Hemp production in Aotearoa

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ABSTRACT

Hemp is new to Aotearoa, the indigenous name of New Zealand (NZ). The NZ government approved the experimental cultivation of hemp in 2001. Eleven cultivars have been cultivated to date, 'Anka', 'Carmen', 'Fasamo', 'Felina', 'Finola', 'Futura 77', 'Kompolti', Uniko B, 'USO 14', 'USO 31', and 'Zola'. Crops have been planted at 19 sites the past two seasons, in a wide range of latitudes, climates and soil types. NZ's fragile soil necessitates careful management of its fertility. Hemp fits into the paradigm of sustainable stewardship, organic soil fertilization, and responsible crop rotation. It can be rotated with existing fodder crops and vegetable crops. Hemp's well-known ability to suppress weeds makes its rotation with pasture an attractive way to clean soil banks of weed seeds. Hemp cultivated for seed produced maximal yields of 2800 kg ha^{-1}; and fibre crops yielded stalk biomass (dry matter) as high as 13,900 kg ha^{-1}. These yields are consistent with or greater than reports from the European literature. Several pests new to hemp were discovered in NZ, but none required pesticides. Birds caused problems in seed crops, requiring control with repellents and bird netting. Future prospects look promising for this new crop.

Keywords: hemp, soil management, seed production, organic agriculture, diseases, pests

INTRODUCTION

This paper continues the “Hemp Production Notes” series published by the *Journal of Industrial Hemp.* The series is designed to present an overview of hemp production techniques adapted to specific regions or countries (van der Werf, 2002).

Aotearoa is the indigenous name for New Zealand (NZ). Hemp cultivation is new here. This is surprising, because NZ was annexed by Britain in 1840, and British colonists were encouraged to grow hemp throughout the Empire (McIntosh, 1997). Hemp never took hold in NZ because a native high-fibre plant, New Zealand flax (*Phormium tenax,* Agavaceae), covered vast acreages around the colony. Indigenous people of Aotearoa (the Maori) taught the British colonists how to process *harakeke* (*P. tenax*) into cordage and cloth.

Anecdotal reports of *Cannabis sativa* hemp cultivation permeate NZ history (McIntosh, 1997), but no hard evidence of hemp cultivation exists prior to World War II. No *Cannabis* specimens at the national herbarium predate 1971. Feral *C. sativa* found around NZ towns and cities was usually attributed to plants growing from discarded bird seed (Webb et al., 1988). The Department of Scientific and Industrial Research (DSIR) cultivated a 1 ha experimental plot in the central North Island in 1941. Shortly thereafter the Ministry of Agriculture and Fisheries (now the Ministry of Agriculture and Forestry, MAF) trialed 4 ha near Foxton (McIntosh, 1997). Claims of hemp cultivation in the 1800s are often based on a publication by Holmes (1900). Unfortunately the “NZ hemp” described by Holmes was *P. tenax,* not *C. sativa.* The NZ cultivation of *Cannabis* for medicinal purposes, however, dates to 1883. A French missionary nurse and medical herbalist, Mother Mary Joseph Aubert, cultivated *Cannabis indica* at her missionary hospital in Jerusalem, near Wanganui (Yska, 1990). The *Dangerous Drugs and Poisons Act* of 1927 rendered *Cannabis* cultivation essentially illegal. Prohibition was renewed by the *Misuse of Drugs Act* of 1961 and subsequent amendments.

The NZ Hemp Industries Association (NZHIA) incorporated in 1996 and petitioned the government for allowance of low-THC hemp cultivation. The NZ Ministry of Health licensed the importation of low-THC hemp seed in 2001. The first hemp trials began the same year, at 11 sites around NZ, covering a total of 55 ha (see Figure 1). The second season, 2002-2003, involved 19 sites (Figure 1). The hemp trials have evaluated plant growth and yield as a factor of cultivar, site location, local climate, and agronomic variables (sowing date, seeding density, fertilizer regimes, etc.). NZ growers are primarily interested in seed crops, rather than fibre crops, although some sites evaluated dual harvest (seed and fibre from the same crop). Eleven cultivars have been tested to date, all from Europe or North America: ‘Anka’, ‘Carmen’, ‘Fasamo’, ‘Felina’, ‘Finola’, ‘Futura 77’, ‘Kompolti’, Uniko B, ‘USO 14’, ‘USO 31’, and ‘Zola’.

SOIL, FERTILISATION, and ROTATIONS

NZ is a small country, covering 26.7 million hectares (M ha), slightly larger than the United Kingdom. Despite its small size, the land offers a continental diversity in latitude (34° to 47° S), altitude (sea level to 3754 m), topography (flat and gentle to hilly and mountainous) climate (subantarctic to subtropical), rainfall (100 to 7500 mm per annum) and a wide array of soil types. The parent materials of NZ soils are largely sedimentary stone (greywackes, argillites, sandstones, limestones). The remaining parent materials are igneous (granites, basalts) or metamorphic (schists, gneisses, marbles). Drifts consist of volcanic ash, river alluvium, glacial material, loess deposits, and coastal sand drifts. Most of the soils in NZ have been shaped by their overlying vegetation and soil microorganisms. These are termed "zonal soils" and some are excellent for hemp cultivation, such as the brown-grey earths ("tuatara" in Maori). Other NZ soils are young and not modified by biological factors; they are solely shaped by their parent material and topography. These "azonal" or "intrazonal" soils also support hemp production, such as sandy pumice soils ("onetea" in Maori) and rendzina soils (Gibbs, 1980). Despite this incredible diversity, most NZ soils tend to be thin, prone to acidification, and frequently deficient in nitrogen, phosphorus and sulphur (Taylor and Smith, 1997). Erosion is a problem because only 15% of NZ is flat (<3° slope). "Rolling" land (3°-12° slope) makes up another 15%. The remaining 70% of NZ is hill country, with the majority of it classified as steep (>28°).

Erosion risk, soil fertility, climate, and rainfall are factored into the *Land Use Capability* (*LUC*) classification system. Annual crops such as hemp can only be sustained on *LUC* Class I, II, or III soils. These soils comprise 3.8 M ha, or 14%, of the NZ landsurface (see Figure 1). Most of the 3.8 M ha lies in pasture, only 0.5 M ha is currently cropped (Taylor and Smith, 1997). Of the 0.5 M ha cropland, about 40% is devoted to rotational crops of grain (barley, wheat, maize, oats) and peas. Hemp fits into this rotation scheme, as it does in Europe (van der Werf, 2002). About 30% of cropland is dedicated to fodder crops (hay, rape, turnips, swedes). The remaining cropland is divided between fruits (kiwifruit, apples, grapes) and market gardens (potatoes, onions, squash, and other vegetables). Hemp can be rotated with fodder crops and vegetable crops, to improve soil structure and "mellow the soil" (Dewey, 1914). Hemp also expels some pests that accumulate in monocrops which are not rotated or diversified (McPartland et al., 2000). For example, hemp rotated with potatoes reduces soil populations of the nematodes *Globodera pallida* and *Globodera rostochiensis,* which threaten potato yields and NZ export status (McPartland and Glass, 2001). Pasture (a mix of ryegrass and white clover) also benefits from rotation with hemp. Even *LUC* Class IV land (too hilly or unfertile or too wet or dry for regular cropping) can be occasionally rotated with hemp for renewal of heavy-use pastures such as dairy lands. Several species of pernicious weeds contaminate NZ pasture, including gorse (*Ulex europaeus*), Scotch broom (*Cytisus scoparius*), and Californian thistle (*Cirsium arvense*). Hemp's well-known ability to suppress weeds makes it an attractive "biological control" to reduce soil banks of weed seeds (McPartland and Nicholson, 2003). Hemp also reduces populations of nematodes found in pasture soil, such as *Heterodera trifolii* and various *Meloidogyne* species (McPartland and Glass, 2001).

Soil health is an issue taken seriously in NZ, and farmers have begun to embrace sustainable methods. A number of factors have fostered organic agriculture in NZ – the fragility of the soil, the relatively unspoiled environment, the frugality of farmers (frugality is the mother of sustainability), health concerns surrounding pesticide use, and the influence of the Maori worldview in NZ society, which is rooted in ecological concepts. Thus NZ agriculture promotes biological cycles, and eschews the use of off-farm inputs and commodities. From a political standpoint, the minimal use of commodities sold by multinational corporations places organic farmers at odds with the Monsantos of the world. Genetically-modified crops, for example, are banned in NZ.

Hemp can be a nutrient hog. A 10 tonne ha^{-1} hemp crop extracts 90 kg ha^{-1} nitrogen, 25 kg ha^{-1} phosphate (P_2O_5), 90 kg ha^{-1} potash (K_2O), 60 kg ha^{-1} calcium, 10 kg ha^{-1} magnesium, and 10 kg ha^{-1} sulphur (Hall, 2000). Fortunately much of this nutrient uptake is returned to the soil when hemp is properly retted in the field. Nevertheless, even a properly retted hemp crop extracts approximately 40 kg ha^{-1} nitrogen, which must be returned to the soil. Rotating with nitrogen-fixing legumes (peas, alfalfa, clover, etc.) does much to replenish the soil. Alternatively, 40 kg ha^{-1} nitrogen can be replenished with about 6 tonnes ha^{-1} cattle manure. Non-organic fertilizers have also been used, such as sidedressing the crop with either of two blends: a) 125 kg ha-1 ammonium sulphate (21-0-0) plus either 45 kg ha-1 potassium sulphate or 40 kg ha-1 muriate of potash, or b) 85 kg ha-1 ammonium nitrate (34-0-0) plus 40 kg ha-1 muriate of potash. Eerens (2003) described fertilizing hemp crops with treated sewage effluent, irrigated at a rate of 3.5 mm per day, which provides an annual supply of 545 kg ha^{-1} nitrogen, 145 kg ha^{-1} phosphate, 156 kg ha^{-1} potassium, 187 kg ha^{-1} calcium, 47 kg ha^{-1} magnesium, and 234 kg ha^{-1} sulphur.

Acidic soil (low pH) is common in NZ, and in most cases represents a deficiency in calcium ion base saturation. Correcting for low calcium will simultaneously correct for low pH. Minor deficiencies can be corrected by applying 1000 kg ha^{-1} hydrated lime (calcium hydroxide) just before sowing seed. Serious deficiencies may require up to 3000 kg ha^{-1} finely ground calcitic limestone (calcium carbonate with small amounts of magnesium carbonate) plus 1000 kg ha^{-1} hydrated lime (Hall, 2000).

SOWING

The seasons in NZ oppose those in the northern hemisphere. September and October are optimal times for sowing on the North Island. On the cooler South Island, October to December are optimal. Seed sown earlier runs afoul of end-of-winter rains (North Island) or frost damage (South Island). Seed sown later in the season faces increased weed pressure and decreased yields. Sowing rates were quantified as the number of seeds planted per square meter or the number of kilograms of seed planted per hectare (Cutler, 2003; McIntosh, 2003). Sowing rate depended upon the desired crop. Seed crops were sown at lighter densities, with reports ranging from 25 kg ha^{-2} to 40-50 kg ha^{-2}. Fibre crops were sown at a density of 150-200 seeds m^{-2}. Crops grown for phytoremediation were sown at fibre crop rates.

Small experimental crops were sown by hand, in furrows or broadcast. Larger sites were sown with small plot drills (eg,10 row Wintersteiger Oyjord cone seeder). Row spacing was set from 10 cm (Cutler, 2003) to 20 cm (Storier, 2002). Seed was placed at a depth of 1-2 cm, although one site placed seed 3 cm, to reduce bird predation (McIntosh, 2003). Rolling after planting with a Cambridge roller also discouraged birds (Storier, 2002). At Massey University, researchers investigated a "market garden" regimen, as part of the Empowering Communities with Industrial Hemp Project (ECIHP). This project investigated the economic viability of cultivation by small landholders. For this regimen, seed was germinated in seed trays and transplanted to the field, at densities ranging from 0.5 to 1.0 plants m^{-2}. The transplantation regimen proved inefficient and transplanted seedlings suffered root binding.

BETWEEN SOWING and HARVEST

Hemp requires little attention between sowing and harvest. The summer of 2002-2003 was extremely dry in the North Island, necessitating irrigation at a few sites planted in sandy soil. Weeds posed no problem in crops sown for fibre, but crops sown at lower densities (seed crops and the market garden regimen) did not close canopy and weeds became competitive, especially fathen, *Chenopodium album.* Organic growers controlled weeds by cultivating crops when 30 cm tall (McIntosh, 2003). At some sites, weed cultivation was combined with fertilizer sidedressing. Non-organic growers recommended Roundup (glyphosate), a non-selective herbicide that kills grasses as well as broadleaf weeds (Storier, 2002).

Pests and diseases appeared rarely and did not require pesticides. Birds caused problems in seed crops, requiring the use bird netting, repellent ribbons, scarecrow balloons and hawk kites. Crops harvested late in the season suffered more damage, as did crops planted near trees or other crops that attracted birds. Bird pests were introduced species (not native birds), such as the Greenfinch (*Carduelis chloris*) and the Eastern Rosella (*Platycercus eximius*). Most of the other pests that caused slight damage to NZ hemp were introduced species, such as the rabbit (*Oryctolagus cuniculus*), brown garden snail (*Helix aspersa*), brown field slug (*Deroceras panormitanum*), budworm (*Helicoverpa armigera*), and melon aphid (*Aphis gossypii*). Storier (2002) described an aphid (not identified) possibly vectoring Alfalfa mosaic virus or Cucumber mosaic virus, two viruses known to infest hemp crops in Europe (McPartland et al., 2000). NZ pests not previously described on *Cannabis* included the brush-tailed possum (*Trichosurus vulpecula*), the passion vine leaf hopper (*Scolypopa australis*), seed-eating caterpillars of the light brown apple moth (*Epiphyas postvittana*), and the orange-soled slug (*Arion distinctus*). In humid regions and wet conditions, the fungus *Botrytis cinerea* rotted flowering tops and stalks. Cultivars producing dense flowering tops, such as Finola, were more susceptible to bud rot than cultivars with open seed heads, such as Fasamo (Storier, 2002). Bud rot was also caused by *Trichothecium roseum,* and stalk rot was also caused by *Sclerotinia sclerotiorum.* To avoid the latter, do not rotate hemp after rapeseed, *Brassica napus* (Storier, 2002).

HARVESTING, YIELD, and PRODUCT USE

Optimal harvest time ranged from February to April on the North Island. Optimal harvest time on the South Island was earlier, from January to April. The shortest time from sowing to harvest was 82 days, for an early maturing cultivar growing at a northern site. The longest time was 150 days, for a late maturing cultivar growing at a southern site (Cutler, 2003).

In seed crops growing unevenly, maturing slowly, or in wet conditions, pre-season desiccation with herbicides (eg, Roundup) was considered an option, depending upon the market for the seed (Storier, 2002). Seed crops were windrowed (swathed) at seed maturity and usually left in the field to dry for two or three weeks. Windrowing was done early in the day to decrease the shattering of seed, a technique originally described by Dewey (1914). Less-fibrous cultivars such as Fasamo were easier to windrow than high-fibre cultivars (Storier, 2002). Some sites directly combined crops without windrowing. Two sites dried seed crops indoors, to reduce bird predation or avoid late summer rains. Small “market garden” seed plots were harvested and threshed by hand or with a fixed Kurpeltz thresher. Larger trials were harvested with small-plot machines such as Wintersteiger Hege combines. Threshed material was cleaned with small seed cleaners such as the Clipper 'Office' benchtop model or Kamas Westrup air screen cleaner.

Seed yield for different cultivars under different conditions averaged 95-180 g seed m^{-2} (=950-1800 kg ha^{-1}) with a maximum of 2800 kg ha^{-1} (Cutler, 2003; McIntosh, 2003). Seed yield for some cultivars was greater than that reported in the literature. One particularly robust 'Kompolti' female grown in the "market garden" regimen yielded 768 g seed (McIntosh, 2003). Seed production for different cultivars grown under various conditions peaked at different plant densities, 'Kompolti' at 20 plants m^{-2} (McIntosh, 2003), 'Anka', 'Fasamo', 'Finola', 'USO 14', and 'USO 31' at 90-120 plants m^{-2} (Cutler, 2003). The hemp seed had a ready market for its oil. Cold-pressed seed oil was directly bottled and sold as a food product, or manufactured into facial soap. The remaining seed cake was composted or sold to fish farms as fish food. Despite its being high in protein and omega-3 fatty acids, the seed cake and whole hemp seed cannot be processed into human foodstuffs, due to government fiat.

Fibre crops were harvested with combine equipment or cut by hand. Stalk biomass (dry matter) yield for different cultivars under different conditions averaged 600-1100 g m^{-2} (=6000-11,000 kg ha^{-1}) with a maximum of 13,900 kg ha^{-1} (Cutler, 2003; McIntosh, 2003). These yields were consistent with reports from the European literature. Most cultivars achieved highest yields of biomass at densities around 120-150 plants m^{-2} (Cutler, 2003).

Harvested stalks were retted for fibre, using microbial, chemical, or mechanical means. The microbial method utilized dew retting, which took four to six weeks. Another microbial method, pond retting, produces superior fibre, but no retting ponds have been built in NZ. Chemical retting (also called enzymatic retting or alkaline digestion) was employed at one site, using caustic soda (sodium hydroxide, $NaOH$). Mechanical retting was tested at one site, using a chaff cutter to chop dried stalks into 100 mm lengths. The chopped and decorticated material easily wind-winnowed into hurds and fibres.

Fibre crops have been sold or supplied to universities, crown research institutes, and private organizations, for manufacture into insulation and composite materials. A "Hemp Premium Lager" manufactured in NZ utilizes a vat filter made of hemp fibre, which removes yeast sediment and produces a clear beer.

REGULATIONS WITH RESPECT TO THC and PHYTOSANITATION

The perimeter of all NZ hemp crops must be posted with signage describing the crop as low-THC hemp, with the licensee's contact information. Hemp cultivated in NZ must contain less than 0.35% THC. Testing is expensive (NZ$300 per site). Only one NZ laboratory is licensed to perform THC analysis, the Institute of Environmental Science and Research (ESR). Up to five plant samples must be submitted per site; samples consist of the top 5 cm of the flowering top, collected within two weeks of harvest. Samples are air-dried overnight and then couriered to ESR in paper containers. ESR removes the stalks and seeds and analyzes the remaining leaf and flowering parts. Samples are tested individually and not batched; thus one sample over the 0.35% limit, irrespective of crop size, means the entire crop must be destroyed. Several crops of 'Kompolti' and 'Uniko B' tested over 0.35% THC and were destroyed. At one site subjected to severe drought stress, irrigated plants tested below the limit, whereas control plants (not irrigated) tested over 0.35% THC.

All plant products entering NZ must be clean of pest organisms, according to the *Biosecurity Act* of 1993. Thus imported consignments of hemp seed must be treated in a hot water dip and/or fungicide solution (caboxin, captan, or imazalil), based on a list of seed-borne pests and pathogens provided by McPartland et al. (2000). The phytosanitation treatment adversely affects hemp seed viability (Storier, 2002). Poor germination rates of imported germplasm were frequently noted, as low as 1% at one site. Nevertheless, phytosanitation of imported hemp seed appears to be unavoidable. Plant breeders in NZ see one obvious solution, the creation of unique NZ hemp cultivars.

CONCLUSIONS

Despite local myth suggesting *C. sativa* hemp has long grown here, 2001 marked the inaugural cultivation of commercial hemp in Aotearoa. The first two seasons demonstrated that hemp thrives in NZ soil, using machinery and techniques adapted from other crops and employing appropriate agronomic practices. Plans for next season are underway, to further evaluate optimal sowing dates, seed densities, and harvest dates. Many agricultural areas were established in NZ by historical accident; orcharding in central Otago followed the lapse in gold mining, viticulture near Auckland resulted from the immigration of a skilled ethnic group at Henderson (Molloy, 1980). As a result, crops have suffered constraints from poor initial sitings (frost in central Otago, gray mold disease in the humidity of Auckland). More test plots in the Northland and Southland are needed, to fully identify sites where hemp grows best in NZ.

In addition to large-scale cultivation, hemp farming by small landholders is economically viable, suggesting a vibrant future in the cottage industry/ecotourism sector. Seed crops will be evaluated with regard to seed quality (protein and fatty acid profiles). Fibre crops will be appraised for their potential use in constructed materials. The generation of raw material currently outperforms the processing industry (eg, fibre manufacturers and seed oil producers).

Thus, prospective markets for hemp products must continue to be identified, along with consumer education and market development.

REFERENCES

Cutler S. 2003. *End of Season Report on Industrial Hemp Trials.* Report submitted to Industrial Hemp Licensing Authority. Ministry of Health, Wellington, NZ.

Dewey L.H., 1914. Hemp. *U.S.D.A. Yearbook 1913,* pp. 283-347. United States Department of Agriculture, Washington D.C.

Gibbs HS. *New Zealand Soils.* Oxford University Press, Wellington, NZ.

Eerens JPJ. 2003. Potential economic viability of growing industrial hemp (*Cannabis sativa*) at the Taupo, New Zealand effluent disposal site*. New Zealand Journal Crop & Horticultural Science* 31:203-208.

Hall B. 2000. Correcting field crop nutrition: soil, fertility, and growth. In: *Hemp Diseases and Pests,* pp. 157-162. CABI Publishing, Wallingford, UK.

Holmes J., 1900. New Zealand hemp. *New Zealand Yearbook* 9:477-479

McIntosh D.J., 1997. *A brief history of Cannabis sativa L. (hemp) in New Zealand*. ECIH web site. www.ecihemp.com/abriefhistoryofhempinnz.htm

McIntosh D.J., 2003. *Industrial hemp trial: yield and density of market garden regime.* Report submitted to Industrial Hemp Licensing Authority. Ministry of Health, Wellington, NZ.

McPartland J.M., Nicholson J., 2003. Using parasite databases to identify potential nontarget hosts of biological control organisms. *New Zealand J Botany* 41(4): accepted for publication.

McPartland J.M., Glass M., 2001. The nematocidal effects of *Cannabis* may not be mediated by cannabinoid receptors. *New Zealand Journal Crop & Horticultural Science* 29:301-307.

McPartland J.M., Clarke R.C., Watson D.P., 2000. *Hemp Diseases and Pests — Management and Biological Control.* CABI Publishing, Wallingford, UK.

Molloy L.F. 1980. *Land Alone Endures: Land Use and the role of Research.* DSIR Discussion Paper No. 3, DSIR Publications, Wellington, NZ.

Storier D. 2002. Growers Guide for fasamo industrial hemp seed production. Plant Research (NZ) Publications, Ashburton, NZ.

Taylor R., Smith I., 1997. *The State of New Zealand's Environment.* GP Publications, Wellington, NZ.

Webb C.J., Sykes W.R., Garnock-Jones PJ. 1988. *Flora of New Zealand. Volume IV.* DSIR Publications, Christchurch, NZ.

Van der Werf, H.G.M., 2002. Hemp production in France. *Journal of Industrial Hemp* 7(2):105-109.

Yska R., 1990. *New Zealand Green: the story of Marijuana in New Zealand.* David Batement Ltd, Auckland, NZ.

Figure 1

Locations of industrial hemp trial sites in Aotearoa, 2001-2004, indicated with **x** marks. Cross-hatched areas of the diagram indicate land areas suitable for hemp cultivation (ie, *Land Use Capability* Class I, II, or III), based on arable land mapped by Molloy (1980).