The majority of big food processors are not waiting and are moving to oils that do not produce trans fats now, fearing litigation from people exhibiting induced health problems. Plant breeders at the USDA are working towards a genetically modified bean that has nutritionally improved oil characteristics. Modified soy will produce an oil that is below 7% in saturated fats, has half the levels of linolenic fatty acids of around 3.5% (which will also increase flavour), and has an increased oleic content from 20% to 60%. A great deal can be learnt from the direction of the soybean industry in the US for this legume will continue to become an increasingly important primary source of human nutrition.

95% of the protein from US soybeans still goes into the livestock feed market. Lupin protein is inherently low in sulphur containing amino acids such as methionine, cysteine and lysine, whereas soybean protein has an amino acid composition similar to that of meat. Biotechnology has already been used in this area of protein composition however bureaucracy halts the commercial adoption of nutritionally improved lupins. Plant breeders using the technology have enabled expression of a high methionine protein from sunflower in lupin seeds. Processors in the US are making good progress in increasing the amount of soy protein going into the human food chain. This is where even more value will be generated in this miraculous bean.

Lupins have around 25% fibre coming from the thick seed coat. This compares to 15% fibre with soy bean. This percentage must be reduced to lower levels and add value to the grain. It may indeed make the grain more susceptible to caterpillar and weevil pests, so pest resistance, preferably multigene, may also need to be added to the future lupin.

Other Examples of Niche Markets for Lupins

The soy sauce industry in Japan is a big consumer of soybeans and may represent one such opportunity. Each Japanese consumer will use around 8.5L of soy sauce a year. It has been shown that lupins can be used to make a similar product called shoyu. It would take around 330,000 tonnes of lupins to produce the soy sauce necessary for Japan's yearly requirements and Australia's total crop in 2002-2003 would not have been enough to supply this single market.

Leguminous Oilseeds – Market Opportunities

Biodiesel and products derived from vegetable oils will prove to be potentially lucrative markets in the future. A great many countries around the world are focussing their efforts on developing biodiesel in particular from canola oil, a crop with a large requirement for nitrogen usually coming from artificial sources. An exception to this is the United States where soybeans are being utilised. This is important, as net energy gains from leguminous oilseeds are far higher than from other oilseeds. Soy biodiesel blends can be found in most major towns throughout the mid west of the US.

Figure 2. Soy biodiesel blends commonly found throughout mid western towns in the United States. This service station was in Great Bend, Kansas.

Transgenic application in this area is occurring in the US particularly in introducing novel oils for high value industrial purposes. Funding into the development of such crop improvements comes from the Soybean Checkoff Fund which is a pool of acquired levies from American soy producers and is operated by the United Soybean Board. Similar crop improvement work has been done by CSIRO with cottonseed in taking low value oil and turning it into a high valued one. Genetic manipulation of the oil component of lupins would certainly be possible in this area, particularly since industrial uses will be independent of current consumer concerns. This once again highlights the need for our lupin breeders to increase oil levels, even if it requires the use of transgenics.

Targeting the Dairy Substitute Market

The market for dairy substitutes using soybeans has been growing rapidly around the world. It also presents potential for the lupin market even as a substitute for soy beans. It is surprising that this is not already occurring given the large price differential between lupins and soybeans. In fact the economics of soybean production in some areas of the world like the Mato Grosso in Brazil make it the number one choice of crop. This is a vast difference to the economics of growing lupins in Australia making it the last choice of crop by the majority of Australia farmers.

The huge growth in the economics of the soybean, have translated to significant increases in land values which give a true reflection of the earning potential of growing soybeans. This situation is unique in the world, yet could be possible in Australia with lupins if significantly higher valued markets were realised and breeding programs were able to increase the overall agronomic characteristics of the crop.

Back to Education and Food Culture

Whilst the importance of education and food culture has been discussed previously, it is time to now emphasise how necessary it is for lupins to become part of a new Australian diet and to be embraced as a way to better the state of the environment. You need only look at food culture in the United States where there would be almost no manufactured foods not containing soybean components, be it soy protein, soy oil, lecithin etc. This then fuels domestic strength for the grain and is a significant reason for the relative cheapness of American manufactured foods in world terms. Compare this to Europe where dairy and egg components are widely used where soybean components could be, manufactured food is significantly more expensive.

From a marketing perspective the sale of lupin protein to foreign markets is not helped by the current prevailing food culture in Australia. After all, it is harder to sell something that you do not eat yourself.

AQUACULTURE – OPPORTUNITIES FOR AGRICULTURE

Depleted Wild World Fish Stocks Fuelling the Growth of Aquaculture

It is important to understand the huge resource drain exerted on marine ecosystems when wild fishing occurs. Commonly preferred fish species are generally all predatory in nature and include cod, tuna, halibut and salmon. The production of 1kg of cod in the wild, a once commonly fished species, would have required ingestion of 10kg of whiting. This amount of whiting would have taken 100kg of copepods, the key link between fish and phytoplankton, which in turn would have demanded 1,000kg of phytoplankton.

Irresponsible overfishing of Atlantic cod forced the Canadian government in 1992 to impose a moratorium on cod fishing. Failure of this fishery to recover in the ensuing years forced Canada to place this fish on the endangered species list (Guterl, F., 2003). A fact that lies in direct contrast to the perceivably limitless resource this seemed to be 50 years ago. It has been estimated that world fish landings have been declining by around 700,000 metric tonnes a year since the early 1980s (Pauly, D. & Watson, R., 2003).

Such pressure on the world's wild fisheries has led to a vast proliferation in aquacultural production systems around the world. On the surface this would appear to be a simple solution to a worldwide problem but as with other food production systems, significant challenges exist.

Atlantic Salmon – The Chicken of the Sea

Commercial aquacultural production of Atlantic salmon began in Norway in the late 1960s. Since then the industry has grown to a US$2 billion dollar industry with around 1.2 million tonnes of fish produced. Production has spread to the UK, Canada, the United States and Chile. It has put the once expensive fish within the budget of the average everyday shopper in the affluent world (Montaigne, F., 2003).

Salmon is rich in omega-3 fatty acids, which is great for the dietary requirements of mankind, but the cost of this is immense to marine environments. The production of one pound of farmed fish requires around 3 to 4 pounds of fish rendered into feed pellets. Fish such as mackerel, anchovies and pilchards are harvested from the world's fisheries to inefficiently satisfy the hungry omega-3 fatty acid dietary requirements of farmed salmon.

Figure 3. The salmon industry represents a big opportunity for agriculture.

Omega-3 Fatty Acids and the Grains Industry

Clearly the biotechnologists of the world recognise the huge potential grain legumes have in being able to deliver cheap protein as well as the essential omega-3 fatty acids to farmed fish. In the process, the need to plunder the stocks of wild forage fish species is removed. In fact, the potential to greatly reduce the cost of feed in these systems exists through this very biotechnological advance. China is the world's largest importer of soybean (4.58 million tonnes from the US in 2002-03) with most of that (3.82 million tonnes) being used to feed its growing aquaculture industry. This is currently combined with fish meal to obtain the essential omega 3 oils.

Work currently underway at Australia's CSIRO provides anti GM activists with an attitudinal dilemma in the face of dwindling world fish stocks. Australia's CSIRO already has transgenic cotton varieties which yield omega-3 rich cottonseed. A manipulation made possible through the transplantation of omega 3 encoding genes from phytoplankton into the cotton genome.

Lupins also being an oilseed (leguminous) have the ability to carry enhanced omega 3 producing genes. The lupin would then become transgenic yet could easily be marketed to China's undiscerning aquacultural industry, obvious by its current reliance on US soybeans which are 80% Roundup Ready.

PERENNIAL GRAINS

Agrotriticum – The First Perennial Wheat

Collaboration between Russia and the United States in the mid 1970s resulted in the breeding of a perennial wheat cultivar known as Agrotriticum W-21. This unique grain was bred by crossing perennial Russian bred *Triticum vulgare* cultivars, with a perennial range grass native to the USA (*Agropyron elongatum*). Yielding lower than annual cultivars and in a world of cheap oil, this breeding program fell by the wayside.

Figure 4. Dr Jerry Glover showing the extensive root system of a perennial wheatgrass grown at the Land Institute in Salina, Kansas.

Future Cropping Systems

Today researchers in the North America are leading the way towards developing perennial grain crops. Perennial grain crops have a number of advantages over annuals and have the potential to achieve major cost savings to production in all grain growing regions around the world. The first and obvious cost saving would come from an establishment cost being averaged over the life of the perennial crop which may be from 3 to 5 years. With dedicated breeding the persistence of such a wheat or any other grain may be able to be increased even more. This will effectively increase the area able to be farmed per unit of machinery having obvious savings benefits to the cost structure of grain production. The longer term cost risk of running and owning machinery is going to increase before it decreases, also highlighting the importance of avoiding overinvestment.

Seed costs are also significant to all grain businesses particularly as seeding rates have tended to increase in the last 5 years. Once again there is potential to spread the cost of seed over the life of the crop.

In Australia, the potential to better manage rising water tables will be possible through the use of these crops. It is far more cost effective to 'drain' the land using income generating crops that produce biomass or grain as opposed to physically attempting to drop water tables through deep drainage, particularly in what weather forecasters predict to be an imminent long term drying trend. The usage efficiency of leachable nutrients such as nitrogen, sulphur and potassium is greatly increased as deeper, more robust root systems are able to tap into nutrient pools at depth and have access to fertilizers after leaching rainfall events. Recharge capacity of summer rainfall events is greatly reduced and would allow for grazing opportunities where livestock is a part of the enterprise mix.

The opportunity for intercropping with leguminous species such as subterranean clover that do nothing more than supply nitrogen is a realistic option. This allows growers to utilise the nitrogen fixing capacity of rhizobium within a cereal production system. The obvious consideration here is water allocation between the grain producer and the nitrogen fixer. Agronomic implications are also complicated within such a cropping system, but nevertheless still manageable.

More robust root systems strengthen a plants ability to deal with root diseases that normally restrict year on year profitability of wheat on wheat rotations. This is where the economics of production needs to be analysed over the life of the perennial as opposed to a rotation of annual crops, some of which, such as lupins, that serve to achieve long term agronomic rather than the short term economic goals of the system.

Perennial Cereal Rye

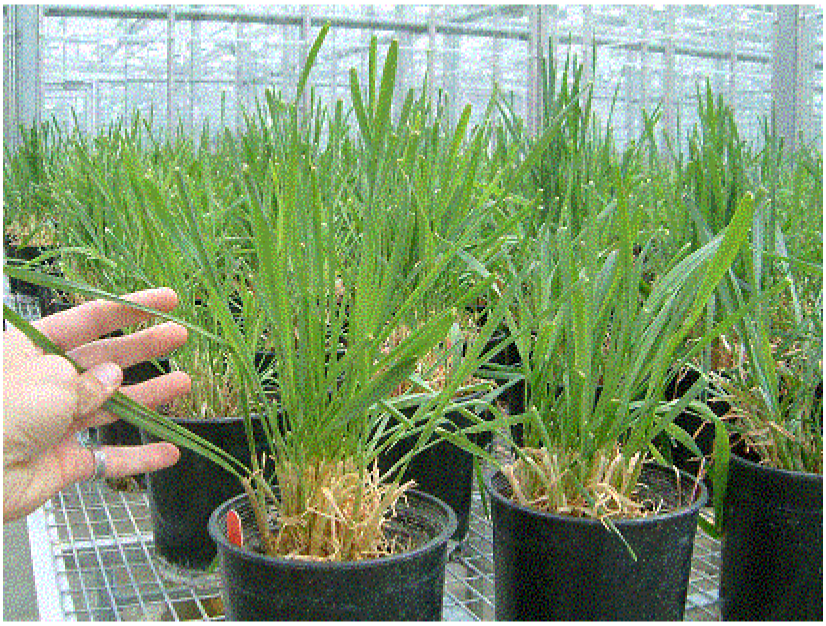

Figure 5. 5 days growth after simulated hay silage cut in perennial cereal rye.

A cultivar of rye which is perennial is being developed at the Lethbridge Agricultural Research Institute in southern Alberta, Canada. The variety (ACE-1) will be available in the coming years, and is first likely to be used in the fodder industry given its prolific ability to generate new growth after being cut. The grain is smaller than annual rye grain, however it will only be improved in time for what may become a significant grain crop. There are issues relating to its ability to self fertilize and so grain yields are not tremendously exciting at this stage of the breeding program.

Regrowth in an ideal glasshouse microenvironment after cutting for hay silage has been observed to be as much as a foot in 5 days. The hay industry could certainly benefit from being able to take more than one cut of a fodder crop in a given year if moisture conditions were favourable.

The other benefit of this crop is the allelopathic capacity of the plant. Allelochemicals are produced and released by the root system of the perennial rye into the soil solution. These inhibit the growth of competing weeds and may even serve to prevent germination of some species. Work is currently occurring in the EU looking at the potential to exploit this natural plant trait to reduce the need for herbicide use. There is no need to emphasise the potential for cost savings in this area if crops effectively produced their own bioherbicides.

Perennial Wheat

Figure 6. Doug Lammer, a wheat breeder from Washington State University, and one of his advanced lines of perennial wheat.

Researchers such as Steve Jones and Doug Lammer at Washington State University are busily selecting for stable perennial wheat lines. These are essentially produced by crossing normal wheat cultivars (*Triticum aestivum*), with a perennial native grass called *Agropyron ponicum*. Advanced cultivars are being evaluated in a glasshouse environment and the sole breeding goal at this early stage is to breed a perennial line of wheat that is stable and retains this trait in the field. In other words, the wheat must be able to persist from year to year. Observations indicate that a plant that is able to keep its leaves green is more likely to survive dormant periods. This is likely because sugars are needed to fuel survival over this period.

Other agronomically important traits can then be easily transferred to 'stable' perennial cultivars once they are developed. The main challenge for a perennial wheat cultivar will lie in the area of disease resistance. Perennial wheat will be an ideal host for rust diseases in particular and would provide a green bridge over the normally hostless summer months in Australia. Biotechnology will almost certainly be needed to grant quick, multi gene resistance to leaf diseases; ensuring pathogens have little chance of breaking down varietal resistance to infection.

Similarly to perennial cereal rye, it may be possible for grazing to occur where favourable seasonal conditions prevail.

Perennial Chickpeas

Experience with perennial grain crops suggests that yields are significantly lower than with annuals. It may be therefore more sensible to focus on producing perennial cultivars of high valued crops where yield then becomes less important to the gross margin of the enterprise. Claire Coyne from Washington State University is actively working on domesticating a line of perennial chickpea (*Cicer oxyodor*) originally collected from Turkey. Chickpeas are a highly valued leguminous crop important as a staple protein source to a number of cultures throughout the world. Perenniality in this legume could offer some significant agronomic advantages over its domesticated annual cousin.

Illinois Bundleflower

A native legume of the Great Plains in the United States, this crop is in the early stages of a selection and breeding program at the University of Minnesota in Minneapolis to domesticate it. The seed can be conventionally harvested and has been recorded as yielding over a tonne indicating there is definitely potential in developing this crop.

The great concern in the US is that the soybean industry with its current irrigation strategy will not be able to sustain production of these beans in drier areas in the future. Some producers are pulling water from ancient aquifers as deep as 100m. The Ogillala aquifer on the eastern side of the American Rocky Mountains was dropped by around 4m last year alone. This leguminous crop may well assume more of a role when water becomes limiting for irrigation in the Western Great Plains.

What are the Challenges for Perennial Grain Crops?

The most obvious problem with perennial grain crops is the likelihood of providing a 'green bridge' for a number of serious fungal diseases such as rusts in wheat, mildews in barley, and ascochyta in chickpeas to name a few. They could also offer year round hosts for insect pests also and localise breeding grounds. This is where the use of biotechnology will be essential to providing multigene resistance to diseases to ensure varieties maintain their resilience to disease in the face of year round infection pressures.

The other major concern with perennial grain crops is their inability to yield as much as annual varieties. Carbohydrates that are produced by the plant and normally end up in the grain in annuals are needed by the perennial root system to survive dormant periods, i.e. winter in the Northern Hemisphere and summer in the Southern Hemisphere. This will likely be addressed in time as perennial plants should actually have the ability to produce more carbohydrates in a year being able to grow all year.

The use of glyphosate would most likely not be possible within a perennial cropping system as a broadly applied treatment. Glyphosate or glufosinate conferred resistance via genetic modification would remove this problem and no doubt generate legitimate concerns within the farming community as to subsequent manageability. It is important to remember here that nothing is resistant to the plough.

Just how dry an environment can be before these varieties cannot persist will be an important question for the Australian grains industry. The need to know this is definitely there given the risk associated with sowing crops in more marginal areas.

ENHANCING NATURAL PLANT DEFENCES AND COMPETITIVENESS THROUGH BIOTECHNOLOGY

Allelopathy - Exploiting Natural Plant Defence Mechanisms

There has long been a knowledge of plant species possessing the ability to produce biological chemicals, or allelochemicals which when released by roots into the soil solution, effectively inhibit the growth and/or germination of competing plants. This is known as allelopathy.

Such chemicals are common to most cereal crop species. A project co-ordinated from Slagelse in Denmark, known as Fateallchem, seeks to analyse their environmental fate and establish precautionary protocols for transgenic manipulation to enhance competitive ability of wheat and barley. The project is headed by Inge Fomsgard and seeks to understand the environmental fate of allelochemicals particularly in Denmark where the nation's water supply is derived from below the soil.

Allelochemicals in Cereal Crops

Rye exhibits the greatest allelopathic effect on successive crops as its residues break down and release chemicals known as hydroxamic acids (HOA). The HOAs are toxic to many weed species but appear to have more effect on broadleaf's. The same situation is the case for wheat and highlights an area of opportunity for plant breeders to exploit this natural competitive characteristic. HOAs are absent in cultivated barley, however some wild species do produce these chemicals. This enables breeders access to the genes necessary for a HOA synthesising cultivated barley.

Dealing with the Potential for Fungal Attack

Oat plants have the ability to produce saponins which are natural soaps, possessing anti-bacterial and anti-fungal activity. The avenacin type of saponin found in oats has been suggested as the reason why it is resistant to take-all. There exists the opportunity here for introducing the ability for avenacin synthesis to other commercially important crops such as wheat. Take-all is a common problem in high rainfall areas where successive wheat crops are grown.

Opportunities to Reduce Labour and Input Costs

The transgenic application of Bacillus thuringienses (Bt) gene to many crops around the world is a great example of shifting the work load over to the crop itself. This gene is very effective at preventing damage from caterpillar pests. The cotton industry in Australia has embraced the benefit of utilising this gene and now has inserted a second gene (stacking) for insect resistance to decrease the eventual likelihood of resistance developing. Multi-gene resistance should be the goal of genetic modifications conferring resistance to pests and disease.

It is extremely desirable to increase the allelopathic capacity of cereal cultivars in Australia. For all commercial grain crops, there should be priority assigned to enhancing and arming new cultivars genetically. The potential theoretically exists to reduce the need for herbicides, with the plant itself becoming the producer and deliverer of a broad spectrum bioherbicide.

Whilst the obvious potential cost saving would come in the form of reducing or removing some of the input cost associated with herbicides, other benefits are also at hand. The opportunity cost of late or ill timed herbicide application is immense to industry. This is also the case with insect and disease management where late detection can easily mean the difference between a good and a bad crop. It has been estimated that between 20-40% of the world's food production is lost to pests and pathogens (Mathias, 2003). Savings in labour demands and machinery costs could also be realised if herbicide applications are reduced or eliminated. Environmentalists should be happy with a system contributing less herbicide in the environment.

WILD FOODS – INCREASING THE RESILIENCE OF AGRICULTURAL SYSTEMS

Opportunities for Australian Agriculture

Native plants as alternative crop species can provide Australian arable cropping systems with a wide range of benefits. Australian soils are old, weathered and generally very poor. Alternatively where they are not poor, rainfall is quite often deficient. Plants that yield fruits, nuts, timber, oils, pharmaceuticals and biomass, can be found in Australia, and a great deal of them in the arid interior. Such native plants are hardy survivors and well adapted to the poor soil fertility and extreme weather conditions. These trees also had the ability to manage salty water tables which have risen throughout the southern grain growing belt and given rise to dry land salinity.

The challenge is to identify those species which have the best economic potential whilst dealing with the environmental problems inherent to the system of production today. Australia has a great number of nitrogen fixing species in the *Acacia* genus (wattles) which have potentially significant economic potential. This is important as they are the drivers of fertility within the system and this process occurs independent of inputs, especially given the fertility of soils is now generally higher than before land was cleared.

Certain species of wattle are already commercially important for timber and also seed production. *Acacia melanoxylon* (Blackwood) is a high value timber native to high rainfall areas in Tasmania. *Acacia victoreae* (Gundabluey) is the most common species with seed that is collected for the wild food industry. This tree grows in 250mm rainfall and above, is long lived for a wattle (10-15 years) and has impressive levels of salt tolerance. Whilst demand definitely exists for wattleseed in the food market, its widespread consumption is inhibited by the high cost of manual harvesting. Mechanisation of this process would allow economies of scale to be realised and the product could then be offered at a more reasonable price to consumers.

The other benefit of the *Acacia* genus is that they are host trees for two particular species from *the Santalum* genus. The sandalwood tree *(Santalum spicatum)* and the quandong *(Santalum acuminatum)* are commonly found all over Australia's arid interior. These trees parasitize the root system of neighbouring wattle trees and derive a large percentage of their nitrogen requirements from them. Both *Santalum* species yield nuts containing 60% oil and 18% protein, which is very important considering there are no artificial fertilizer inputs required for this result. The quandong also has flesh surrounding the nut which has an established though infant market. It is integral to the shaping of an Australian culinary culture more attuned to the Australian environment. The prospect of an economically significant dry land horticultural cropping system including the aforementioned arid species seems logical with low input requirements reducing the economic risks of production in potentially extreme seasons. Sandalwood also has the added benefit of having a timber highly prized for its aromatic oil, commonly used in the cosmetics industry.

The problem of declining rural populations could certainly have the biggest chance of reversal with the establishment of dry land horticultural enterprises in broadacre agricultural areas. Labour requirements would certainly be increased with intensification in individual farming operations.

The level of biodiversity within Australian agricultural systems is very low. This lack of diversity means that the resilience of crops to withstand attack by insect pests is also very low. Beneficial insects require habitat in which to form base populations. From these levels, they can quickly increase in number when pest infestations occur.

It is likely in the future as energy costs trend upwards that more and more agricultural land will be taken out of food production and used in biomass accumulation for energy generation. Biomass is an attractive proposition since it can be used as energy demand dictates. This will present our agricultural systems with some interesting opportunities. Energy production plants already exist in Western Australia that will be powered by biomass from *Eucalyptus* species (mallees). Some *Acacia* species might also be suitable for such end uses. Particularly those that are fast growing, coppice and/or have suckering capacity. One such species is the manna gum *(Acacia microbotrya)*, a native to the Wheatbelt of Western Australia.

The Wild Berry Industry of Sweden

The Swedish wild food model is unique in that all commercial supplies come from wild harvest. Sweden is also unique in that it is an extremely affluent country having such a sustainable cultural attachment to this natural resource. Around 20,000 tonnes of lingonberries are harvested from the wild each year with this being just a small percentage of the total probable production in Sweden's forestry resource. Cultivation of any of the indigenous species is rare owing to the huge natural resource that already exists.

Harvesting techniques for these wild berries is not mechanised nor is it likely to be in the future. Without access to cheap labour from eastern European countries such as Poland, the associated labour cost of harvesting would make these berries far too expensive for the average consumer.

Utilisation of wild berries and other fruit species is firmly entrenched within Swedish food culture. The evolution of Australian food culture needs to be encouraged in a similar direction in order to facilitate widespread agricultural adoption of wild food crops. A unique food culture can then become an exportable commodity and many successful examples of this exist, eg Italian and Greek. This also serves to enhance the cultural experience tourists gain when they visit from overseas.

Wild Blueberries in Atlantic Canada

The wild blueberry industry of Atlantic Canada is an excellent example of the successful commercialisation of a wild food plant. Dr Dave Percival from the Nova Scotia Agricultural College was able to provide me with an excellent understanding of the issues facing this emerging industry. The fruit is harvested from native forest areas altered agronomically to favour increased berry production by removal of pine trees and application of basic agronomy principles. The marketing strategy for the fruit is a model to be followed for all wild food species. Although benefiting immensely from having nutraceutical qualities being the world's highest source of antioxidants, the wild blueberry has a more intense flavour which has not been diluted by irrigation and excessive artificial fertilization. This is a common characteristic of all wild foods including game meats – enhanced flavour, colour and nutritional benefits.

Input costs for this production system once the blueberries are established are very low owing to the blueberry's adaptation to the maritime environment. Soils are very similar to most areas of Australia being very acidic, highly phosphorus retentive and high in iron and toxic aluminium. These are soil conditions that normally require high phosphatic fertilizer rates and remediation via application of lime. The blueberry is similar to a great many arid Australian native plants in its ability to produce is such poor soil health.

The most important development in this industry was the mechanisation of the harvesting process, which slashed production costs. Producers would not have been able to survive without this development. This will be an essential key for wild food producers in Australia if increased demand is to be created.

The wild blueberry industry is coordinated cooperatively as an organisation called the Wild Blueberry Association of North America (WBANA). This federation of growers and processors commissioned a public relations campaign that aimed to achieve a number of marketing goals:

1. Creating and enhancing the image of wild blueberries over conventionally produced blueberries. This fruit today has the enviable reputation as being the number one antioxidant fruit in the world. Wild blueberries possess inherently more antioxidants than conventionally farmed blueberries.
2. Creating and maintaining wild blueberry demand. Research was commissioned and conducted by independent research scientists to further expand on existing knowledge of the phytochemicals contained within the wild blueberry. This allowed industry to catch the wave of interest in nutraceutical foods that came in the late 1990s.
3. Creating a premium perception of wild production. A memorable brand identity was created using a set of product differentiators referred to as “The Wild Advantage”. This was to educate those in the food processing industry as to why they should use wild over conventional.

The use of the media played a pivotal role in achieving all of these goals, although a number of other information and marketing techniques also helped create demand for wild blueberries:

1. Media relations, special events and promotions were selected to achieve marketing goals. This involved identifying appropriate food writers and producers of trade and consumer publications, radio and television programs across North America.
2. Major trade shows were attended facilitating information extension regarding superior nutritional characteristics, processing techniques, and availability.

3. Harvest festivals were used as a focus to encourage media interest and sow cultural seeds for the future of the industry. The festivals offered tours of orchards showing harvesting techniques, processing plants and cooking demonstrations.

Interestingly the environmental merits of wild blueberry production are not central to the marketing plan, probably as fields are established by effectively clearing remnant vegetation and farmed in a conventional manner. Nevertheless, the marketing plan used by WBANA is an excellent example of effective consumer education and the associated product demand that was generated.

For the Australian wild food industry, the achievable environmental gains from production would clearly be a marketable attribute particularly where these benefits could be quantified. The three aforementioned crops of Acacia, Sandalwood and Quandong have strong environmental and potentially economic benefits over broad acre grain crops.

Wild Foods of the Canadian Prairies

A number of wild food crops have been evaluated in Saskatchewan, the heart of the Canadian Prairies. Of these, the Saskatoon (*Amelanchiar alnifolia*) and Chokecherry (*Prunus virginiana*) appear to have the most potential and already commercial groves of saskatoons are producing significant quantities of fruit. As with the wild blueberry, mechanisation of the harvest process for saskatoons has enabled cost effective production of this berry.

Similarly to other wild food crops, inputs costs after establishment are low owing to adaptation to soil and weather conditions. Irrigation is commonly supplied, however dry land production is possible where planting densities are significantly lower and moisture conservation is encouraged through effective weed control. This technique is common to dry land olive production in the Mediterranean where tree spacings may be as large as ten by ten metres.

The greatest environmental problem created through annual grain production in the Prairies is soil erosion. Perennial tree crops such as the Saskatoon and Chokecherry enable producers to manage this problem with their robust, suckering root systems whilst providing economic incentive in berry production.

CONCLUSION

The future of the Australian grains industry is yet to be written. We have the benefit of both hindsight and foresight in determining where we collectively take this industry. To think we can continue to produce forever the way we currently do would most certainly be a dangerous attitude to have. On the other hand to be open to future developments no matter how unfamiliar they may seem will be essential.

Australia's importance in the supply of food in the world will continue to increase as populations increase. Our current reliance to a great extent on some markets in the Middle East could be seen to be very risky with bulk commodities like wheat particularly in light of the current global situation. On the other hand protein and oil are far more valuable commodities that will be more easily marketed in 'safer', premium markets.

The three most immediate areas where sustainable and profitable gains can be realised in the Australian grains industry in my view are as follows. Firstly, a lupin crop as profitable and agronomically as desirable as a cereal or canola crop must be developed. It will not be found, it will need to be bred. And secondly, profitable perennial grain crops must be also bred and developed in conjunction with other breeding programs running around the world. Thirdly and finally, commercialisation of the sandalwood nut must occur to secure oil and protein production potential in a future of increasing energy prices.

RECOMMENDATIONS

New lupin cultivars must be bred that can compete with and join in the economic success enjoyed by the soybean. This means the following:

1. First and foremost oil must constitute around 18%, or higher if possible, of the seed weight. This will most likely involve making interspecific crosses between *Lupinus angustifolius* and *Lupinus mutabilis*.
2. Fibre levels must be reduced from 25% down to 15% or lower to in effect concentrate the levels of protein and oil contained in the seed.
3. The oil composition of the new lupin will need to be high in oleic fatty acids and low in linolenic fatty acids.
4. Sulphur based amino acids need to be included in the seed protein.
5. Transgenic gains should be embraced where the whole process can be accelerated.

Perennial grain breeding needs to become a part of mainstream breeding programs. Where possible work should be done in conjunction with international research efforts to avoid duplication of the costs associated with such breeding programs. A leguminous perennial oilseed, such as a perennial grain lupin, might be the ultimate crop to aim for in the longer term. Perennial cereals though should be targeted a well. Background genetics from wild perennial Australian genera should be utilised where possible to obtain physiological traits adapted to this harsh climate. Australia is home to many perennial grasses and wild relatives of mung beans and soybeans.

Sandalwood *(Santalum spicatum)* will need to become an important industry to southern grain growing areas of Australia. Mechanisation of nut harvesting and soybean style processing for oil extraction leaving protein meal are essential for t

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