Industrial Hemp

and its Potential for New Zealand

A Report for the 1999 Kellogg Rural Leadership Course

November 1999

Charles N Merfield
charles@merfield.com

1. Contents

1.1 List of Contents

1.2 List of Figures

1.3 List of Tables

2. Executive Summary

- Cultivation and use of hemp predates written history. It was a critical crop for a number of civilisations including Europe.
- Industrial hemp is a herbaceous annual with phenomenal rates of growth. It is relatively easy to grow, though it requires good land, high levels of nutrients and water. It has few pest or disease problems apart from birds. Under most conditions it will out-compete and smother weeds.
- It produces a very high quality oil, high quality fibre, and has a considerable number of potential end uses.
- The levels of industrial hemp production and consumption have been continually falling throughout the world over the last two hundred years due to competition from other products and prohibition.
- While Industrial hemp is the same species as marijuana (*Cannabis sativa*) it has no psychoactive properties and is of no value to the 'drug community'. It will not exacerbate marijuana use. On the contrary, it will harm marijuana production by cross fertilisation, destroying seed lines and reducing the psychoactive value of marijuana crops.
- Industrial hemp can only be grown in New Zealand under licence from the Ministry of Health. There is currently a moratorium on the consideration of licence applications.
- There are a small number of potential outlets for industrial hemp grown in New Zealand. Organic hempseed is the most clearly identified of these. The economics of hemp production appear to be moderate. There are a number of technical, and economic problems with quality fibre production. There is greater potential for lower grade fibres in terms of possible end uses.
- New Zealand along with the USA are one of the few remaining countries that do not allow production of, or are trialing, industrial hemp. Europe, Canada and Australia are all producing or investigating industrial hemp. This is putting New Zealand at a social and economic disadvantage.
- There are many overly enthusiastic and unfounded claims for industrial hemp. Such claims have been reiterated in material promoting industrial hemp produced in New Zealand.
- The potential for industrial hemp to become a weed is unknown.
- Industrial hemp offers the New Zealand agricultural and processing industries a possibly useful new product to trial.

3. Recommendations

- That the potential for industrial hemp to become a weed is established.
- That the moratorium on the consideration of granting industrial hemp licences should be immediately removed.
- That the Ministry of Agriculture take over from the Ministry of Health as a more appropriate Governmental Department to co-ordinate the re-introduction of industrial hemp.
- That the Industrial Hemp Working Party recommended by Dr Boyd be rapidly formed to establish the systems and licences required for industrial hemp production.
- That a government funded, thorough, economic and agronomic study of industrial hemps potential in New Zealand be completed.
- That trial / research crops in potential industrial hemp growing areas be planted to gain accurate economic and agronomic information.
- That farmers and communities that wish to grow industrial hemp are granted licences.

4. Introduction

This report is aimed at farmers, processors and the sections of government involved in the re-introduction of industrial hemp. It aims to provide, assuming no prior knowledge, background information on hemp and the issues surrounding it. It analyses the current political and legal situation; and estimates the potential economic, social and environmental costs and benefits for New Zealand, and makes recommendations based on that analysis. There are detailed briefings on the history, biology, agronomy, and end products of industrial hemp. These provide important technical information and support the analysis and recommendations of the report. These can be left unread if the reader's main focus is policy issues.

Industrial hemp (*Cannabis sativa* L.), one of the oldest crops plants know to humans, is undergoing a sudden and rapid return to popularity. It has been in decline since the first decades of the 19th century, due to competition from substitute crops grown in Asia and China, petrochemical derived substitutes, and its relationship with marijuana / hashish (used for their psychoactive properties). The publication of the book "Hemp & the marijuana conspiracy : the emperor wears no clothes" in the early eighties (Herer 1990) sparked the resurgence of industrial hemp. There is now a strong international grass root movement pushing for the reintroduction and expansion of industrial hemp and its associated products. The key issue restricting hemp's resurgence is its relationship with marijuana / hashish. Many European, all North American and most ex-European colonial countries, banned industrial hemp cultivation for the greater part of this century due to its relationship with marijuana / hashish. Most, with the exception of New Zealand and the USA, have now legalised the production of hemp or have granted research licences to study its potential. Secondary issues restricting its reintroduction are lack of suitable cultivars, agronomic information, processing facilities, markets, and continued competition from substitutes.

From hereon industrial hemp grown for non psychoactive use will simply be referred to as hemp. What is commonly referred to as marijuana, hashish, cannabis, weed etc. grown for its psychoactive properties will be collectively referred to as marijuana. When referring to both hemp and marijuana the taxonomic name *Cannabis sativa* (L.) (*C. sativa*) will be used.

5. History

Cultivation and use of hemp predates written history. Chinese writings from the Sung dynasty (about 500 AD) state that the emperor Shen Nung first taught the people of China to cultivate hemp and make cloth around 2,800 BC. The Spaniards brought hemp to the Western Hemisphere as early as 1545. It was introduced to the United States in 1645 by the Puritans in New England as a fibre source for household spinning and weaving.

Hemp was a very valuable crop for many centuries. It had a huge range of applications, clothing, ropes, paper, and food. Britain's sea power was based on adequate supplies of timber and hemp. Sailing ships required many tonnes of hemp for rope and sails. Wars were fought over its supply. Australia and New Zealand were considered ideal places by England to grow hemp to reduce its dependence on Russian hemp, and governments have forced or pressured farmers to grow hemp including the USA during the second world war (Ehrensing 1998).

The start of hemp's decline was due to increasing numbers of alternative, cheaper fibres, such as jute, from China and Asia, in the early 1800s. Technological breakthroughs in the late 1800s such as the cotton gin and the ability to make paper from trees created new products that were cheaper or more desirable than hemp (Ehrensing 1998). The rise of the petrochemical industries at the start of the 20th century brought further competition. The final nail in hemp's coffin came with the 1937 U.S. government's Marijuana Tax Act which placed all hemp production under control of U.S.

Treasury Department regulations. The act required the registration and licensing of all hemp growers with the federal government in an effort to restrict production of marijuana. Many other countries followed the USA lead and made hemp production and possession illegal. However in much of Asia, China, South America, Eastern Europe, and a few western European countries it remained legal.

The publication of the book "Hemp & the marijuana conspiracy : the emperor wears no clothes" in the early 1980's (Herer 1990) sparked the resurgence of industrial hemp. Since then there has been a steady progression of countries that had banned hemp changing their laws to legalise it again. The USA and New Zealand are among the last few countries in the English speaking world and Europe that still prohibit hemp. The area growing hemp has dramatically increased in those countries that have legalised it. For example Europe's production has grown from 2762ha to 22,000ha from 1989 to 1997.

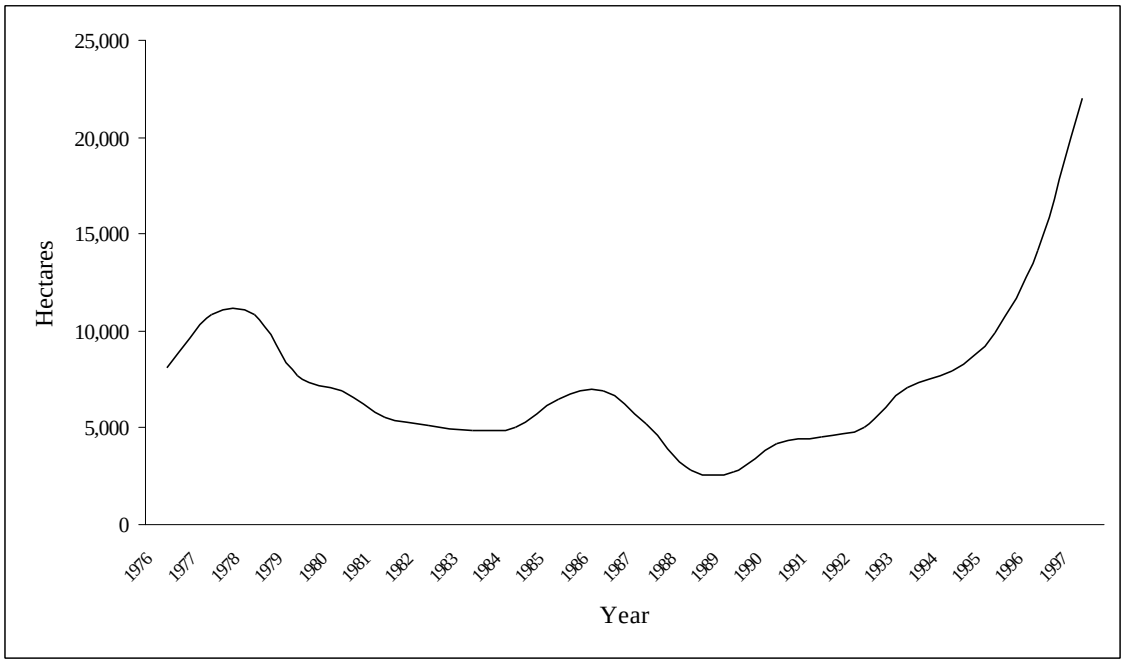

Figure 1. Area of hemp grown in Europe between 1976 and 1997 (Bócsa & Karus 1998)

6. Botany

6.1 Hemp vs. Marijuana

Hemp belongs to the family Cannabinaceae (genus *Cannabis* species *sativa*). Hemp is a race of *C. sativa* that has low levels of DELTA9-tetrahydrocannabinol (THC) the psychoactive constituent of marijuana and higher levels of cannabidiol (CBD). THC levels of less than 0.3% cannot produce any psychoactive effects. To produce psychoactive effects THC levels have to be in excess of 1% (Grotenhermen et al. 1998). Marijuana races have THC levels between 3% and 20%. Plants with between 0.3% and 1% have zero to a minimal psychoactive effect. Most countries that have legalised hemp insist that the plants grown have a THC level below 0.3%. A number of hemp advocates have suggested that the limit be raised to 1% as this level has no illicit appeal and would widen the number of cultivars that can be grown. Also the natural level of THC in hemp is 0.3-1% (as evidenced by wild hemp, that grows in places such as the Hunter Valley in Australia and in Kentucky, USA, left over from previous times when hemp was grown in these areas) (Thompson et al. 1998). Low THC cultivars thus have to be actively bred to keep the THC low. A 1% THC limit

for hemp would reduce the need for this selection. It would also create a greater 'safety' margin. Growing conditions can affect THC levels so it is possible that cultivars with THC levels close to the 0.3% limit may exceed that, due to conditions during growing, thus changing the status of the crop from legal to illegal. Marijuana also has to be constantly selected to maintain its high THC levels and will revert to low levels without such intervention.

CBD, the other active constituent of *C. sativa*, reduces the psychoactive effects of THC, and produces unpleasant effects such as headaches when consumed. Therefore not only is the percentage of THC important in determining *C. sativa* value as a drug but also the CBD:THC ratio.

While most botanists now consider hemp and marijuana to be the same species, with a number of geographic races or ecological form groups, some hemp advocates have promoted suggestions that hemp and marijuana are different species in the hope such a classification would ease hemp's legalisation (Roulac & Hemptec 1997). Debate on whether hemp and marijuana are different species is of no practical consequence as all the suggested species, races and forms interbreed with each other easily and spontaneously (Bócsa & Karus 1998).

6.2 Botanical Description

Hemp is an herbaceous annual. It has a single woody stem which grows to between 1 to 5 meters high. At low densities spreading branches develop and stems range between 30 to 60 millimetres in diameter. At high densities stems are unbranched and without foliage except near the top and range from 6 to 20 millimetres in diameter. Leaves are palmately compound with 5 to 11 pointed, serrate leaflets (Dewey 1913).

Figure 2. Female (left) and male (right) hemp plants (Dewey, 1913).

Hemp has a well developed primary root with numerous branched secondary roots. In light, well-drained soils, primary hemp roots can reach depths of 2 to 2.5 meters, and secondary root branches may grow 60 to 80 centimetres below the soil surface (Bócsa & Karus 1998).

Hemp is naturally dioecious with separate male (staminate) and female (pistillate) plants which have different growth characteristics. Males tend to be taller and slender with few leaves surrounding the flowers, while females are shorter and stockier with many leaves at each terminal inflorescence, see Figure 2. Males senesce and die soon after their pollen is shed, while female plants remain alive until the seeds mature. Relatively stable monoecious varieties have been developed through breeding and selection. Unisexual F1 hybrids can be produced through a cross between monoecious males and dioecious females to produce 70-85% females, 10-15% monoecious and only 1-2% male (Bócsa & Karus 1998). Higher seed yields are obtained from these hybrids due to the predominance of females.

Hempseeds are smooth, nearly spherical, range in colour from light brown to dark grey and are often mottled. Seed size varies widely from 2.5 to 4 millimetres in diameter and 3 to 6 millimetres in length (Dewey, 1913). Thousand seed weights range from 2 to 70 grams.

Hemp stalks have a hollow wood core called hurds that provide the vertical strength of the stalk. Surrounding this is the vascular cambium (the growing tissue), an outer ring of cells consisting of bundles of phloem, and cortex, called bast fibres, which give the stem tensile strength. On the outside is the bark, (Figure 3).

Figure 3. Hemp stems showing bark, secondary bast fibres, and woody core.

There are two types of bast fibres. Primary bast fibres which extend nearly the entire length of the stalk and are coarser, and secondary bast fibres which are shorter, finer fibres that are found next to the wood core.

6.3 Growth Patterns

Hemp is a short day photoperiodic plant, i.e. decreasing day-lengths promote flowering (Bócsa & Karus 1998). Its growth can be divided into six stages (Figure 4)

1. Germination
2. Slow growth, which lasts from the appearance of the first pair of true leaves to the fifth set of leaves
3. Rapid growth, which lasts till the formation of flower buds
4. From bud formation to first flower opening
5. Flowering
6. Seed production

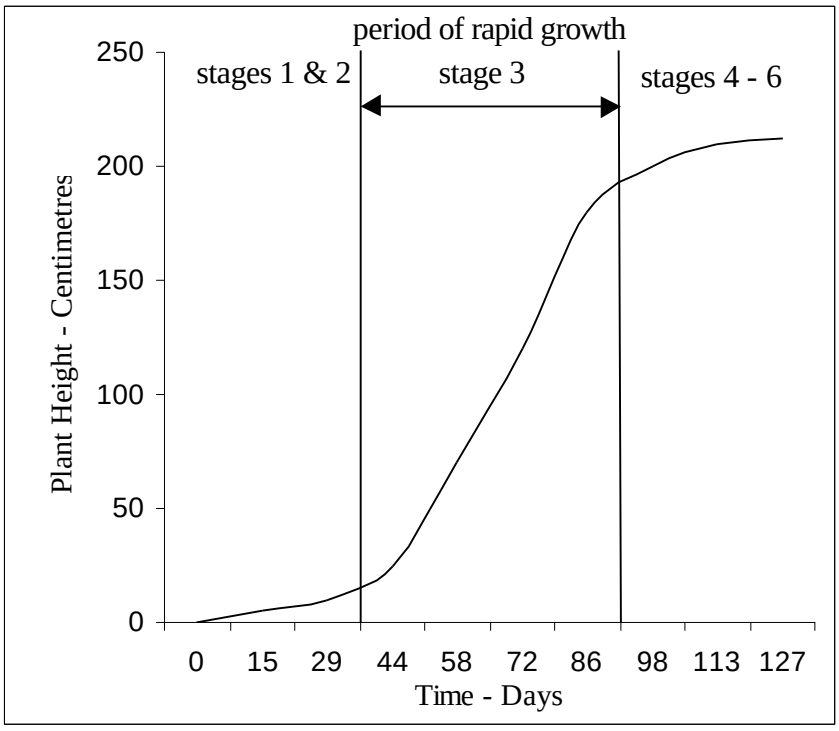

Figure 4. Growth cycle of hemp (Bócsa & Karus 1998)

Hemp is one of the fastest growing crop plants. In ideal conditions the tallest cultivars can grow up to 11cm a day. Growth rates of 2cm a day, during the rapid growth stage, are common.

6.4 Breeding

Both France and eastern block countries, which never banned hemp, have extensive breeding programs. France is mainly responsible for the production of the less than 0.3% THC cultivars. Scientists such Dr, Iván Bócsa and others have hundreds of hempseed lines held in places such as Russia and Hungary. They have been responsible for the production of monoecious and F1 hybrids as well as improvements in yield and quality. There is considerable variability in hemp and with large amounts of genetic material in China and Asia there is considerable potential for major improvements in desired crop characteristics.

7. Agronomy

7.1 Introduction

Hemp is a comparatively easy crop to grow. There is a general impression, fuelled by hemp advocates, that hemp will grow anywhere and has no pests or diseases. This is completely untrue. It has a few potentially economically important pests or diseases, even though there are over three hundred pest insects and about a hundred diseases found on hemp. Browsing mammals such as rabbits and deer are very partial to hemp, and birds are a major seed pest (McPartland 1996b). Hemp requires moderate to high fertiliser levels, particularly nitrogen, because of the huge biomass produced. Hemp does not thrive on poor soils. Previously, economically viable production, was confined to good quality soils. Hemp has a very high water requirement, but it is also sensitive to water-logging, especially during the first two growth stages (see page 8). Seed harvest uses standard combine harvesters. Harvesting for quality fibre is more difficult, while harvest of lower quality fibre and hurds uses standard cutting and baling equipment.

While hemp is a multi product plant producing both seeds and fibre it is not possible to produce high quality fibre and ripe seeds from the same plants.

As is the case with other photoperiodic crops, it is essential to use cultivars appropriate for the latitude, climate and soils of the farm. Attempting to grow unsuitable cultivars will most likely result in an economic loss.

7.2 Fibre vs. Seeds

While hemp can produce a number of high quality products it is impossible to produce high quality fibre and high quality seed from the same crop. To maximise fibre quality the plants must be harvested at the start of flowering as the bast fibres become excessively lignified past this time. Female plants have the highest levels of lignification. Stems from seed production are thus not suitable for fabric manufacture and are either incorporated back into the field or sold to produce products such as particle boards and cellulose.

7.3 Temperature

Mediterranean forms of hemp require 1,900-2000°Celsius growing degree days[1] (GDD) for fibre production and 2,700-3,000°C GDD for seed production. Northern European countries such as the UK, Denmark and Northern Germany do not have sufficient GDD to produce seed. Table 1 shows the GDD for a geographical spread of New Zealand locations. The 121 days figure equates to the approximate length of time required for fibre production while 151 days roughly approximates to the time required for seed production. Thus there are a range of climates that appear suitable for fibre, and a few for seed, production using Mediterranean cultivars. More northerly adapted cultivars may well perform better in marginal growing areas.

Table 1. Monthly total of growing degree days for a range of New Zealand weather stations, with totals at 120 days and 151 days. Adapted from (Anon 1999)

Weather Station	Nov	Dec	Jan	Feb	121 days	Mar	151 days
Napier Nelson Park	483	564	601	557	2,186	549	2,735
Kerikeri	477	549	595	568	2,170	564	2,734
Gisborne Aero	477	555	595	545	2,154	539	2,693
Hamilton, Ruakura	450	524	567	539	2,062	530	2,592
Palmerston North	432	508	555	525	2,002	515	2,517
Rotorua Aero	432	502	555	519	1,990	508	2,499
New Plymouth Aero	435	502	549	519	1,987	524	2,511
Nelson Aero	429	502	549	508	1,970	499	2,469
Christchurch Gardens	426	499	539	496	1,943	481	2,424
Taupo	414	490	539	505	1,930	484	2,414
Alexandra	423	499	530	493	1,928	468	2,396
Wellington, Kelburn	405	477	524	493	1,882	490	2,372
Queenstown	396	468	515	479	1,841	443	2,284
Westport Aero	405	468	502	479	1,837	487	2,324
Timaru Aero	381	453	490	444	1,752	434	2,186
Invercargill Aero	342	403	434	400	1,565	384	1,950

* GDD were calculated by multiplying monthly average temperatures by the number of days in each month.

[1] Growing degree days is a measure of the total heat required for a plant to reach a specified point in its growth cycle, normally the point of harvest. It is calculated as the sum of the average daily temperature during the growing season.

Seeds will germinate in eight to ten days at 8-10°C. The young plants can survive a -5°C frost up to the time they have four to five pairs of leaves. Temperature has a marked effect on growth. Plants grown at 19°C in controlled conditions achieve the same height as plants grown at 10°C in forty days compared to ninety days.

7.4 Light

As noted in section 6.3 hemp is a short day photoperiodic plant. Time to flowering is dependent on daylength and cultivar. Some cultivars will eventually flower regardless of daylength (even with 24 hours of light) while others will not flower unless there are short days. Figure 5 shows the number of days of growth till flowering for two different cultivars under different daylengths.

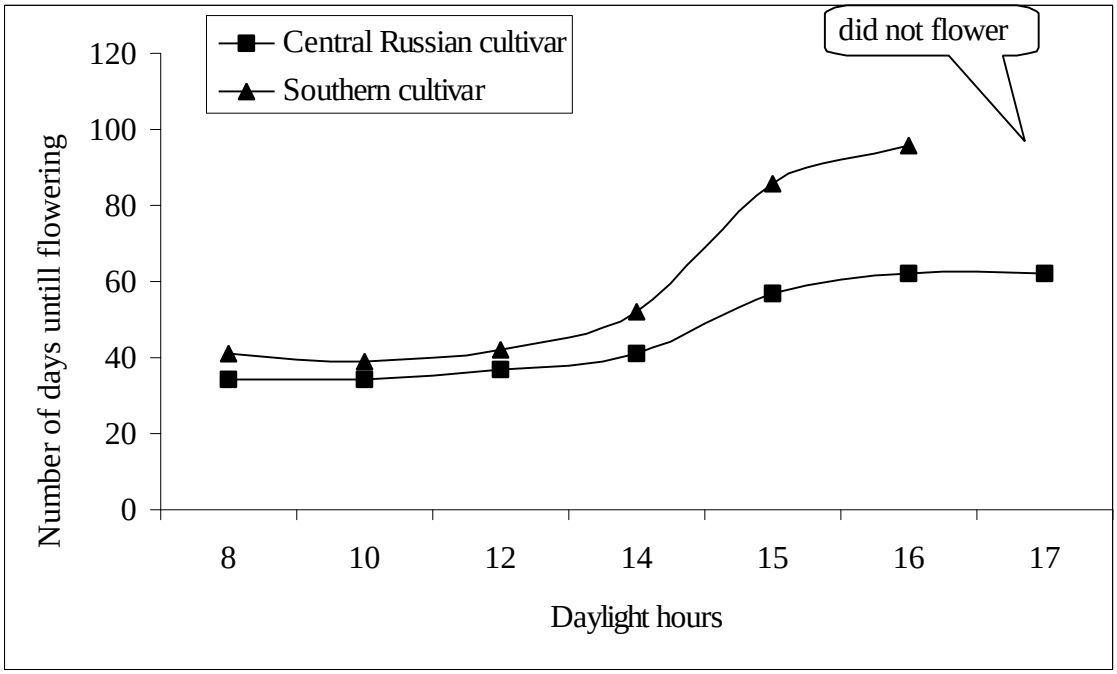

Figure 5. Comparison of the time to flowering (days) of two hemp cultivars under different daylengths (Bócsa & Karus 1998)

It is essential that suitable cultivars, matched to a farms latitude, are used or the potential for economic loss, due to poor or uneven crop maturity, is high.

The amount of light has a marked effect on the rate of hemp growth, as would be expected for a high biomass producing crop. Exact figures on the amount of light required are scarce.

7.5 Water

Fibre hemp can produce up to 15 tonnes of dry matter per hectare. Such phenomenal growth in such a short period of time requires considerable amounts of water. Fibre hemp requires between 250 to 300mm of water (this includes available soil moisture). Some studies have shown much higher requirements of up to 700mm (Bócsa & Karus 1998). This is a huge water demand, especially as it is concentrated during the rapid growth phase. For comparison, Christchurch receives an average of 635mm of rain a year. Hemp has the ability to explore a considerable volume of soil, reaching down 2-3m providing it is not impeded by pans or water logging, and thus able to extract water from a large volume of soil. Even with this ability hemp production in much of New Zealand, especially the cropping areas on the east coast, will require considerable amounts of irrigation. Information on irrigating hemp is scarce. The only equipment that could effectively irrigate a crop that can reach several meters high and is very dense, is large rain guns or boom

irrigators. Rain guns may have to be adapted so the nozzle is above crop height or it is likely to seriously damage several meters of crop either side of the track. The crop in the rain gun track is likely to be worthless. It is unlikely that side roll or hand shift irrigation could be used once the crop is over 1-1.5m in height.

7.6 Soil

With hemp's high demand for water and nutrients, especially nitrogen, good quality soils are required. Suggested pH is slightly lower than for many of crops at 5.8 to 6.0. The soil needs to be free draining as waterlogging will kill the plants, particularly young plants. Waterlogging also promotes damping off (*Botrytis* and *Pythium* species) in seedlings. Any soil pans should be broken up by sub-soiling. Stalk yield is often two tonnes to the ha lower on class II soils compared with class I.

7.7 Nutrients and Fertilisers

Due to the very rapid growth rates nutrients need to be well supplied and freely available.

Nitrogen is considered the most critical nutrient. Insufficient nitrogen will cause yield losses, while excess will reduce fibre quality.

Phosphorous is required throughout the growth period of hemp with demand progressively increasing. It plays an important role in the elasticity and tensile strength of the fibres.

Potassium requirements are also substantial and, like phosphorus, uptake increases with the growth of the crop, peaking during fibre development. Potassium has an even greater effect on fibre quality than phosphorous.

The information on other nutrients is scarce and inconclusive. Prior to the use of artificial fertilisers farm yard manure was extensively used to fertilise hemp fields. It is likely that manure or compost applications would be of benefit for organic hemp crops.

Table 2 shows the amounts of fertiliser required per tonne of stalk yield for a range of soil types and classes.

Table 2. Fertiliser requirements (kg/tonne of stalk yield) for hemp, for soil classes, I-III with a range of soil nutrient levels (Bócsa & Karus 1998)

kg/tonne stalk	Nutrient Content of Soil				
Soil quality	Poor	Low	Average	Good	Excellent
Nitrogen					
Class I	21.5	18.0	15.0	14.0	8.0
Class II & III	23.0	20.0	18.0	15.5	10.0
Phosphorus					
Class I	12.0	10.0	9.0	8.0	4.0
Class II & III	17.0	14.0	12.0	10.0	7.0
Potassium					
Class I	24.0	18.0	10.0	12.0	7.0
Class II & III	27.0	24.0	22.0	20.0	8.0

While hemp requires large amounts of nutrients while growing, much of this is returned to the soil. With fibre hemp most of the leaves are removed during harvest and returned to the field. If the hemp is retted in the field then many of the nutrients left in the stem are also returned.

7.8 Rotations, Cultivations and Sowing

Due to its high demands on soil nutrients hemp should be grown early in the rotation. It is widely reported that it leaves the soil in good condition afterwards due to the return of old leaves to the field and the extensive root system. There have also been reports to the contrary. Some researchers have noted increased yields following hemp (Thompson et al. 1998). Others have claimed allopathic effects, such as reducing pest nematodes (Dragla 1997). Hemp can be grown in the same area for several years without apparent ill effects, however, this is not recommended. As hemp is not closely related to other crop plants it is valuable in any rotation.

As with all crops the soil should be managed and cultivated to achieve a well structured tilth with the minimum number of cultivations. As hemp has a smaller seed than many other broad acre crops, a finer seedbed is required than would be sufficient for crops such as cereals. Cultivations should ensure that the soil is uncompacted and soil pans must be broken up by sub soiling.

7.9 Pests and Disease

Hemp has over 300 identified pests and about 100 diseases (McPartland 1996b) (McPartland 1996a). However most pests and diseases do not cause any economic damage. There are a few hemp specific insect pests that can cause crop loss, for example the hemp flea (*Psylliodes attenuata* Koch) and European Corn Borer (*Ostinia nubilalis*). Pest control has been required in the past to avoid crop losses. There are also hemp specific diseases, such as hemp rust (*Melampsora cannabina*). A number of fungicides are suitable for their control. Hopefully such obligate hemp pests and diseases will not be present in New Zealand and border quarantine should keep them out. However illicit marijuana growing, and the importation of European high THC marijuana could harbour or introduce hemp specific pests and disease.

General insect pests could also cause significant crop loss, but normal control techniques both conventional and organic, should be able to control these. Fungal diseases such as *Pythium debaryanum* and *Botrytis cinerea* (damping off diseases) can be a problem, especially in wet conditions. These can be controlled by ensuring free draining soil, and in non-organic systems, seed treatments and fungicides are effective.

Vertebrate pests such as rabbits and birds can be problematic. Many herbivores find hemp highly palatable. If large numbers of them are present they will need controlling. Birds are highly attracted to the seed (McPartland 1996a). Experience with organic linseed (*Linum usitatissimum* L.) in New Zealand has shown that consumption of seed by birds increases progressively over time in any one locality. Hempseed may well face a similar problem.

Broomrape and dodder both attack hemp. Most seed sources are free of the parasitic plants' seeds due to field hygiene, and seed cleaning. Seed from China can be contaminated. Resistant cultivars are available.

7.10 Weed Control

Hemp grown for fibre, if it establishes well, will outgrow weeds and smother them. It is thus valuable for organic farmers. If it suffers from poor establishment, especially if the conditions favour weeds, then the hemp may be out competed by the weeds (Bócsa & Karus 1998). For seed crops the situation is not so clear. Some claim that herbicides are necessary on the wider crop spacings, while others find that non chemical weed control techniques are more than sufficient.

7.11 Weather damage

Hail can cause considerable damage to crops grown for good quality fibre. Strong winds that flatten the crop, break stems and prevent them from being aligned for fibre processing are a problem. As noted previously hemp is very susceptible to waterlogging and prolonged heavy rain that is unable to drain from the field will cause crop loss.

7.12 Drilling

Soil temperatures should be 10-12°C at sowing to ensure rapid germination and growth to out compete weeds. Seed should be sown at 3-4cm depth, at the lower depth on lighter soils and at the shallower depth on heavy soils. Depths outside this range will lead to uneven germination and / or plant loss. Seeding rates for textile fibre production are 70-80 kg/ha and row widths should be 12-20cm. If this rate is exceeded the yield of quality fibre will decrease. The lower rate of 70 kg/ha to give a population of 3.5 million plants/ha is recommended (Bócsa & Karus 1998). Crops for paper production should have row spacings of 20cm and 45-60 kg/ha to give a populations of 2.2-3 million plants/ha. Lower rates are not recommended as this produces thicker stalks that machinery cannot handle.

Seeding rates for hempseed vary. Bócsa and Karus (Bócsa & Karus 1998) recommend rates between 50-60kg/ha at 20cm row spacings to 70cm rows at 2-2.5kg/ha. This is based on the principle of keeping the number of plants per meter row constant. Wider spacings will increase the number of branches, and hence yield, but also produce thicker stems. The higher seeding rates are used for dual purpose crops producing both fibre and seed while the larger spacings are for seed only. If row widths exceed 40cm the weed suppressing effect of hemp is lost and chemical or mechanical means of weed control will be required.

Hempseed loses its viability quite rapidly. It should be stored under dry, cold conditions if it is to be used for sowing. It is not recommended to sow seed with a germ rate below 85% (Bócsa & Karus 1998).

7.13 Harvesting

7.13.1 Oil

Hempseed can be harvested with a combine harvester. Axial-flow combines are best at threshing and cleaning the seed (Ehrensing 1998). However, hemp grown at the low population densities recommended for seed production rather than combined fibre and seed production may well be too tough for harvesters to cope with. In all cases hemp is much tougher than other commonly combine harvested plants and will cause increased wear on machinery. The cutting bar of the combine is often raised to about 1.5m or the lower seed bearing branches, thus avoiding the thick stems at ground level. These can then be harvested using more robust and aggressive mowing machinery.

The time of harvesting is critical. Too early and seeds will not be viable and have lower nutritional values. Too late and yields will be significantly reduced. Unfortunately seeds mature at different rates on both different plants and on the same plant, with the lower seeds maturing first. Seeds are ripe when the seed husk is hard and has its characteristic marbling. When the majority of seeds in the middle of the flowering head are ripe, harvesting should begin as soon as possible. Seed should be dry when harvested and a moisture content of below 12% is required for storage (Bócsa & Karus 1998).

7.13.2 Quality Fibre

The harvest of quality hemp fibre is the most problematic. To be of value the stems must be kept parallel. Until recently the only two options were hand harvest or the use of old machines, mainly of Russian origin. However new machines are being produced that can mechanically harvest while keeping the stems parallel leaving them as a swathe in the field (Figure 6).

Figure 6. A modern European forage chopper for cutting and windowing hemp (Ehrensing 1998)

To get the best quality fibre harvest should be done when one third of the anthers on the males are shedding pollen and when flowers first appear on the females.

Once cut, the traditional approach was to ret (rot) the stalks in the field to separate the bast fibres from the rest of the stem and to break the chemical bonds that hold the bast fibres together. This process involved the stalks being left in the field, kept moist by dew, rain or irrigation, and occasionally turned over a period of two to three weeks. This enabled microbes to decompose the stems. After this process the fibres can be mechanically separated. Field retting is difficult to control, it relies on adequate temperatures and moisture to enable the microbes to work, and tends to have uneven results. Alternatives to field retting are described in section 8.1.

If water retting is used, (see section 8.1) then the leaves can cause problems. In East Europe chemical defoliation was used (Bócsa & Karus 1998). This is not acceptable for the western markets, and alternative techniques are ineffective. Field retting or alternative retting techniques are needed for these markets.

Handling and transport of both fresh or retted stalks is problematic, due to the need to keep the stems parallel and because they are very bulky. Various hemp-specific binding and baling machines are used in Europe to enable mechanical handling. The bulkiness of the crop makes transport expensive. Processing facilities need to be sited within 30km of the crops according to "The Hemp Product Line Project" by the Nova Institute of Germany, reported in Thompson et al. 1998. Kenex Ltd. in Canada have stated they will be purchasing hemp from a 50km radius.

Non Quality fibre and Hurds

For other fibre uses such as paper and composite products there is no requirement for the stalks to be kept parallel, or uncut. Existing machinery such as hay mowers, forage harvesters, and baling equipment are able to satisfactorily harvest the hemp. It should be noted that hemp is hard on machinery due to its thick woody stalks, and increased maintenance costs should be expected. Mechanical handling is no different that for other baled products such as straw. Even after baling,

the material still has a high bulk : value ratio and transport over long distances is generally uneconomic.

8. Primary Processing

8.1 High Quality Fibre

The processing of hemp to produce high quality fibres is complex. As noted in section 7.13 hemp can be retted in the field to separate the bast fibres from themselves and from the rest of the stem. This process is difficult to control and produces variable results. An alternative is water retting where the stalks are soaked in water, which gives more control and better quality fibre. This requires large amounts of clean water and the leaves have to be removed from the stems to stop the chlorophyll from discolouring the fibres. Water retting also creates large volumes of polluted water that needs treatment. Alternatives to these processes are required. Simple techniques such as ensilage for a number of months have proved very effective at bast fibre separation; however, fibre strength is much reduced.

Once retted, the fibres need to be separated. There are a number of ways to achieve this. Originally this was done mechanically using crushing and beating actions. New processes are being researched with some now in the implementation phase. These rely on chemical or physical processes, or a combination of the two. An example is steam explosion process technology (STEX) where the fibres are treated with a waterproofing solution exposed to intense steam and alkaline chemicals in a pressure vessel. After a period of 1-30 minutes the pressure is suddenly released causing the fibres to separate.

A breakthrough in the post harvest processing of hemp, both retting and fibre production would considerably decrease the price of hemp fibres, and thus increase its market potential. Ideally these would be small scale facilities that enable small local industries to be developed. If they are large scale, and thus require considerable capital investment it will be a hindrance to the uptake of hemp.

8.2 Oil Production

Hempseed can be processed using standard equipment used for other oil seeds. The bulk to value ratio of hempseed is much lower than fibres, so processing plants do not have to be close to processors. With hemp containing unrivalled quantities and mixtures of essential fatty acids and amino acids, much of the early market of the seed will be for high value oil, cold pressed under inert gasses, and various high value human foods.

9. Economics

Some of hemp's decline is linked to its association with marijuana. Some hemp advocates claim that hemp was too competitive against the emerging petrochemical companies so political pressure was put on hemp, both by public and private lobbying, to get it banned, i.e. there was a conspiracy against hemp. While there may be some truth in this, hemps decline started much earlier than the rise of the chemical companies. Alternatives from the East and technical innovations such as the cotton gin all played their role. Even after hemp was banned in most of the west, production continued to decline in places it was still legal to grow, right up to the start of the 1990s (Figure 7). Hemp has thus been continuously out competed by alternative products. It would therefore be very optimistic to expect that hemp will suddenly supplant its competitors, coming from so far behind in the marketplace.

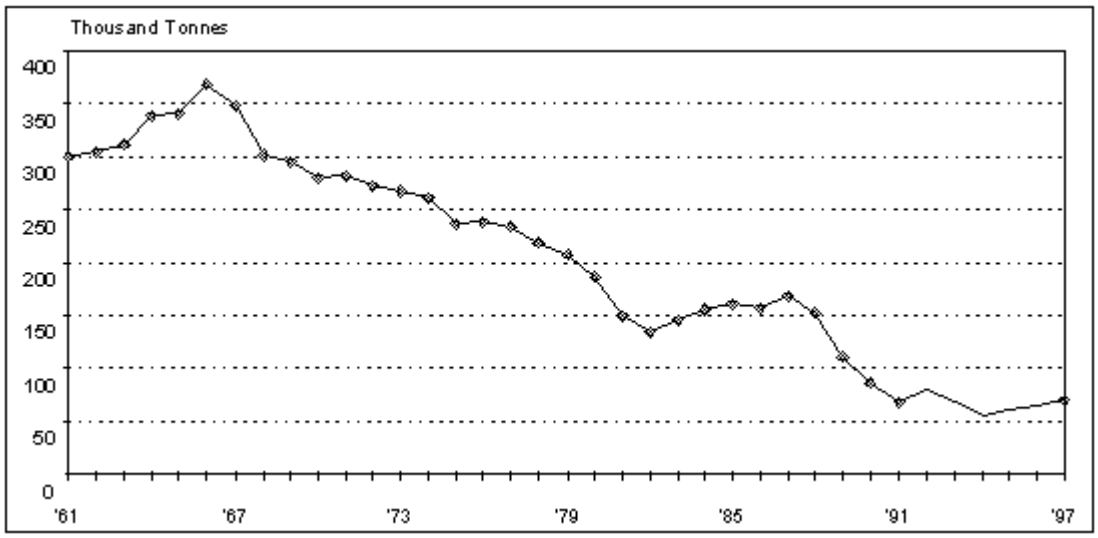

Figure 7. World Production of Hemp Fibre and Tow, 1961-1997 (Gardner Pinfold Consulting Economists Limited & White 1999)

If hemp is to be economically profitable, not just technically feasible, hemp products need to meet at least one of the following criteria:

- They need to be cheaper than competing products
- They need to be technically superior to competing products
- They need to have environmental benefits that can be turned into an economic advantage
- They need to have a novel use, with no competitors
- They can retail to a niche or luxury market where cost is not a driving factor.

Unfortunately many hemp products fail to achieve any of these criteria. Many hemp products are more expensive than their competitors. To be used in many manufacturing processes, e.g. textiles, existing machines have to be altered, or new machines that can handle hemp purchased. This means that if the end products made from hemp and its competitors sell at the same price, the cost of the hemp raw material will have to be significantly lower than its competitor over a reasonable length of time to justify the cost of re-tooling.

Hemp is touted as having environmental benefits, or more accurately it has a lower environmental impact than its competitors, especially cotton. However environmental costs are not taken into account in most production systems (i.e. they are economic externalities). Unless mechanisms are put in place, e.g. governmental regulations, then this environmental advantage counts for little. Exceptions include organic production systems where a greater number of externalities are incorporated into the product price by restrictions on production practices.

The number of novel markets are few. Most accounts of hemp's potential markets are as a substitute for existing raw materials.

Luxury markets appear to be currently driving the hemp revival. Hemp consumption is centred in Europe and North America where it is considered trendy, or to have environmental benefits by consumers. Retail outlets commonly target the young and alternative market, which relish hemp's association with marijuana, giving it a 'protest' value. Such fashion based markets are notoriously fickle, and can disappear on a whim or when economic prosperity declines. A classic example of this was the organic boom and then slump in the United Kingdom in the late 1980s and early 1990s directly correlated with the economic boom and depression of the same period.

The predictions for creating jobs needs scrutiny. While it is true that some novel industries will be created, most of the markets that hemp moves into will be to replace or supplement existing markets. For example the end markets for fibre board or clothing are unlikely to expand because

hemp is now used as the raw material instead of wood and cotton. Hemp will thus be substituting existing raw materials. For example, if in the USA, less cotton is grown due to the production of more hemp, then cotton producing and processing jobs will be lost at the cost of new hemp producing and processing jobs, so the numbers of new jobs created will be limited, or could decrease. Large scale substitution of hemp for other products could however change employment patterns, for example a shift in workers from cotton to hemp growing areas. Similar effects could well occur in New Zealand if there is widespread uptake of hemp.

In summary, hemp has a considerable uphill struggle to become a widely grown crop. It certainly has potential. A conservative, University of Kentucky economic analysis concluded that hemp could earn Kentucky farmers up to US$790/ha for seed and straw production, though this would reduce over time to the same level as other crop's returns as more farmers grew hemp and drove the price down. They also estimated that the establishment of one hemp processing facility and one paper pulp plant, would create 771 equivalent full time jobs in Kentucky. Kentucky is ideally placed for growing hemp (it was the premiere growing area prior to hemp's prohibition) and has a wide number of outlets for all hemp products (Thompson et al. 1998). In comparison the study by Oregon State University on the potential for hemp in the United States Pacific Northwest (Washington, Idaho and Oregon States) concluded that hemp production was technically feasible, but that yields in that area were not enough to be economic and that only a small area would likely be grown (Ehrensing 1998). If hemp production is marginal in large and wealthy areas of the USA, then its success in New Zealand is by no means guaranteed.

10. Products, Markets and Potential Hemp Outlets

10.1 Introduction

Hemp can be processed into a diverse range of products, including, foods, cosmetics, textiles, and industrial materials. This fact has been used to claim that hemp's potential is huge as there are so many possible products. However, as section 9, on the economics of hemp, points out, there is a large gap between a potential product and its financial viability. This section will describe potential hemp products, likely markets and outlets, and then analyse the potential for those products to use New Zealand grown hemp. This allows an estimation of hemps potential to contribute to the economic, social and environmental wellbeing of New Zealand.

10.2 Fabrics and Yarns

Clothing is a high profile market for hemp. Hemp fibres are also used in other fabrics and textiles such as upholstery, rugs, fashion accessories and carpets. Hemp fibres have a number of superior properties to alternative products such as cotton and synthetics (e.g. nylon). These include strength, durability (particularly when wet) low UV light transmission and warmth. They also have disadvantages, primarily higher cost, and the need for manufacturing machinery to be adapted. However upholstery and other heavier grade textile machinery can use with hemp fibres without adaptation.

Quality hemp fibre yarns, fabrics and clothes produced in New Zealand would be competing against cheaper imports principally from China and Asia. The textile and clothing industries in New Zealand are in decline due to a reduction in tariffs on imported goods against which they cannot compete. Therefore quality hemp fibre, yarn, textile and clothing manufacture in New Zealand

would most likely be restricted to cottage industries, providing suitable small scale fibre processing technology becomes available. Benefits to New Zealand are likely to be few.

10.3 Industrial

There are increasing numbers of 'industrial' products using hemp. These include products such as;

- Wood fibre boards, where the addition of hemp improves the strength or decreases weight.
- Composites using a range of plastics, e.g. fibreglass.
- Pure hemp board, which is lighter, stronger, biodegradable and can be pressed into a range of shapes.
- Geotextiles e.g. weed matting.
- Insulation materials.

German car manufacturers are using hemp board in internal mouldings, due to its superior strength to weight ratio and it helps them meet environmental goals, both legislative and company set.

There is a potential market for hemp in New Zealand in industrial products. However hemp will be competing with much cheaper wood chips and wood processing by-products in many of these products. Wood is also harvested year round, while hemp, as an annual, has a short harvest period. This means that considerable quantities of unprocessed or semi processed hemp will have to be stockpiled, which is expensive. Re-tooling is also required for a number of processes when hemp is to be included. There are also other cheaper sources of fibrous materials such as wheat straw that could be used instead of hemp in some processes.

Hemp is also not the only natural fibre that is trying to find novel uses. For example, with the ever decreasing prices for wool, organisations such as the Wool Research Institute of New Zealand (WRONZ) are developing a wide number of alternative uses for wool, such as insulation, construction materials, composite boards, glue etc. (Lochie McGillivray, NZ Wool Board, pers. com.). Thus hemp will be facing competition not only from existing products but also new ones touting the same technical and environmental advantages. However, hemp does have an advantage over wool because it is cheaper.

There are thus a number of existing or new industrial products that could use both high and low grade hemp fibre, hurds and whole stalks. Competition from alternative raw materials and alternative end products will be high. The potential markets in, and thus overall benefits for, New Zealand would thus appear limited at present.

10.4 Paper

Hemp paper is more resistant to decomposition, stronger, especially when wet, less prone to yellowing and uses less chemicals in production than tree based paper. It is also more expensive. Hemp paper has been used for many years for archiving paper (ironically the American constitution was written on hemp paper) and non writing papers such as cigarette paper, tea bags and filters where wood paper is too weak, or alternative fibres, including hemp, are more cost effective. Tree based paper manufacturing equipment has to be modified to use hemp, due to different moisture holding capacities and drying times. The price of hemp fibre would have to decrease considerably for hemp paper to compete with tree based papers. Transport and storage of the raw hemp are also a problem as noted in section 10.3. Ironically New Zealand imports paper, often from countries to which it exports wood chips. The local paper industry is not large, and new hemp paper plants are expensive (the University of Kentucky Report estimated only one was feasible for the whole State of Kentucky (Thompson et al. 1998) so it is very unlikely one will be built in New Zealand. Hemp papers are thus unlikely to be a major market for New Zealand grown hemp, with consequentially limited benefits for New Zealand.

10.5 Carpets

Hemp has considerable technical potential in the carpet industry. Coarse fibres can be used to make underlay materials, or the backing for carpets. Finer fibres can be used on their own or in mixtures with wool or synthetics to produce carpets with superior characteristics such as wear, non pilling and biodegradability. Pure hemp carpets are also possible. Most existing carpet machinery can use hemp without modification. The price of raw materials is a small part of the final cost of a carpet so the higher price of hemp would not be such a barrier. New Zealand has a number of carpet manufactures who could use a range of different quality hemp fibres. Carpet manufacture would appear to be a potentially valuable outlet for hemp fibre. However, it is likely that hemp will be a substitute for wool. The overall benefit, of even large areas of hemp being grown for carpet production, appear to be marginal as demand for wool will correspondingly decrease. The social economic and environmental benefits to New Zealand from this outlet appear to be small at present.

10.6 Animal Bedding and Feed

Hurds (the broken up woody core) have traditionally been a by-product of fibre production with no worth. A new and valuable market for hurds is in high quality bedding for race horses, and pet litter. The hurds are more absorbent, have better odour suppressing abilities and are less allergenic than alternatives such as wood shavings, straw and hay. A University of Kentucky study identified race horse bedding as an important hemp outlet, and hurds are extensively used in Germany for this purpose (Thompson et al. 1998). While New Zealand has an international reputation for its race horses and they are concentrated in a small number of geographical areas, such as Hamilton and Christchurch, many of the horses are kept outside. The level of stabling is thus lower than other countries. Hurds have a very high bulk to price ratio, even when compressed, and cannot be economically transported very far. More processed forms such as pet litter can be economically transported further, but still not great distances.

There may thus be a limited market in New Zealand for hurds for animal bedding. However fibre processing facilities would have to be close to major race horse stabling areas. If this were the case such an additional outlet for the hurds could bolster fibre hemp’s competitiveness. It would not be economic to grow hemp just for this market.

Hempseed is a valuable food for both human and other animals, and is currently a component of bird seed mixes. It is envisaged that most, if not all, hempseed production in New Zealand would be for human consumption for the foreseeable future. Current demand is mainly for certified organic seed. It is possible that the solids left after oil extraction could be used for animal feed, but it also has a potential as an ingredient in human foods as well, which would be a more lucrative market. There will also be competition from imported non-organic hempseed which is likely to be cheaper than locally produced seed. The potential animal feed market for hemp in New Zealand appears to be limited. Benefits for New Zealand in this market area are also likely to be very small.

10.7 Food

All hemp food products originate from hempseed. Of all the claims about hemp, the nutritional value of its seed is one that stands up to scrutiny and deserves fuller description. Whole hempseed contains approximately 20-25% protein, 25-35% oil, 20-30% carbohydrates and 10-15% insoluble fibre (Theimer & Mölleken 1995). It also has a rich array of minerals, particularly phosphorous, potassium, magnesium, sulphur and calcium, along with modest amounts of iron, zinc, carotene, and dietary fibre. The highly polyunsaturated oil has uses similar to that of linseed oil (e.g., fuel for lighting, printer's ink, wood preservative), and as a raw material for soaps, detergents, and body-care products. However, it is the nutritional qualities of the oil that are particularly important (Deferne & Pate 1996). It has all 8 amino acids essential to the human diet, as well as

carbohydrates and a small amount of residual oil. Its protein is primarily edestin, a highly assimilable globular protein of a type similar to the albumin found in egg whites and blood (Deferne & Pate 1996). However, heat-treating whole hempseed denatures this protein and renders it insoluble, possibly affecting digestibility.

To retain its valuable constituents hempseed oil must be un-refined, and cold pressed from non-heat treated seed [2]. Such oils are off-yellow to dark green in colour and have a pleasant nutty taste. The seed, and thus oil, does not contain THC. Any trace amounts are probably due to contamination from plant residues (Bócsa & Karus 1998).

Hempseed oil is unusually high in polyunsaturated fatty acids 70-80% and less than 10% saturated fatty acids. Table 3 shows hemp to compare favourably with other oils. Unsaturated oils oxidise very easily however, which is why such oil quickly becomes rancid on exposure to the air. This process is accelerated by heat and light. Any oil high in polyunsaturated fats should not be heated as this creates toxic trans-fatty acids. It is best consumed raw, in dressings or as a garnish.

Table 3. Oil profiles of major GLA sources (% total fatty acids) Adapted from Erasmus in (Deferne & Pate 1996)

	Less healthy/Chemically stable ←→ More nutritious/Chemically unstable				
	"Saturated"		"Monounsaturated"	"Polyunsaturated"	
	Palmitic	Stearic	Oleic	Linoleic	Linolenic
Hemp	6-9	2-3	10-16	50-70	15-25
Soy	9	6	26	50	7
Canola	0	7	54	30	7
Wheatgerm	0	18	25	50	5
Safflower	0	12	13	75	0
Sunflower	0	12	23	65	0
Corn	0	17	24	59	0
Cottonseed	0	25	21	50	0
Sesame	0	13	42	45	0
Peanut	0	18	47	29	0
Avocado	0	20	70	10	0
Olive	0	16	76	8	0
Palm	85	0	13	2	0
Coconut	91	0	6	3	0

The 3:1 ratio between linoleic and linolenic acid has been claimed optimal for human nutrition and scores highly against other plant oils. It is believe that polyunsaturated fatty acid forms late in the seeds maturity, so crops must be ripe at harvest (ElSohly 1996 in Deferne & Pate 1996).

Gamma-linolenic acid (GLA) is also found in hemp. GLA has a number of health benefits and is frequently prescribed for the treatment of eczema, and mastalgia (Deferne & Pate 1996).

Existing machinery can be used to process hempseed, and hempseed and its products can be used in a very wide range of foods. With the continual growth of the heath food market, there being a range of New Zealand based food processors, and transport cost being smaller relative to hempseed's value, there could be a number of markets for hempseed in New Zealand. Human foodstuffs appear to offer the most valuable outlets for hemp and thus have the largest benefit for New Zealand. However much of this consumption will be replacement of existing products, new jobs will be limited. The health benefits are unlikely to be gained by the lower socio-economic groups who need them most, as hemp products are likely to be too expensive for them to purchase. Consumption is likely to be restricted to educated higher socio-economic brackets.

[2] Hempseed was often heat treated at the point of entry to countries where hemp production was illegal, to make it infertile, so that people could not grow hemp from the seed.

10.8 Bodycare

Hempseed extracts, particularly the oil, are increasingly being used in bodycare products. Bodycare stores such as the "Bodyshop" which targets environmentally and politically aware consumers have introduced whole ranges based on hemp. There are also rigorous medical studies that demonstrate that hemp oil has a number of benefits for the skin (Weil 1993). It is possible that hemp grown in New Zealand could be used for bodycare products. However it is likely to find it difficult to compete with imported seed, or finished goods imported from abroad. Much of the hemp product purchases will replace a similar non-hemp alternatives. The overall benefit to New Zealand is again likely to be limited.

10.9 Pharmaceutical and Medicinal

There are increasing claims for medicinal effects of marijuana particularly from North America, where there are increasing efforts being made to allow doctors to prescribe it. This is highly unlikely to happen in New Zealand in the current political environment. There are a number of medical benefits from the oil, as noted previously, both as a preventative supply of essential nutrients and as a curative for certain medical conditions. There could be a number of health benefits for New Zealanders from hemp products. However the health problems that they cure are often the result of poverty. With the likely high cost of hemp foods and the charges associated with the current New Zealand health system, those that would most benefit from hemp products are unlikely to be able to afford it. Thus the social benefits are not as high as first appear.

10.10 Fuels

Due to the large amount of biomass produced, a number of claims have been made that hemp could be used as a fuel source, either burnt directly or converted into liquid fuels such as ethanol. There are at present a wide range of biomass alternatives to hemp that can be used for fuel but are discarded. An outlet for hemp based fuel use in New Zealand is very unlikely, and the benefits for New Zealand practically zero.

10.11 Certified Seed

Due to the need to have locally adapted cultivars and phystosanitary requirements on imported seed it is likely that some growers will concentrate on producing certified seed-lines. These attract premiums over that for processing seed. However it is likely that the number of certified seed producers in New Zealand will be limited, unless export markets are developed. There is thus a low potential economic benefit for New Zealand from certified hempseed production.

11. Financial Analysis of Hemp Production

11.1 Hemp Gross Margin

It is very difficult to create an accurate gross margin for hemp in New Zealand. There are a number of estimated or calculated gross margins in overseas reports, but these are often dependent on a number of local factors, such as rainfall, which affect yield. Such variations are also present in New Zealand. A good example of this are the variations in gross margins for the same crop produced in different areas of New Zealand, such as process sweetcorn. Gross margins are $1,112, $1,298 and $1,675 for Rangitikei Marlborough and Gisborne respectively (Burtt 1997). Also, published gross margins for New Zealand crops, produced by different organisations, have very different costings

for the same operation. For example the cost of cultivations in gross margins for broadacre crops produced by the Farm Management Group at Lincoln University average $56/ha while the NZ Vegetable & Potato Growers Federation Inc. (Vegfed) average is $286 (Burtt 1997). With such variations it is very difficult to select accurate costing figures.

Also, presently, there is only one confirmed outlet for hemp - hempseed for oil. There are markets for processed hemp which are confirmed, however, there is no processing infrastructure in New Zealand so there is a gap between the farm gate material and that required by processors. As noted previously, processing is the most problematic area due to lack of technology. Purchase prices for farm gate hemp fibre are thus unknown and can only be estimated from overseas prices.

The gross margin below thus needs to be read with extreme care. The sensitivity analysis is slightly more useful in indicating the effects of yield on returns however it is still reliant on the subjective selection of costs and prices.

Yields overseas for combined seed / fibre production average at about 1.5tonne/ha for seed and 5tonnne/ha for stalk. This information, with production costs from the Financial Budget Manual (Burtt 1997), have been used for the estimated gross margin (Table 4) and yield sensitivity analysis (Table 5).

Table 4.Estimated gross margin for organic hempseed in Canterbury

Income		
Seed @ $900/tonne and 1.5tonne/ha	$1,350	
Fibre @ $150/tonne and 5tonne/ha	$750	
Total		**$2,100**
Expenditure		
Cultivation and drilling, includes one primary, and two secondary cultivations	$250	
Certified seed @ $7/kg and 50kg/ha	$350	
Fertiliser or compost	$100	
Irrigation four times at 50mm	$300	
Harvesting & delivery	$150	
Total		**$1,150**
Gross Margin		**$950**

Table 5. Sensitivity analysis for Sensitivity analysis of the effect of yield on gross margin

		Yield tonne/ha seed					
		0.8	1.2	1.5	2	2.4	2.8
Yield tonne/ha stalk	4	$170	$530	$800	$1,250	$1,610	$1,970
	4.5	$245	$605	$875	$1,325	$1,685	$2,045
	5	$320	$680	$950	$1,400	$1,760	$2,120
	5.5	$395	$755	$1,025	$1,475	$1,835	$2,195
	6	$470	$830	$1,100	$1,550	$1,910	$2,270

Gross margins for conventional crops from the 1997 Financial Budget Manual, (Table 6) and organic gross margins (Table 7) are given as comparisons.

Table 6. Calculated crop gross margins per ha for Canterbury crops (Burtt 1997)

Wheat	$953
Barley	$714
White clover	$1023
Ryegrass seed	$849
Field peas (marrowfat)	$1318
Green beans (process)	$895
Peas (process)	$680

Table 7. Estimated organic crop gross margins / ha (Tim Chamberlain, organic farmer, pers. comm.)

Peas Process	$900
Beans	$1,500
Onions	$7,000
Carrots	$5,000
Potatoes	$3,000

In comparison, an analysis of returns for fibre production in Europe at high, medium and low yields indicated that without subsidies hemp produced a negative return except for the highest yield (Bócsa & Karus 1998).

11.2 Area of Hemp Required to Supply Identified Outlets

The areas of hemp required are vital to estimate hemps potential for New Zealand. At present there are only two clearly identified end users of hemp. Fortunately they are complimentary as one requires hempseed the other medium grade fibre making the crop more economic for farmers.

11.2.1 Hempseed Outlet

David Musgrave of Waihi Bush cold presses organic flax oil. It has similar nutritional values to hemp as outlined in section 10.7, however hemp is a superior product. David estimates he could process and sell the seed from 1-200ha [70-500 tonnes] using his existing plant and has markets for oil from 2-300 tonnes of seed. He current price is $900/tonne for certified organic seed and $600/tonne for non-organic seed (David Musgrave, pers. comm.).

11.2.2 Lower Grade Hemp Fibre Outlet

Lindsay Newton, director of New Wool Products Ltd. based in Nelson, has, for the last ten years, been developing ways to turn wool into insulation. The resulting product is proving very successful. In areas where it is sold, it has taken up to 40% of the fibreglass insulation market. Lindsay has trialed hemp fibres as a replacement for a major proportion of the wool. He has been using waste hemp fibres from Chinese textile mills and medium grade fibre (similar to Jute) processed by the pectinase method, from the Centre For Alternative Technology, Machynlleth, Wales. The resulting product has better acoustic properties, equal insulation value, and better fire retardant properties than a pure wool product. (Lindsay Newton, pers. com.)

The New Zealand insulation market is worth approximately $40 million/pa. Average cost of insulation is $6/$m^2$ equating to about 6.5 million m^2 of insulation used a year. At a weight of approx. 1.2kg/m^2 for the combined wool/hemp insulation this equates to 7800 tonnes of insulation a year. Taking into account the ratio of wool to hemp in the product, if the entire New Zealand insulation market switched to hemp/wool product total demand for hemp fibres would be 5000 tonnes/pa. (Lindsay Newton, pers. com.)

Currently the wool product is more expensive than fibreglass, however it is technically superior in a number of areas thus making it competitive overall. Imported processed hemp fibres cost between $600-$700/tonne compared to $2000/tonnne for recycled wool. A hemp based product will therefore be price competitive with fibreglass. Locally produced and processed hemp may be cheaper, due to reduced transport distances, thus making a hemp/wool product cheaper and technically superior to fibreglass.

However processing the raw stems into fibre suitable for the insulation manufacturing process needs further investigation. No processing facilities currently exist in New Zealand and the cost of retting and processing, and the capital required for a processing facility have not yet been determined. These costs will be critical in determining if New Zealand grown fibres will be used rather than imported ones. Fortunately the hemp stem is only required to be a minimum of 15cm in length. It is should thus be able to be harvested with existing cutting and baling equipment. Bales can be stored in the field until they are required. This alleviates capital expenditure on specialist machines by the farmers and reduces storage costs as on farm storage is cheap.

If processing is feasible the complete displacement of fibreglass from the insulation market appears possible. Average yields for fibre from combined fibre and seed crops is five tonnes/ha. At this level of production 1000ha of hemp would be required to supply the 5000 tonnes/pa required. It is unlikely a hemp/wool product would take over the whole market, for several years and that initial demand for hemp would be considerably lower, and may well match the 1-200ha required for seed production.

If hemp production is allowed, a processing plant is feasible, thus creating outlets for both seed and fibre 200ha of hemp could be grown and sold in New Zealand. If processing is not feasible it is unlikely that the returns from seed production alone would be sufficiently high to tempt farmers to produce it. Fibre production alone is also unlikely to be economic for this market without the production of hempseed as well. This fact may constrain the domestic supply of hemp fibre for insulation.

12. Environmental Benefits

A number of claims for environmental benefits are made for hemp and it is commonly perceived as an ecologically friendly crop. Unfortunately many claims do not stand up to scrutiny. For example, hemp advocates claim that hemp can produce over four times the amount of biomass than trees for a given area and time, and thus claim that hemp should be grown in preference to trees. However hemp can only be grown on fertile, generally flat land and requires a considerable input each year in terms of cultivation, sowing, husbandry and harvesting. Trees can be grown on very marginal land, and climates that are completely unsuitable for other crops or habitation. In New Zealand more trees, particularly natives, are needed, not less, to address problems of hill erosion and loss of native tree species.

Hemp does have advantages in that it uses considerably fewer pesticides and herbicides than alternative fibre crops, particularly cotton (Kraenzel et al. 1998). Fibre and fibre/hempseed crops generally require no weedkiller. It can reduce soil nutrient loss and erosion, and improve soil structure due to the extensive root system and return of dead leaves to the soil (Bócsa & Karus 1998). As with all environmental claims several, rigorous analyses should be completed, such as a life cycle analysis, to create a more accurate description of hemp's environmental benefits, rather than ill thought out extrapolations of hemp's technical features.

New Zealand's environment suffers due to a number of introduced plants. Hemp has not been tested for its potential to become a weed here.

In conclusion the environmental benefits of hemp for New Zealand are not at all clear.

13. International Situation

The USA and New Zealand stand out as being the last countries to start the process of the re-introduction of hemp. Those countries in Europe which had banned cultivation have now revoked such bans and in most cases have a straight forward licensing system, and considerable subsidies for hemp production. Canada has completed trials and is now licensing producers. Australia has conducted a number of trials and produced a number of quality reports e.g. (Graham et al. 1995) (Anon 1995). A number of states in the USA are vigorously pushing for legislative changes, especially those that were the centre of the previous hemp industry, such as Kentucky. Much of Asia, China, and the previous USSR never banned hemp production. Hemp is now a legitimate crop in most of the world. New Zealand is thus rapidly loosing the few potential economic, social and environmental benefits that may have been gained by growing and processing hemp due to competitors having a considerable technological and marketing, head start.

14. Politics and Legislation

The political and legal situation of hemp in New Zealand can best be described as confused and bureaucratic.

14.1 Legal Situation

To grow, possess seed or plant material of any form of *C. sativa* a licence, issued by the Director-General of Health, under the Misuse of Drugs Act 1975, is required. hemp products from which all the resin has been extracted are exempt *C. sativa* preparations which have concentrated the resin / THC are more strictly controlled than unprocessed plant material (Boyd 1997). This means that fibres, and their products such as rope and textiles, can be imported and processed here. The situation with hempseed oil is less clear. While there is no THC in hempseed, and thus none in the oil, police and customs have concerns about it, and want it tested.

There have only ever been two licences granted, both to Crown-owned research establishments, contracted by the police, to investigate methods of control of illicit crops. Due to increasing numbers of applications to grow hemp the Associate Health Minister Maurice Williamson enacted a moratorium on considering any further applications for licences following a review of Australian hemp trials. A report was produced by Dr G R Boyd (Boyd 1997) and considered by the National Drug Intelligence Bureau (NDIB) which consists of the Police, Customs and Ministry of Health.

New Zealand is a signatory to the United Nations Convention Against Illicit Traffic in Narcotic Drugs and Psychotropic Substances 1988 and the Single Convention on Narcotic Substances 1961, both of which are administrated by the International Narcotics Control Board (INCB) a United Nations' organisation that controls international trade and sets schedules to the Narcotics and the Psychotropics Conventions (Boyd 1997). These include *C. sativa*, however they do not apply to the cultivation of *C. sativa* exclusively for industrial or horticultural purposes. I.e. the production and trade of hemp and its products is legal under international agreements to which New Zealand is a signatory.

14.2 Political Situation

The release of Dr Boyd's report gave great hope to those groups lobbying for hemp production. Dr Boyd's report recommended that:

- The moratorium on considering applications for hemp be lifted to allow trial plots for research purposes.

- A working party should be established to consider and recommend the criteria, forms of control, audit, and conditions required for licences to grow, import and possess, hemp. The party should include NZ Police, Customs Dept., Ministry of Agriculture, Ministry of Health, Federated Farmers, NZ Hemp Industries Association Inc.
- Policy development should take into account that licences need to be issued well in advance of the October to February growing season.

Hemp lobbyists expected that the working party would be quickly formed, and issuing of licences for research would soon commence. The process has become bogged down and the working party has not been formed. This is due to lack of drive from the government, and differing positions of the organisations suggested for the working party, which vary from lack of interest, through concern to hostility.

14.2.1 Positions of Organisations Involved with the Proposed Hemp Working Party

The Ministry of Health

Recommended the lifting of the moratorium, and went as far as creating draft press releases announcing the decision. It believes that the THC content of hemp is so low it does not create a psychoactive effect and it would make smokers ill before it had any effect (Anon 1998). The Ministry of Health are also responsible for the co-ordination of the government's decision making on this issue. A number of hemp advocates including DJ "Mac" Macintosh of the New Zealand Hemp Industries Association Inc. (NZHIAI) has stated that the Ministry of Health is not the appropriate Government Department to be co-ordinating this issue, and that hemp is not a health issue it is a business and a law enforcement issue (McIntosh et al. 1998).

Federated Farmers

Federated Farmers are very supportive of the introduction of hemp to New Zealand and have been actively lobbying the government. (Tony St Clair, CEO Federated Farmers, pers. com. 1999).

Customs

Customs' role would be to ensure compliance with licences at the border. They do not envisage new resource implications if licences to import seed to grow hemp in New Zealand are granted. Customs did indicate concern at police views on law enforcement issues relating to increases in the availability of marijuana (Anon 1998).

Ministry of Commerce

The Ministry of Commerce declined the opportunity to comment (Anon 1998).

New Zealand Hemp Industries Association Inc.

The NZHIAI is naturally pro hemp.

MAF

The Ministry of Agriculture (MAF) is mainly concerned with its responsibilities under the Biosecurity Act 1993. If import licences are issued MAF would need to issue an import health permit (cost of $70) the first of which would also require a comprehensive pest list for hemp which would take two weeks and cost $1250.

Police

The police have a considerable number of concerns. They also want extensive research and confirmation of the commercial viability of hemp production before the moratorium can be lifted and the working party formed. This is a circular position as the research and commercial viability cannot be confirmed till the moratorium is lifted and the working party decides on licence requirements. Specifically the police are concerned about

- ad-hoc government policy on hemp
- increased demand on police resources
- unknown costs for THC testing and verifying imported seed for oil production
- cross fertilisation of hemp by marijuana
- an erroneous believe that hemp sometimes has more THC than marijuana
- that there are no distinguishing features between hemp and marijuana
- the use of hemp as a 'cover' for production of marijuana
- that licences holders may use their position to deal in marijuana
- that hemp cultivation may increase marijuana production and use.

(C B Ronald, CIB, pers. com. 1999)

14.2.2 Current Situation

Pro hemp lobbyists have been astounded by the police's statements and strongly rebutted them. Rod Donald the Green Party Co-Leader said that "We are concerned that the minister of Health's refusal to grant licences to grown hemp is based on a [police] report of extremely poor quality full of inaccuracies and assumptions" A number of pro-hemp groups met with the police to address their concerns. There has been no statement from the police yet to indicate a change in their position.

There are contradictory messages coming out of the government. In a letter to David J Musgrave on the 18th June 1999 the Prime Minister, the Rt Hon Jenny Shipley said that the "the Minister of Police and the Police have an open mind about the proposal [for trial hemp plantings] and were happy to contribute to a working party to analyse the subject matter in greater detail…". However the Hon Tuariki Delamere, Associate Minister of Health, in a letter to Rod Donald on the 9th June 1999 said that "I do not believe that the working party recommended by Dr Boyd is the appropriate forum to resolve the outstanding issue raised by the police".

It appears unlikely that progress will be made on lifting the moratorium and granting licences unless there is a change of government. New Zealand is now in the detrimental position of not being able to establish the potential for hemp in this country. If it does allow hemp cultivation it will be one of the last countries in the world to do so, placing it a considerable competitive disadvantage, as export markets will have been claimed by other countries, and the local market will be supplied by imports.

15. Discussion

15.1 Over Optimistic Claims

As noted before, some hemp advocates have made a number of at best 'optimistic' claims about hemp which continue to be reported as facts. A good example is the potential uses of hemp. A popular figure is that there are over 25,000 products that can be made from hemp. A few seconds reflection show such claims are meaningless. Derivatives of crops such as soya beans or oil seed rape (canola) can be found in hundreds of thousands of different end user products around the

world, from food through paint to mechanical lubricants. It is true that hemp is a multi product plant with capabilities to produce very high quality oil, high quality protein, high quality fibre, cellulose, and wood. However much the same can be said of many crop plants. Cereals produce both grain and straw. Fruit trees produce both food and wood. This does not mean that within the current western economic and agricultural systems all the potential products from a crop are either useful or have value. For example straw from cereals could be burnt in power stations to make energy, made into substitute wood products, fermented into alcohol to run internal combustion engines, used as a mulch, animal feed etc. On face value straw could save the world! In most western economies straw is a useless by-product, creating a disposal problem.

The figure of 25,000 products for hemp, noted above, originates from an article called "New Billion Dollar Crop" in the February 1938 issue of Popular Mechanics claiming that hemp has over 25,000 uses (Kraenzel et al. 1998). The article is neither original research, nor based on it. Great care must be continually taken when reading information on hemp. Little of it is original, statistically valid research, or reviews and compilations of original research. Much is rehashed unsubstantiated claims such as the '25,000 uses of hemp'.

This continued recycling of 'optimistic' claims was present in the earliest publications such as the Hemp & the marijuana conspiracy : the emperor wears no clothes (Herer 1990) and has continued since then. The reasons for this have not been clearly researched, however likely causes are that the hemp renaissance has been a grass roots movement that lacks the financial and research resources to conduct thorough investigation and analysis. In addition during the early stages of its revival the widespread prohibition meant that it was not possible to conduct trials and information had to be gathered from dated material and marginal sources. This situation is now changing with increasing numbers of governmental, university and other research organisations researching hemp in a rigorous fashion.

An analysis of why potential uses do not eventuate into actual uses is elaborated in section 9. However, it is noted that many hemp advocates are also advocates of alternatives to the current economic, and agricultural paradigms, for example, organics and sustainability. Plants such as hemp, have a higher potential in such alternative systems than they do in the current ones.

15.2 The Quality of New Zealand Hemp Publications

It is disappointing to note that two publications promoting hemp, written in New Zealand, "The five minute guide to industrial hemp" (McIntosh et al. 1998) and "Industrial hemp: a potential crop for the Nelson region" (Smale et al. 1998) fall into this trap and make a number of unlikely, unsubstantiated claims, such as the number of products, 50,000!, the creation of tens of thousands of jobs (a University of Kentucky report estimated 771 full time equivalent jobs created in the State of Kentucky (Thompson et al. 1998)) and so on. It is noted that the five minute guide notes that it is opinion, based on the authors experience. However, uncritical readers will still take such information as accurate, and it will install an impression of a lack of credibility, on both the authors and the NZHIAI, in more critical readers. This is unlikely to help speed the introduction of hemp in New Zealand, and may in fact achieve the opposite of the authors intentions.

There are high quality international reports on hemp's potential such as the "Economic impact of industrial hemp in Kentucky" (Thompson et al. 1998) and "Feasibility of industrial hemp production in the United States Pacific Northwest" (Ehrensing 1998), based on economic analysis using conservative production data, and clearly identified markets to create a credible, bottom up numerical analysis. Good books also exist on agronomic aspects of hemp, e.g. the "The cultivation of hemp; botany, varieties, cultivation and harvesting" (Bócsa & Karus 1998). There is also a peer reviewed scientific journal devoted to hemp, "The Journal of the International Hemp Association" a biannual publication of the International Hemp Association, looking at a broad range of topics from hemp chemistry to marketing opportunities.

Such quality analysis and publication however, requires time and resources far beyond the producers of the two New Zealand reports noted above. There is however potential for grants from the research funding agencies in New Zealand to fund a quality, thorough, in depth analysis of hemp's potential in New Zealand. Such research would provide leverage to those who promote hemp in New Zealand. Organisations such as the NZHIAI can access these funds, particularly if they liase with Universities or Crown Research Institutes (CRI).

15.3 The Need for Accurate Information

There appears to be a limited potential for hemp in New Zealand. Unrealistic and overly optimistic claims will hinder this process. Government is sceptical of unfounded data. Farmers are often as sceptical as the government, and generally conservative in their adoption of new crops. There are a regular procession of novel crops, animals and markets promoted to farmers. They watch as most fail, revealing the high level of hype from the original promoters. If hemp is to be a credible option for New Zealand farmers they, and government, need to be presented with conservative economic analyses, concise and accurate agronomic and market information. Overly optimistic predictions, without solid foundations will discourage the adoption of hemp.

15.4 The Need for Legalisation

This report has indicated that there are a limited number of potential outlets for hemp in New Zealand. This is no reason to continue to stop hemp production. There are a number of areas, such as Motueka, that appear to be climactically and topographically suited for hemp production and are currently struggling economically (Smale et al. 1998). They should be allowed the opportunity to establish, through trials, the potential of hemp in their area. This is the only way to accurately calculate the returns hemp can make to individual farmers, their communities and New Zealand. If hemp is legalised in New Zealand then it is likely that innovation will occur as people make the best of a new crop. It is unethical, and economic stupidity, to deny New Zealanders the chance to evaluate hemp, while citizens in most other countries are free to do so.

15.5 Hemp as a Tool in the Control of Marijuana

Concerns, predominately by the police, that hemp will increase marijuana production and consumption are completely ill founded and very seriously damage the credibility of their information gathering and analysis skills. Numerous rigorous scientific reports have demonstrated that hemp cannot be used to gain psychoactive effects. In their claims to the contrary, the police and Dr Boyd have only cited anecdotal evidence.

Marijuana production requires that plants be grown on wide spacings. Fibre hemp is much too dense to grow marijuana. Even the more widely spaced hempseed crops would still be unsuitable. Marijuana has been selected for dwarfism to allow it to be cultivated indoors and underneath other vegetation. It will not compete with seed hemp and thus be swamped. In addition, to produce the high levels of THC demanded by marijuana smokers, male plants are destroyed to leave only female plants as fertilisation of the female flowers starts seed production, and stops THC production. Without pollen females continue to produce more flowers and THC, thus producing a very dense, sticky flower spike. Any marijuana plants in a hempseed crop would be rapidly fertilised rendering the marijuana very low grade indeed and full of seeds. No marijuana user wishes to smoke seeds.

The police have also expressed concern that marijuana would fertilise hemp and increase THC levels. This is patently absurd. Male marijuana plants are destroyed, as noted above. The amount of pollen released by hemp fields would thus be many orders of magnitude greater than the 'local marijuana patch'. Therefore the reverse is the case and hemp would destroy the value of the

marijuana by fertilising the females, making them produce seed instead of THC. Even the seed produced would be worthless as the THC levels will be a combination of the very low THC hemp variety and the high THC marijuana. Plants from such seed may well have no psychoactive effect at all. Anecdotal evidence from Canada is that this is already happening and marijuana growers are having their livelihoods destroyed. If the police wish to improve their control of marijuana they should be promoting industrial hemp not opposing it.

It is worth noting that Dr Boyd of the Ministry of Health got this matter completely wrong in his report when he stated "Reversion to higher-THC producing strains after several generations can be expected" (Boyd 1997). However in comparison he also noted "There has been little interest in the Austrian crops by the drug-using community as they have realised hemp is low in THC and hydroponic growing is much more lucrative and easily concealed" (Boyd 1997).

In conclusion the police need to conduct a more thorough analysis of the available data and come up with a sensible position on hemp that does them justice.

15.6 Biodiversity and Native Flora and Fauna

New Zealand has seen a massive loss in its native flora and fauna since the arrival of humans and accompanying species. Hemp has an unknown potential to become a weed. It is important that the Department of Conservation (DoC) are consulted in this matter and its potential established.

16. Conclusion - Hemps Potential for New Zealand

This preliminary analysis of the potential outlets for hemp in New Zealand indicates that there are very limited existing outlets for hemp fibres or seeds. The number of potential outlets that could emerge five to ten years after the first crops are grown appear to be few due to the reasons noted in section 10.

The returns to the farmer for producing hemp are difficult to estimate from currently available data. It will require many trials with different cultivars and sites, over several seasons, in different prospective hemp growing areas to determine the profitability to the farmer. The general impression from overseas is that hemp is no wonder crop and returns are likely to be similar to other broad acre crops. If it is unprofitable then hemp based product manufacturing in New Zealand will be dependent on imported raw materials. It is more likely that for many products, finished items will be imported instead as this is often more economic than local manufacture.

The economic potential thus appears to be limited. Some products will replace existing ones, and will thus have a limited impact. This impact will depend on whether the new and existing products are produced in New Zealand or imported. The replacement of an imported produced with a locally produced one will be beneficial to the country as a whole, while the opposite situation would be detrimental. Novel products may well increase the size of the market and thus GDP, however the number of such products appears limited.

Social advantages are unclear. Economic expansion may create new jobs, however product replacement may just alter employment patterns - not necessarily for the better. The potential for decentralisation of processing due to the constraints on the distance unprocessed hemp can be transported are unclear due to technological problems of processing. Thus the revitalisation of rural communities is far from guaranteed. On the other hand, widespread production of hemp in traditional marijuana growing areas could reduce the income for marijuana growers due to cross pollination of marijuana. These areas are often socially deprived, with the poorest members growing the marijuana. A decline in their income could thus increase rural social problems not decrease them.

The environmental advantages are also unclear. New Zealand does not grow crops such as cotton that require large amounts of agrichemicals, that could be replaced by hemp. The crops that hemp may replace use comparatively low levels of herbicides and pesticides. Reductions in agrichemical use appears small. Biodegradable hemp products may replace non-biodegradable such as plastic thus reducing waste streams, however many biodegradable end products, and also green waste, end up in landfills, due to New Zealand's antiquated waste management systems. A more rigorous analysis of environmental impacts, such as cradle to grave analysis are required to make accurate comparisons. A task beyond the scope of this report.

In conclusion hemp is thus unlikely to be anything but a useful addition to New Zealand's crop mix, with a small number of processing industries for the foreseeable future. It will not be the saviour of New Zealand as claimed by some hemp advocates.

However having reached these conclusions there are no valid reasons for hemp production to be banned in New Zealand. A more extensive, economic, and agronomic analysis, or crop trials, may demonstrate that there are greater opportunities. Even if such work is a long time coming, or if it also indicates the potential benefits are few, it is absolutely no reason to stop New Zealanders trying this crop to establish its potential for themselves.

17. References

Anon. 1995. Industrial hemp: Prospects for an industry in Western Australia. Ministry for Primary Industry and Fisheries (October)

Anon. 1998. Application for licences to import and or cultivate hemp. Ministry of Health, No. TT05-06-5. (5 April)

Anon. 1999. Mean Air Temperatures 1961-1998, Vol. 1999. MetService, http://www.metservice.co.nz/knowledge/data_mean_air_temps.asp

Bócsa, I. & M. Karus. 1998. The cultivation of hemp: Botany, varieties, cultivation and harvesting. (translated by Chris Filben) Hemptech, Sebastopol.

Boyd, G. R. 1997. Commercial cultivation of *Cannabis sativa* for production of industrial hemp: Legislative and security aspects of recent Australian trials. Ministry of Health (September)

Burtt, E. S. 1997. Financial budget manual 1997. Lincoln University, Department of Farm and Horticultural Management, Lincoln.

Deferne, J. L. & D. W. Pate. 1996. Hemp seed oil: A source of valuable essential fatty acids. Journal of the International Hemp Association 3: 4-7.

Dewey, L. H. 1913. Hemp. USDA Yearbook.

Dragla, P. 1997. Industrial hemp, A cropping guide for farmers growing industrial hemp for the 21st century. Industrial hemp production. Kenex Ltd

Ehrensing, D. T. 1998. Feasibility of industrial hemp production in the United States Pacific Northwest. Oregon State University, No. 681. (May)

Gardner Pinfold Consulting Economists Limited & J. White. 1999. A maritime industrial hemp product marketing study. Marketing and Food Industry Development Branch, Nova Scotia Department of Agriculture and Marketing

Marketing and Business Development Branch, New Brunswick Department of Agriculture and Rural Development, http://agri.gov.ns.ca/pt/agron/hemp/hempms00.htm

Graham, C., D. Beltrame & P. Fitzgerald. 1995. Discussion paper on the feasibility of a hemp fibre industry in Australia`. Rural Industries Research and Development Corporation (November)

Grotenhermen, F., M. Karus & D. Lohmeyer. 1998. THC-limits for food: a scientific study. Journal of the International Hemp Association 5: 101-105.

Herer, J. 1990. Hemp & the marijuana conspiracy : the emperor wears no clothes, 1990 ed. Hemp Publishing, Van Nuys.

Kraenzel, D. G., T. Petry, B. Nelson, M. J. Anderson, D. Mathern & R. Todd. 1998. Industrial hemp as an alternative crop in North Dakota: A white paper study of the markets profitability, process, agronomics and history. The Institute for Natural Resources and Economic Development (INRED) North Dakota State University, No. 402. (July 23)

McIntosh, D. J., R. Barge & T. Brown. 1998. The 5 minute guide to industrial hemp in New Zealand. New Zealand Hemp Industries Association Inc., Auckland.

McPartland, J. M. 1996a. *Cannabis* pests. Journal of the International Hemp Association 3: 52-55.

McPartland, J. M. 1996b. A review of *Cannabis* diseases. Journal of the International Hemp Association 3: 19-23.

Roulac, J. & Hemptec. 1997. Hemp horizons: the comeback of the world's most promising plant. Chelsea Green Publishing, White River Junction, Vermont.

Smale, P. E., S. B. Burnett & B. Coulter. 1998. Industrial hemp: A potential crop for the Nelson region. Motueka Employment and Small Buiness Center (1 March)

Theimer, R. R. & H. Mölleken. 1995. Analysis of the oil from different hemp cultivars - perspectives for economical utilization, pp. 536-543. Bioresource Hemp, 2nd ed. nova-Institute, Cologne.

Thompson, E. C., M. C. Berger & A. S. N. 1998. Economic impact of industrial hemp in Kentucky. University of Kentucky (July)

Weil, A. 1993. Therapeutic hemp oil. Natural Health