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Producing Biomass from Hemp (Cannabis sativa)

Key external stakeholders:

Farmers
Industrial Users
Scientific Community

Practical implications for stakeholders:

- *Farmers*: can benefit from new knowledge on growing hemp in Ireland, specifically on the fertilizer requirements of hemp as well as on harvesting techniques for hemp. Hemp is an effective break crop, additional break crops are urgently needed in Ireland since the demise of the sugar beet industry.
- *Industrial Users*: benefit from the knowledge that hemp can be grown in Ireland with relatively low inputs to produce high yields of biomass. Potential industrial users include the building industry, industries which produce insulation products as well as the bioenergy industry.
- *Scientific Community*: benefits from this project as new information is now available on the fertilizer requirements of hemp as well as on the optimum harvesting techniques for hemp crops.

Main results:

- Highest yields were obtained from the variety with the latest maturation date
- Hemp yields increased with applied nitrogen up to an application rate of 120 kg N/ha
- There was no response to applied potassium, irrespective of initial soil potassium level or variety
- Finger bar mowers and disc mowers can be used for mowing hemp
- Once cut, hemp stalks rapidly loose moisture even during changeable weather periods
- Hay rakes which feature a cam-type action can be used successfully to rake the mown hemp crop into windrows
- Baling can be problematical if hemp is cut as whole stalks but can be simplified considerably if hemp is cut into lengths by, for example, a tiered mowing bar system
- Yield increases in succeeding cereal crops can be expected after hemp is included in an arable rotation

Opportunity / Benefit:

This project has shown that relatively low fertilizer inputs are required to produce high yields of hemp. Thus, this project has demonstrated that hemp can be used as a low input break crop if suitable markets exist.

Collaborating Institutions:

Not applicable

Contact John Finnan Email: john.finnan@teagasc.ie.

Teagasc project team: Dr. John Finnan (PI)
Brendan Burke
External collaborators: Not applicable

1. Project background:

The use of biomass as a source of energy forms a significant part of government strategy to reduce fossil fuel dependence and to mitigate the impact of climate change. The most significant targets include the use of biomass to replace 30% of the peat burned for electricity, the use of biomass to produce 12% of the heat market and the expansion of biomass fuelled CHP (combined heat and power). A bioenergy action plan has also been produced. Future markets for biomass may arise from the production of second generation biofuels. However, energy crops and short rotation coppice have not been grown in this country to any significant extent and relatively little research work has been carried out in Ireland.

The most popular energy crops are all perennial species which, after establishment, remain in the ground for a long number of years. Growers unable or unwilling to invest in such a long term commitment may wish to consider an annual energy crop such as *Canabis sativa* (Hemp). Hemp has been periodically grown in Ireland since the 18th century and was identified as an energy crop with high yield potential. An annual crop which produces high biomass yields under low input conditions is of interest as a combustion feedstock for the production of heat and electricity. Additionally, hemp as a species exhibits unusually high concentrations of cellulose which can make up >60% of the stem (Struick et al., 2000). The species should therefore be an excellent feedstock for the production of second generation ethanol by enzymatic hydrolysis. Additionally, hemp can also be used as an insulation product in both the building and automotive industries. Thus, there are a number of potential markets for hemp.

In previous research, hemp was grown over a three year period and achieved respectable yields (12.5t/ha) without the use of agrochemicals and with a relatively low fertiliser input. The work established, however, that the highest biomass yields could be achieved at low seeding rates. Further research was however needed to optimise the production of hemp. In particular, no research had previously been carried out in Ireland on the harvesting and the fertilization requirements of hemp crops. The objective of this current project was to carry out research on these areas of hemp production in order to ensure that best practise advice was available on all aspects of hemp production.

2. Questions addressed by the project:

- What are the nitrogen fertilizer requirements of hemp crops grown for biomass?
- What are the potassium fertilizer requirements of hemp crops grown for biomass?
- What are the most efficient ways to harvest hemp crops?

3. The experimental studies:

Nitrogen fertilization trials were carried out at a number of sites over a three year period. The only input used to grow hemp over this period was fertilizer, hemp crops were grown without any agrochemicals. The response to nitrogen of hemp varieties with different maturation dates was studied in the first year of the study (2008). These varieties were sown on both light and heavy soils on which crops had previously been grown as well as on an organic soil previously in grassland, all varieties received nitrogen application rates from 0 to 150 kg N/ha. The experiments were harvested by hand in September 2008.

Nitrogen response experiments in 2009 and 2010 concentrated on a late maturing variety of hemp (Futura 75), experiments in 2008 had confirmed that the highest biomass yields are produced by late, maturing varieties. In 2009 and 2010, Futura 75 was grown on two sites (heavy and light soil). Nitrogen was applied at rates between 0 and 150 kg N/ha, all nitrogen treatments were applied at sowing but some treatments were also applied either at emergence, after emergence or split between a number of application dates. The experiments were harvested by hand in September.

Potassium response experiments were conducted in 2011 on four different sites with different levels of soil potassium. Three varieties with different maturation dates were grown at each site, potassium fertilization rates between 0 and 150 kg K/ha were used. The experiments were harvested by hand in September 2011.

A range of conventional agricultural l machinery was used to harvest the hemp crops during the course of the study with the objective of determining the optimum harvesting procedures for hemp crops. Additional, post-cutting drying rates were also quantified. Winter barley was grown after hemp at one site in 2012, grain yields were quantified and compared to an adjoining site where winter barley was grown after a preceding cereal crop.

Contact John Finnan Email: john.finnan@teagasc.ie.

4. Main results:

- Biomass yields increased with increasing maturation date from 11.1 to 12.2 tonnes of dry matter per hectare. Highest yields were obtained from the variety with the latest maturation date.
- Hemp yields increased with applied nitrogen up to an application rate of 120 kg N/ha after which there was no further response to higher levels of nitrogen application. This result was obtained at all sites in all years irrespective of soil type, previous cropping history or soil nitrogen level.
- Yield was not increased by applying nitrogen after sowing (ie at emergence or after emergence) or by splitting nitrogen between a number of application dates. Late applications of nitrogen were found to reduce initial growth in comparison to the growth produced when nitrogen was applied at sowing although late season growth was enhanced when late applications of nitrogen were used.
- There was no response to applied potassium, irrespective of initial soil potassium level or variety.
- Finger bar mowers and disc mowers can be used for mowing hemp. Drum mowers and conditioner mowers are unsuitable, however, as hemp stalks will readily wrap around the drums and conditioners respectively. Baling can be problematical if hemp is mown as whole stalks, the baling operation becomes much easier if hemp stalks are cut into a number of sections during mowing. When baling hemp crops cut as whole stalks, round balers typically perform better than square balers while belt balers or variable chamber balers typically perform better than roller balers.
- Tiered mowing systems offer a superior method for mowing hemp, drying rates are enhanced with the use of such machines and subsequently the baling operation is less problematical.
- Once cut, hemp stalks rapidly loose moisture even during changeable weather periods. Hemp stalks can decrease in moisture content from 65% to 35% in the first week after cutting and can reach a moisture content as low as 16% after a number of weeks.
- Hay rakes which feature a cam-type action (swather rakes) can be used successfully to rake the mown hemp crop into windrows.
- Hemp crops can be cut and chipped in one operation using self-propelled harvesters with kemper headers. However, the fresh chips need to be ensiled immediately to avoid heating.
- Yields increases can be expected in cereal crops grown after hemp. The magnitude of the increase will depend on previous cropping history and soil type.

Windrows of whole stalks of hemp after raking with a swather rake

Round bale of whole stalks of hemp

Contact John Finnan Email: john.finnan@teagasc.ie.

5. Opportunity/Benefit:

This project has shown that only relatively low fertilizer inputs are required to produce high yields of hemp. Thus, this project has demonstrated that hemp can be used as a low input break crop if suitable markets exist.

6. Dissemination:

Main publications:

Finnan J and Burke B (2012) Potassium Fertilization of Hemp (Cannabis sativa). Industrial Crops and Products 41, 419-422.
Finnan J and Burke B (2013) Nitrogen fertilization to optimise the greenhouse gas balance of hemp crops grown for biomass. Global Change Biology Bioenergy. Doi 10.1111/gcbb12045

7. Compiled by: Dr John Finnan

Contact John Finnan Email: john.finnan@teagasc.ie.