THE PERFORMANCE OF *CANNABIS SATIVA* (HEMP) AS A FIBRE SOURCE FOR MEDIUM DENSITY FIBRE BOARD (MDF)

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SUMMARY

Industrial hemp (*Cannabis sativa*) was successfully grown over a three-year period without the use of agrochemicals, and with a relatively low input of nitrogen fertilizer at 120 kg/ha (96 units/ac). The yields achieved were encouraging at an average of 12.5 t/ha of whole stems at 15% m.c. over the three years. Sowing in early- to mid-April at a seed rate of half the conventional recommended rate of 50 kg/ha proved to be sufficient to achieve the maximum yield of stems where long fibre yield and finess (quality) are not required. For this study the hemp was produced as a raw material for the fibre board industry, where the whole stem and not just the long blast fibre is required. Hemp is relatively disease-free with Botrytis and Sclerotinia the only diseases encountered. For both, spraying is not possible due to the height of the crop. Infection rarely causes economic losses.

Harvesting hemp proved difficult with conventional farm harvesting equipment. The development of the hemp crop as an industrial raw material will require the development of harvesting, chopping and storage techniques that can cope with the height, bulk and fibrous nature of the crop.

INTRODUCTION

Up to the early 1900's hemp was one of the world's most significant crops. Three quarters of the world's paper and the majority of twine, rope, ship sails, rigging and nets were made from hemp fibre. Hemp oil was the most widely used oil for lighting. However, around the 1930's, hemp as an agricultural crop, all but disappeared from world markets. This coincided with the US banning of marijuana and the release of the first "plastic fibre" by Dupont. So in the space of a century hemp has gone from one of the world's most widely used industrial crops to one which is only recognised as a source of an illicit narcotic (Hever, 1995).

From the mid-1980's, the search for alternative non-food crops began in Europe (Werf, 1994). Hemp was quickly identified as one of the most promising species. The high yields, 12-14 t dry stems/ha and a long list of possible industrial uses, from paper to an energy source, prompted a re-examination of hemp in Ireland (Rice, 1997; Crowley and Rice, 1998). Historical records show that hemp was successfully grown in Ireland during the 18th Century (Neenan, 1969).

Two objectives were set for the re-evaluation of the hemp crop: (1) to establish the yield potential of the new low T.H.C. varieties now available and (2) to examine the potential of whole hemp stems as a source of fibre for the fibre board industry.

METHOD

A series of fully randomised field trials were undertaken from 1997 to 1999. In each year a seed rate, date of sowing and variety evaluation trial were carried out. A commercial area of 5 ha was sown in 1997 to evaluate harvesting and storage systems for handling big quantities of hemp and to supply 20 to 30 tonnes of raw material for the commercial evaluation of whole hemp stems in the manufacture of medium-density fibre board (MDF).

All crops were sown with a standard, narrow row (12 cm) corn drill. Fertilizer input varied according to soil analysis, with phosphate and potassium applied at 16 to 35 and 50 to 100 kg/ha respectively.

All the nitrogen was applied to the seedbed before sowing at 120 kg/ha. No fungicides, insecticides or herbicides were applied to the growing crop at any time. At harvest time the plots were cut and weighed. Twenty stems were taken at random from each plot and all leaf and flower material removed to establish stem DM yield. Stem diameters at the mid-point of the stem were also measured. A sub-sample of retted stems scutched on a laboratory scutcher to establish the percentage fibre present.

RESULTS AND DISCUSSION

Growth and development

Once sown the hemp established within 10 days and grew slowly for the first month. The growth rate increased subsequently, completely crowding out any weeds that developed. By mid-June the hemp crop was generally free of any weeds. The hemp flowered from mid-July to mid-August depending on sowing date and seed rate.

Seed rate

The fibre content of hemp stems increased and the fineness of the blast fibre (quality) improves with increasing plant density in hemp. This has resulted in high seeding rates (50-140 kg/ha) traditionally used in hemp growing, where the long blast fibres for use in the spinning industry were the primary objective (Van der Werf, 1994). For this project, increasing whole stem yield was the primary objective, regardless of fibre content and quality.

A series of experiments were conducted to study the effect of density on stem dry matter yield using the variety Fedora 17. The results are presented in Table 1.

Table 1: The effect of seed rate on stem yield (t/ha @ 15% m.c.) in hemp, 1997-1999

Seed rate (kg/ha)	1997	1998	1999	Stem diameter '97 (mm)
50	15.1	11.9	10.9	7.90
40	16.3	12.9	10.3	9.83
30	17.1	12.7	11.5	10.23
20	17.2	12.8	10.4	10.55
s.e.	1.05	0.91	1.21	1.01

Reducing the seed rate from 50-20 kg/ha resulted in a significant increase in stem yield in two of the three years.

The lower-seed rate plots had fewer extremely weak dwarf plants, with significantly less Botrytis-infected plants. The stem diameter also increased with a reduction in seed rate. Based on these results the traditional seed rate of 50 kg/ha may not be the most appropriate where the objective is maximum biomass yield. The results show that a seed rate of 20-30 kg/ha produced the highest yields resulting in a significant saving in seed costs of around £87/ha.

Sowing date

Hemp grows well at low temperatures and will tolerate frosts of up to -5 or -6^{o}C (Senchenko, Timonin, 1978), with older seedlings more tolerant than young plants. For this reason the recommended sowing date in the literature is generally mid-April to early May (Mattieu, 1980).

Earlier sowing will increase stem yields. Sowing in mid-March instead of mid-April can increase yields by 2.3 t/ha (Hayo van der Warf, 1994) but the risk of frost damage is increased. In Ireland the risk of a -5 to -6^{o}C frost is very small in April. To assess the yield potential of early-sown fibre hemp, sowing date experiments were carried out in 1998 and 1999. The results are presented in Table 2.

Table 2: The effect of date of sowing on stem yield t/ha @ 15% m.c, 1998-1999

Sowing Date	1998	1999
Late March	15.3	12.5
Mid-April	11.2	10.9
Early May	10.5	8.3
Mid-May	8.4	6.7
s.e	1.12	0.99

Early sowing had a significant positive effect on the yield of stems with a steady decline in yield with delayed sowing. No frost damage was recorded in either year. These results show that for maximum production hemp should be sown in late March, where possible, at a seed rate of 25-30 kg/ha. To reduce the risk of frost damage during April, early to mid-April sowings would be advisable. This will produce the maximum biomass yield where fibre content and/or quality can be ignored, as is the case when producing a raw material for the fibre board industry.

Varieties

Under EU regulations varieties of industrial hemp must contain less than 0.3 $\pm$ 0.03% Tetrahydrocannabinol (THC). In Ireland *Cannabis sativa* (hemp) is classed as a controlled drug under the Misuse of Drugs Regulations and possession of the material is an offence. To enable the development of an industry based on hemp, a licence to grow approved varieties of hemp can be obtained. The approved list of varieties is published by the Department of Health and Children. All varieties evaluated in this project were selected from this list and grown under licence.

Seven varieties (Table 3) were sown in '96, '98 and 1999. The trials were sown from 10 to 20 April in each of the three years and harvested in late August/early September. A sample of twenty stems was removed to the laboratory and all leaf and head material removed. The two fractions, (stem and leaf material) were dried separately. The stem yields (t/ha @ 15% m.c.) are presented in Table 3.

Table 3: Stem yield (t/ha @ 15% m.c.) of seven hemp varieties over three years, 1996-1998

Variety	1996	1997	1998	3 years mean
Fedora 17	12.3	16.3	9.9	12.8
Fedrina 74	12.8	16.5	10.7	13.3
Felina 32	11.8	14.9	9.2	12.0
Ferimon	12.4	15.8	12.0	13.4
Futura	13.1	16.0	10.6	13.2
Loverin 110	12.6	15.8	10.6	13.0
Kompolti	14.0	16.9	12.5	14.5
Mean	12.7	16.0	10.8	13.2
s.e.	1.21	1.80	1.05	1.15

The differences between the varieties over the three years were not significant, although the variety Kompolti was consistently the highest yielding variety in these trials.

The stem length and % leaf DM were also calculated for these variety trials. The three-year mean figures are given in Table 4 along with the average loss of stem yield as the cutting height is increased from ground level to 20 cm.

Table 4: The % of non-stem DM at harvest and the % of stem DM remaining as stubble when harvesting hemp

Variety	% Leaf DM	1st. 10 cm	2nd 10 cm
Fedora 17	29.7	8.1	7.3
Fedrina 74	26.5	8.1	7.3
Felina 32	31.4	8.6	8.5
Ferimon	24.2	7.9	7.8
Futura	19.6	8.3	8.3
Loverin 110	17.7	8.2	7.9
Kompolti	24.5	8.5	8.1
s.e.	5.32	0.25	0.41

The data shows that at harvest, an average 25% of the total biomass yield of hemp is in the form of leaf and flower material. This material is of no commercial value and is generally lost during the field drying and subsequent baling of the crop. It is important, therefore, when recording the yield of hemp that only stem yields and not total biomass yields are quoted. Because a long stubble is left in hemp fields to aid drying of the cut crop, significant yield losses of around 15%

are incurred. The average stem lengths recorded in these trials varied from 190 cm for Fedora to 225 cm for Lovrin.
The percentage fibre, as measured using a laboratory scutcher, varied from 29.4% for Felina to 35.4% for Kompolti. Fibre yields ranged from 2.70 to 5.98 t/ha over this series of trials.

Diseases

Over the three years of the project the only disease encountered was *Botrytis cinerea*. High humidity combined with high temperatures can result in a high proportion of the weaker plants being killed by Botrytis. The large plants, while showing symptoms of the disease, usually survive to harvest. Hemp is also susceptible to Sclerotinia. While both diseases can be controlled by spraying, in practice this will prove difficult because of the crop height. Further work on this aspect is required to establish if any economic increase in stem yield is possible.

Harvesting

The density and height of a mature hemp crop can cause problems when cutting and baling hemp with existing farm machines. Using part of the commercial hemp crop the performance of the following machines were evaluated.

Rape swather

This machine is designed to handle oilseed rape with a straw length of approximately 1.5 m. It had great difficulty handling the hemp. The normal work rate is 2 to 7 ha/h. This was reduced to 0.8 ha/h or less on the hemp. Stubble height is very easily controlled.

Drum – top drive mowers

These are designed for cutting grass silage. These mowers failed to handle the hemp.

Disc – bottom drive mowers

These are available from 1.65 m to 4 m cut widths and handled the hemp crop easily. Work rate was up to 2 ha/h. These machines did not create a swath of the cut material and control of the stubble height is difficult. This cutting system

required a follow-up windrowing operation. Suitable machines are available. A Stoll windrower was used very successfully on the Carlow site.
Once cut and windrowed, the straw has to be gathered and made safe for handling, transport and storage. Again a number of approaches were tried.

Round baling

Hesston belt baler: This machine worked very well and had no problems baling the crop provided the swath width was narrower than the pick-up width of the machine.

Welger fixed-chamber roller baler: Again, this machine is capable of baling hemp, but our experience suggests that belt-type balers are more suitable. For both types, bales of hemp weighed 220 to 250 kg.

Forage harvesting

Precision-chop forage harvesters fitted with rotary maize headers are capable of harvesting hemp and delivering a chopped material into conventional silage trailers. The chop length of these machines can be increased by reducing the number of chopping knives and reducing the drum speed. However, our experience suggests that the crop must be green and cut before natural retting sets in on the standing crop.

Once harvested, the chopped material requires storage for up to one year under conditions that prevent deterioration of the material.

A prototype machine which makes high-density polythene-wrapped bales was evaluated. Generally, the machine handled the hemp satisfactorily with bales weighing approximately 400 kg. The wrapped bales are suited to long-term storage and easily transported.

End uses (MDF)

Hemp has a wide range of industrial uses, from paper pulp to woven fabrics. To fully exploit hemp an industrial infrastructure is required to separate the long blast fibres from the shorter hurd fibres. Since this industry does not exist in Ireland, the concept of using the whole stem as a raw material for the fibre industry was investigated. The industry uses approximately 2 mt of wood at present.

Replacing even 10% (200,000 tonnes) of this figure with whole hemp stems would create a market for over 6,000 ha of hemp. This would not only increase the level of available raw materials for the MDF industry but would make available a very useful break crop to the tillage sector.

The hemp straw produced at Oak Park was baled and later chopped using a big bale chopper. The chopped material was mixed with wood chips at a ratio of 1:7.7 (13%) on a dry matter basis and incorporated into a Medium Density Fibreboard (MDF) manufacturing process. The resulting MDF board passed all quality tests at the factory. On the basis of these results the industrial experts were satisfied that hemp could replace up to 20% of wood chips in their process.

Serious problems arose, however, when commercial quantities of chopped hemp stems were introduced to the intake and conveyor systems at the factory. The loose long blast fibres caused damage to bearings, shutting down the whole intake system. So while whole hemp stems are very suitable for MDF production, the material must be chopped in lengths of 2.5 cm to 10 cm with no fibres unravelling on the stems. At present no machinery is available to carry out this process satisfactorily. For hemp to become a successful raw material source the fibre board industry requires the design of an efficiently chopping mechanism and a means of storing the harvested crop for up to twelve months without deterioration. Both of which were outside the scope of this project.

CONCLUSIONS

- Hemp can produce high yields of stem material, (10-14 t/ha) for processing.
- The crop can be produced on any arable mineral soil.
- Sowing in early to mid-April will ensure maximum yields.
- Seed rate can be reduced significantly, where fibre quality is not a priority.
- The crop can be produced without the aid of agrochemicals.
- Whole chopped hemp stems can be used up to a maximum of 20% inclusion rate in the manufacture of medium density fibre board (MDF).

- The development of harvesting and storage techniques are required before commercial development can take place.

REFERENCES

Crowley, J.G. and Rice, B., 1998. Hemp production and uses in Ireland. *Journal of the International Hemp Association*, **5**, (1).

Van der Werf, **H.** 1994. Crop physiology of fibre hemp (*Cannabis sativa* L.). Wageningen Agricultural University, Netherlands ISBN 90-9007171-7.

Hever, J. 1995. The Emperor Wears No Clothes. ISBN 1-878125-00.

Mathieu, J.P. 1980. Chanvre. *Techniques Agricoles* **5**, 1-10.

Neenan, M. 1969. The cultivation of hemp in Ireland. *Fibra* **14** (1): 23.

Rice, B. 1997. Potential for energy from agricultural and forest biomass in Ireland. Teagasc, 19 Sandymount Avenue, Dublin 4.

Senchenko, G.I. and Timonin M.A. 1978. Hemp, Kolos, Moscow, 258pp.