ENERGY FROM BIOMASS

Summaries of Biomass Projects carried out as part of the DTI's Technology Programme: New and Renewable Energy

URN NUMBER: 05/1110

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April 2005

ENERGY FROM BIOMASS: Summaries of Biomass Projects carried out as part of the DTI's Technology Programme: New and Renewable Energy

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This is a summary of work carried out under contract as part of the DTI Technology Programme: New and Renewable Energy, which is managed by Future Energy Solutions. The views and judgements summarised are those of the various contractors and do not necessarily reflect those of the DTI or Future Energy Solutions.

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INTRODUCTION

These summaries provide easy access to the results of the many projects carried out in the 'Energy from Biomass' Programme Area of the DTI's Technology Programme: New and Renewable Energy.

The summaries in this volume cover key contractor reports on this subject published between January 1998 and December 2004. The original volumes of project summaries (covering all reports published from Programme inception to December 1997) are available also from the DTI's publication website (www.dti.gov.uk/publications); references are provided below:

Vol. No.	Report Ref.	Title	Published date
Volume 1	BM/04/00048/REP/1	Wood Fuel Supplies and Supply Chains	October 1998
Volume 2	BM/04/00048/REP/2	Wood Fuel Supplies and Supply Chains	October 1998
Volume 3	BM/04/00056/REP/1	Converting Wood Fuel to Energy	December 1998
Volume 4	BM/04/00056/REP/2	Anaerobic Digestion for Biomass	December 1998
Volume 5	BM/04/00056/REP/3	Straw, Poultry Litter and Energy Crops as Energy Sources	January 1999

The projects in this current volume are summarised under chapter headings derived from the DTI's Technology Route Map ('Technology Status Report – Biofuels (Energy from Forestry and Agriculture)', July 2001). These headings, with the route map objectives and targets, are presented below:

1. Environmental and Social Impacts

Route map objectives

It should be a continuing role of the Programme to generate and deliver a steady flow of high-quality scientific information for all stakeholders, so that:

- the benefits are acknowledged;
- the disadvantages are identified so that they can be dealt with.

2. Short Rotation Willow and Poplar as Energy Crops

Route map objectives

The key development issues for SRC fuels are:

- to improve the dry matter yield from the current figure of 8 tonnes/ha to 17 tonnes/ha, while maintaining pest and disease tolerance;
- to achieve full understanding of the environmental implications of widespread deployment.

3. Straw & Perennial Grasses as Energy Crops

Route map objectives

The key development issues for the perennial grasses are:

- to establish the basic parameters for cultivation in the UK;
- to establish the basics of a crop breeding programme;
- to improve the success rates for establishing miscanthus from 25% to 90%;
- to establish the impact of the conversion options of each crop;
- to bring the agronomy and environmental impact work to the same status as that for SRC.

4. Fuel Supply Chain

Route map objectives
Feedstocks from residues are critical to deployment in the short and medium term. Work should focus on incremental development that will reduce the delivered cost. The key development issues for forestry wood fuel chains are:

- to reduce the delivered cost from £35/dry tonne to £25/dry tonne over the next ten years;
- to develop a realistic estimate of the current availability of residues;
- for SRC, to improve the work rate of harvesting and other machines by a factor of two.

5. Small-Scale Power Generation and CHP

Route map objectives
Distributed power applications have substantial development issues:

- how to engineer increased availability within the capital cost constraints;
- smaller-scale gasification processes, in particular, have issues relating to gas cleaning prior to the prime mover, and emissions from reciprocating engines;
- A radical change in approach is probably needed to achieve success in this area;
- Targets £850/kWe with minimal labour and a plant availability of more than 65%.

6. Biomass Heating

Route map objectives
There are no significant issues associated with heating appliances that are fired by wood or pellets. The R&D role is to enhance UK competitiveness through innovation.

7. Advanced Power Generation Technology

Route map objectives
The Programme should support the development of advanced gasification and pyrolysis projects, and large-scale demonstrations of both should be in place by 2005. This will involve active collaboration with EU programmes. The R&D Programme should, in the medium and long term, focus on UK strengths in gasification and gas turbine technologies, and should include support for equipment and process development.

8. Anaerobic Digestion

Route map objectives
Environmental pressures, rather than the renewable energy market, will drive the deployment of anaerobic digestion for farm residues. The priority for the Programme should be limited to support for innovative developments by UK industry.

9. Transport Fuels

Route map objectives
In the short term, the priorities are to support UK innovation and, within the next two years, to establish the potential for fuels that offer an acceptable cost of carbon abatement.

10. Biomass Wastes

Route map objectives
A priority should be to initiate work that will substantially improve the quality and quantity of information available to the market.

FURTHER INFORMATION

Where a DTI publication 'Unique Reference Number (URN)' is identified, a copy of the report can be downloaded, if available, from the DTI's Publication Website (www.dti.gov.uk/publications).

Copies of the other project reports are available for loan from the British Library (http://www.bl.uk).

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SECTION 1

ENVIRONMENTAL AND SOCIAL IMPACTS

PROJECT SUMMARY LISTING

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Report Ref. B/U1/00645/REP (URN 01/797) Publication date: August 2001

ESTIMATING THE ENERGY REQUIREMENTS AND CO_2 EMISSIONS FROM THE PRODUCTION OF THE PERENNIAL GRASSES MISCANTHUS, SWITCHGRASS AND REED CANARY GRASS

ADAS Consulting Ltd

OBJECTIVES

- To identify all the operations and inputs involved in the production, handling and transport of the energy grasses miscanthus, switchgrass and reed canary grass.
- To evaluate the direct and indirect energy requirements and CO_2 emissions resulting from the operations and inputs identified.
- To identify and make a qualitative assessment of the other environmental/agronomic consequences of growing, handling and transporting the energy grasses.

SUMMARY

Miscanthus, reed canary grass and switchgrass are three herbaceous perennial grasses that are currently being grown commercially or are being evaluated as potential energy crops for the UK.

All are harvested annually and require low inputs of agrochemical fertilisers and pesticides. The research reported aimed to calculate the energy ratios and carbon ratios of the three crops. The energy ratio is the ratio of energy contained in the biomass upon delivery to the power station to energy input in all phases of growing the crop. Similarly the carbon ratio is the ratio of carbon (C) contained in biomass upon delivery to the power station to C (in CO_2) emitted as a result of operations during all phases of growing the crop. In the first instance, base-case scenarios were developed for each species and the energy ratios calculated for these. For all crops, a productive lifespan of 20 years was assumed. In the cases of miscanthus and switchgrass, this length of time was attained from planting in the first season only; for reed canary grass, re-sowing was estimated to be required every five years.

Energy inputs consisted of: i) the energy sequestered into the production of machinery used during crop husbandry; ii) the energy associated with fertiliser and other agrochemical formulation (indirect energy costs); and iii) the fuel energy used in all aspects of husbandry from planting to harvest, storage and transport to the power station. The model used was Microsoft Excel-based, developed from an ADAS database, which holds information on the indirect and direct energy burdens of agricultural operations. The report provides a detailed analysis of the underlying information used to generate the energy ratios.

COST

The total cost of the project, £9,800, was met by the Department of Trade and Industry (DTI).

DURATION

Seven months – January 2000 to July 2000

BACKGROUND

The use of renewable biofuels to generate part of the UK's energy requirements is central to the government's objectives (DTI, 1999a) of reducing CO_2 emissions by 12.5% by 2010. The government envisages that, in order to achieve this target, 10% of the UK's energy demand will be met from renewables, a significant proportion of which will be generated from the combustion of energy crops.

An energy crop is a plant species that is grown specifically to be harvested and used as a feedstock for thermo-chemical processes to produce energy. Any plant species has the potential to be an energy crop. The principle underlying energy generation from crops is that the plant, during photosynthesis, captures as much radiant energy incident upon it and stores this energy as fixed carbon (sugars, oils or ligno-cellulose), cellulosic biomass, which consumes less input energy (light, etc) per unit of energy stored than for many speciality plant components. The process of combustion releases this stored energy into a form that can be used (heat or electricity).

The most advanced energy crop in the UK is currently short rotation coppice willow (SRC; *Salix* spp.), and four SRC-powered electricity-generating stations are currently under development. However, other plant species that combine high yields, efficient water and nutrient use, perennial nature and ease of husbandry have been studied as alternatives or supplements to SRC, and principle amongst these are miscanthus (*Miscanthus* spp.), switchgrass (*Panicum virgatum*) and reed canary grass (*Phalaris arundinacea*). Miscanthus and SRC are supported crops under the English Rural Development Plans (MAFF, 2000).

Energy cropping can be considered a less intensive form of agriculture than food cropping. The plants are perennials (herbaceous perennial grasses or short-rotation woody crops) and thus require less cultivation than conventional food crops. Energy crops also have the potential to be more efficient in their use of fertilisers (ie there is some nutrient retention and cycling between growing years that does not occur with annual crops).

Overall, the fertiliser and agrochemical inputs required by energy crops are generally less than for conventional agriculture for several reasons. They often have heavier and deeper rooting patterns, allowing the soil to be utilised to a greater depth for water and soil nutrients and providing more time to intercept fertilisers as they move through the soil. This can also give energy crops greater capacity to intercept fertilisers in lateral flows from adjacent areas. Heavier rooting puts more carbon into the soil and so assists in creating more productive soil conditions (e.g. by enabling the slow continuous release of nutrients or the binding of chemicals).

THE WORK PROGRAMME

In the first instance, base-case scenarios were developed for each species and the energy ratios calculated for these. For all crops, a productive lifespan of 20 years was assumed. In the cases of miscanthus and switchgrass this length of time was attained from planting in the first season only; for reed canary grass, re-sowing was estimated to be required every five years. Energy inputs consisted of: i) the energy sequestered into the production of machinery used during crop husbandry; ii) the energy associated with fertiliser and other agrochemical formulation (indirect energy costs); and iii) the fuel energy used in all aspects of husbandry from planting to harvest, storage and transport to the power station.

The model used was Microsoft Excel-based. It was developed from an ADAS database that holds information on the indirect and direct energy burdens of agricultural operations. The report provides a detailed analysis of the underlying information used to generate the energy ratios.

RESULTS

Energy ratios in the base-case scenarios were 20, 29 and 36 for reed canary grass, switchgrass and miscanthus, respectively. Thus, the energy consumed in producing, storing and delivering the crops to the power station amounted to only 2-5% of the energy stored in the biomass. These ratios were all very positive and were greater than previously reported for energy grasses or SRC.

Equally, the carbon ratios, at 30, 41 and 53 for reed canary grass, switchgrass and miscanthus, respectively, were very positive. These results reflect the fact that the energy grasses studied are high yielding, low input crops currently free of significant pest and disease impact.

A sensitivity analysis was undertaken on all crops, by changing individual variables to reflect the range of cropping situations that might be experienced. The variables that had the major impact on energy ratios were yield and fertiliser input. These two components accounted for the variation seen between miscanthus and switchgrass in the base-case scenarios. The relatively poor performance of reed canary grass was due to low yield and the need for more frequent establishment. Transport distance to the power station also exerted a significant impact on energy ratios. Doubling the return journey distance to 160 km decreased energy ratios by approximately 10%.

The indirect impact of switching from either arable or pasture production to energy cropping was considered. Carbon sequestration in soil reserves was predicted to increase under energy cropping when converted from arable production. The emissions of nitrous oxides were predicted to decline. However, the magnitude of these changes was insignificant compared with overall energy or carbon ratios.

Operation	Total energy MJ ha^{-1} ADAS Model	DTI Model	Difference %	Direct energy MJ ha^{-1} ADAS Model	DTI Model	Difference %
Manganese spray	210	214	1.9	101	128	21.09
Residual weed control	1960	2005	2.2	101	155	34.84
Mower + baler + cart to store	1807	1718	-5.2	1,125	1042	-7.97
Storage	424	353	-20.1	0	0	
Transport	1805	2281	20.9	1640	1869	12.25
Total	6233	6572	5.2	2960	3195	7.36
Energy ratio	**46.5**	**44.1**	-5.4			

Table 1 Comparison of overall energy use in the ADAS and Forestry Commission models.

Finally, the methodologies and source data used in the current exercise were compared with those developed by Forest Research for SRC. Thus, the Excel version was compared with a batch-run model programmed in FORTRAN 77. The Fortran inputsheet required considerable amendment before it was able to process data for the annually yielding energy grasses, but upon completion the models were seen to vary by only 5%.

CONCLUSIONS

The energy ratios reported in this are not only greater than for arable crops and conventional grassland but also higher than any previous estimate of energy grasses or SRC. Similarly, the carbon ratios are extremely high.

Previous estimates of energy ratios have differed markedly between authorities, due to differences in the methodologies employed.

That they have surpassed conventional food crops in popularity with farmers is not surprising, as energy crops can be considered to be a less intensive form of agriculture. The inputs required by energy crops are generally less than for conventional agriculture for several reasons:

- There are fewer husbandry operations during a 20-year productive lifetime than for arable crops. For example, energy crops are perennials and thus require less cultivation than conventional crops.
- Energy is focused into ligno-cellulosic biomass rather than the more energy-intensive protein or sugars of food crops.
- They have low nutrient demands (ie there is some nutrient retention and cycling between growing years that does not occur with annual crops). These energy crops also have the potential to be more efficient in the use of fertilisers.
- They have lower pesticide requirements than arable crops.
- Existing machinery can be used, thus increasing machinery utilisation rates.
- They often have heavier and deeper rooting patterns. This allows the soil to be utilised to a greater depth for water and soil nutrients and provides more time to intercept fertilisers as they migrate downward through the soil. This can also give energy crops greater capacity to intercept fertilisers in lateral flows from adjacent areas. Heavier rooting puts more carbon into the soil and so assists in creating more productive soil conditions. This is achieved by enabling a slow, continuous release of nutrients and by binding chemicals (so that they are selected on the basis of their production of cellulosic biomass, which consumes less input energy (eg light) per unit of energy stored than many specialty plant components).
- They increase the soil carbon sink, and as a result of lower fertiliser requirements and soil disturbance. They also reduce NO_X emissions from soils.
- They are harvested into a relatively dense bale, which allows greater weight to be carried in each lorry journey to the power station, thus reducing the total number of lorry journeys required.

This work is the first to present detailed analysis of the energy ratios of three energy grasses using a consistent methodology and up-to-date research findings. When validated against the ‘Forestry Commission’ model, only 5% variation was found, a figure that was attributable to the more-current input data for energy sources used in the ADAS model.

Comparable levels of energy use, both direct and indirect, were achieved in each model. For identical field operations, differences in direct energy use were as much as 7%, and the indirect energy in machinery use was comparable for similar operations.

The impacts of carbon sequestration, atmospheric emissions and biodiversity have all been assessed as positive. Where quantified in terms of reduced global warming potential (CO_2 sequestration or emission), they have shown insignificant impact on the energy ratios calculated under the base-case scenario, relative to the amounts being mitigated through displacement of fossil energy generation.

POTENTIAL FOR FUTURE DEVELOPMENT

The following future work is recommended:

- Consolidation of the ADAS and FC models, in a user-friendly system that includes the more recent input data; this would benefit the biomass industry and should be seen as priority.
- Extension of the life-cycle analysis of these grasses to consider thermo-chemical conversion routes.
- Linking the developed life-cycle analysis models with Geographic Information Systems and physiological production models (in order to identify the most energy efficient locations for future energy cropping and power plants).
- A review of direct and indirect energy requirements for the production of current agrochemicals (to update the data available and to include current products).

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Report Ref. B/U1/00649/REP (URN 01/1043) Publication date: August 2001

DEVELOPMENT AND DELIVERY OF A WORKSHOP METHODOLOGY: "PLANNING FOR BIOMASS POWER PLANT PROJECTS"

Pat Delbridge Associates International (with Barton Willmore Partnership)

OBJECTIVES

- To provide a proven workshop methodology to be used with stakeholders around biomass power plant planning applications.
- To raise awareness (through the workshop process) of the key issues and concerns that may exist among the various stakeholders in biomass power plant planning.

SUMMARY

In order to meet European and UK government targets for renewable energy, the future will bring an increasing number of applications and a need for those applications to be successful.

Following discussions at the Department of Trade and Industry's (DTI) Environmental Liaison Group, it was suggested that a feedback mechanism would be desirable to enable stakeholders to voice their issues and concerns around biomass power plants. In order to produce this feedback, a workshop methodology was designed, with a view to being replicable (to allow it to be implemented elsewhere around the country).

The report describes the approach used to formulate a workshop methodology to inform planners and other biomass stakeholders of the key issues that may arise when planning for biomass power plants. In doing this, questions, concerns and information needs can be met in advance of an application being determined.

The result of this project was a workshop methodology and workbook guide aimed at informing and understanding the stakeholder issues and concerns around biomass through stakeholder discussions. This workshop and workbook guide are held in a 'How To' Manual (available with the report), entitled:

A 'How To' Manual for Carrying Out a 'Planning for Biomass Power Plants' Workshop.

COST

The total cost of the project, £30,990, was met by the Department of Trade and Industry (DTI).

DURATION

7 months – May 2000 to November 2000

BACKGROUND

Producing energy through sustainable means has been recognised by the UK government as an important element in our energy future. The introduction of government targets to produce energy through renewable sources (such as the renewable energy targets and the climate change targets to reduce carbon dioxide emissions) is seen as a key driver for the future development of renewable energy in the UK.

Biomass power production can offer a significant contribution to meeting these targets in the future, offering a sustainable energy source with less environmental impact than other energy options processed from non-renewable sources. It is generally accepted that there will be an increasing number of biomass power plant applications submitted in the future.

To date most planning permission applications for biomass power projects have been granted but there are also some examples of 'stalled' applications. Questions have been raised amongst biomass proponents regarding the information needs of planners and other key stakeholders in relation to these applications.

In order to move forward with developing biomass power production in the UK there are two key questions, which need to be addressed:

- What are the difficulties that biomass applications may face?
- How can we improve the chance of success of appropriate applications?

This project arose in response to these questions.

The approach used to formulate a workshop methodology, which informs planners and other biomass stakeholders of the key issues that may arise when planning for biomass power plants, is described in the report. Through this process, questions, concerns and information needs can be met before an application is determined.

THE WORK PROGRAMME

The following programme of activities was carried out:

1. An evaluation of written material, including background material, produced in support of planning applications for biomass energy products
2. One on one interviews with stakeholders around biomass power plant applications
3. Two pilot workshops held in Nottinghamshire and Hampshire
4. Preparation of a final report and 'How To' Manual for planners.

CONCLUSIONS

The first phase of the project involved a scoping exercise of the stakeholder issues and concerns. One-on-one interviews were held with stakeholders around biomass applications that had been successfully sited and those that had run into difficulties. The stakeholder categories identified were central government, regulatory authorities, developers, planners, NGOs and local community and resident groups. This phase provided valuable insight into the real and perceived issues and concerns that exist around biomass power plant applications and the role they might play in the success or failure of planning applications.

The compilation of information from the stakeholder interviews can be summarised into three key issues, to be explored in more detail through the pilot workshops:

- The Not In My Back Yard (NIMBY) syndrome, which can exist around all new developments with the potential to impact on a local community or local environment
- The lack of trust in the developer caused by suspicion and misunderstanding of the intent of the developer
- A general lack of awareness and understanding of biomass as a renewable energy resource by planners, politicians and other stakeholders.

The second phase of the project involved designing a workshop methodology, which was tested and informed by two pilot workshops, in Nottinghamshire and Hampshire.

The workshop methodology draws on participants' experiences of biomass power plant planning and looks in more detail at the questions, issues and concerns emerging from the different stakeholder groups. The reasons why some applications succeed or fail are explored and discussed. Finally participants are asked to identify a set of needs and challenges in supporting the development of biomass in the UK for each of the stakeholder groups, thus highlighting the importance of the role that every stakeholder group plays in increasing the likelihood of appropriate planning applications for biomass power plants being approved.

Three key messages evolved from the workshops:

- A more informed and proactive approach to biomass power plant applications was necessary
- Consideration of the stakeholders information needs in a biomass development were necessary
- General education and awareness raising of the importance of renewable energy and the issues, including biomass, was required.

All of the feedback that was gathered from the pilot workshops about both the process and the content of the workshop day, have been fed into the 'How To' Manual (entitled A 'How To' Manual for Carrying Out a "Planning for Biomass Power Plants" Workshop).

[Note: the Workbook is meant as a guide to aid the workshop organiser in identifying the participants, information needs and format by which the workshop can be held.]

POTENTIAL FOR FUTURE DEVELOPMENT

Some key changes were identified in feedback forms that could be considered in the development of workshop methodology:

- The purpose of each section in the workbook needs to be clearly set out to enable participants to have a constant reference as to what they are trying to achieve.
- A number of participants felt that there should be a representative from DEFRA or the DTI to speak from a Central Government perspective.
- An explanation about the changes, in the funding of biomass, from the NFFO to the new Renewables Obligation. Participants felt it would be useful for a representative from Central Government to do this.

- The questions which participants were asked to address when working on the case study were felt to be too broad. Participants felt they needed to have further context and be more specific.
- When participants have limited experience, the small groups may be more effective if each is facilitated to encourage meaningful dialogue.
- Biomass needs to be put in context against other renewable energies and energy efficiency to aid understanding.

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Report Ref: B/W2/00575/REP Publication date: November 2001

ASSESSMENT OF THE VISUAL IMPACTS OF SRC PLANTATIONS

Fawcett and Fawcett

OBJECTIVES

To assess the visual impact of Short Rotation Coppice (SRC) and whether the Guidance currently available in relation to visual impact has been effective.

SUMMARY

There have been previous studies on the public perception of SRC, in terms of relation to landscape and its role as an alternative energy source. A number of concerns were raised over the impacts of SRC: scale of planting, reduction in variety of landscape, regimentation and cloaking of landscape features.

This investigation looked into the potential landscape impacts of SRC and then at how appropriate/helpful current guidelines are, with suggested amendments.

COST

The total cost of the project £18,160 was met by the Department of Trade and Industry (DTI).

DURATION

19 months – May 1998 to November 1999

BACKGROUND

SRC is a new crop and gaining public acceptability is a key step if it is to be widely grown. Inevitably, one of the most important aspects of its acceptability is the perception of the visual impact of the crop on the landscape.

THE WORK PROGRAMME

The main element of the work programme centred on a detailed investigation of eight case study sites: four in North Yorkshire, two in West Yorkshire, one in South Yorkshire and one in Nottinghamshire.

The sites were selected to represent the widest possible range of landscape types and sensitivity available. Site (i) and (ii) lie within the Nidderdale Area of Outstanding Natural Beauty (AONB), sites (iv) and (v) are in urban fringe locations in West Yorkshire, site (vi) is within an area of reclaimed sand and gravel workings and sites (iii), (iv) and (viii) are in differing farmland types, but in lowland landscapes.

A further five sites were assessed on a reconnaissance basis, all of which are in North Yorkshire. Sites (ix) and (x) are within the Nidderdale AONB, sites (xi) and (xii) are in a predominantly arable farming, lowland landscape. Site (xiii) surrounds and lies within the curtilage of a small sewage works set within the countryside.

The sites were studied on a number of occasions at different times of the year to assess the changing character of SRC through its developmental stages, the rate of development and the effect of seasonal change.

Current guidance was then appraised with regard to its effectiveness. There are two main categories of potential impact: 'Landscape Impacts' which are changes in the fabric, character and quality of the landscape as a result of development, and 'Visual Impacts' which are impacts on the character and perception of the visual environment.

The Guidance in respect of SRC in the landscape consists of two documents:

(i) The Forestry Practice Advice Note 1: Short Rotation Coppice in the Landscape. (1996)

(ii) Good Practice Guidelines: Short Rotation Coppice for Energy Production. (1996)

The first was being reviewed and a second issue was due out very shortly.

RESULTS

The effect of SRC on the landscape

Although SRC was seen to have physical and visual characteristics common to both traditional farm crops and forestry, the investigation of case study sites showed that SRC has certain landscape characteristics and combinations of characteristics which are unique.

The change in character and appearance of SRC as it grows, develops and is harvested is significant in determining its effect on the landscape. In the early stages SRC resembles an agricultural crop in terms of height, colour and row planting. As the crop reaches eye level it typically assumes some of the characteristics of forestry plantations. The crop grows rapidly from 0.20m to 5.0-6.0m in a 4-5 year period and changes colour with the seasons. The crop at the tallest stage of growth tends to submerge existing landscape features and pattern of enclosure is lost. Also at this stage the crop affects views.

The extent to which the current Guidelines are being used

Turning first to site assessment and selection, on the basis of the investigations undertaken as part of this study, it seems clear that potential SRC sites materialise usually by way of an expression of interest from farmers and landowners. A decision is then taken by the developer on whether to proceed on the basis of a range of considerations which include taking a view on the principle of the suitability of the potential site in landscape terms.

In the event that application is made to the Forestry Commission for a grant of financial assistance under the terms of the Woodland Grant Scheme a further opportunity exists to assess the suitability of the site both by officers of the Forestry Commission and by officers of the relevant local authority, usually the District Council, where these are consulted.

CONCLUSIONS

As SRC becomes widely planted it will inevitably give rise to changes in the character and appearance of the rural landscape. Early studies of the perception of SRC indicated that adverse effects are likely to centre on scale and concentration of planting, reduction in diversity and variety in the countryside, regimentation and the cloaking or submergence of existing landscape features.

To understand the effects of SRC on the landscape, it is necessary to consider both the inherent characteristics of SRC itself and those characteristics of the landscape which are likely to be susceptible to change as a result of the introduction of SRC.

Although SRC shares some of the landscape characteristics of traditional farm crops and some of forestry it does have certain characteristics or combinations of characteristics which are unique.

Of the 13 SRC sites investigated as part of this assessment, four sites have been said to give rise to adverse effects in relation to the value of the landscape, as a result of the following: the perception of SRC as an exotic or alien crop; the loss of traditional permanent pasture and meadowland; the swamping or submergence of existing pattern of fields; and the impact on adjacent residential properties. The remaining nine sites were not recorded as giving rise to adverse effects.

The evidence indicates overwhelmingly that the acceptability of SRC in the landscape depends first and foremost on selecting an appropriate site.

POTENTIAL FOR FUTURE DEVELOPMENT

A key amendment to current guidelines is:

The importance of assessing the suitability or otherwise of prospective SRC sites at the outset must be stressed. Clearer guidance on how these assessments are to be carried out should be provided (see reference below).

FURTHER INFORMATION

For further information, see the Forestry Commission Guideline Note ‘Short Rotation Coppice in the Landscape’ (Bell & McIntosh, August 2001).

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B/U1/00644/REP (URN 01/1342)

CARBON ENERGY BALANCES FOR A RANGE OF BIOFUELS OPTIONS

Resources Research Unit, Sheffield Hallam University

OBJECTIVES

The particular aims of this project were to produce a set of baseline energy and carbon balances for a range of electricity, heat and transport fuel production systems based on biomass feedstocks. The specific objectives were:

- To agree the selection of up to 15 biofuel technologies for assessment.
- To collate existing information on these technologies.
- To produce a series of flow charts representing these technologies.
- To divide the technologies into relevant modules.
- To review the collated information for establishing base case energy and carbon requirements for each module within each technology.
- To identify any significant emissions of greenhouse gases other than carbon dioxide for each module.
- To estimate such emissions where relevant data exist.
- To specify which values are uncertain and the additional information needs.

SUMMARY

This work is set within the context of the emergence and establishment of a variety of biofuel technologies, which use biomass to provide commercial sources of energy whilst offering significant potential benefits, in terms of savings in fossil fuel resource depletion and greenhouse gas emissions. It is well-known that all technologies, including biofuel options, involve the use of fossil fuels in their production and operation, resulting in associated greenhouse gas emissions. Hence, the actual benefits realised by biofuel technologies depend, crucially, on their energy and carbon balances. These indicate the magnitude of their fossil fuel inputs (and related greenhouse gas emissions) relative to subsequent fossil fuel savings (and avoided greenhouse gas emissions) resulting from their use as alternatives to conventional sources of energy. A considerable number of studies have been conducted for evaluating such energy and carbon balances for a range of biofuel options. However, these studies have been performed in a variety of ways and are presented with different degrees of transparency. Consequently, a consistent approach is needed to provide a coherent and comprehensive assessment and

comparison of the energy and carbon balances for a range of important biofuel options in the United Kingdom.

COST

The total cost of the project, £46,813, was met by the Department of Trade and Industry (DTI).

DURATION

14 months – January 2002 to February 2003

BACKGROUND

There is a variety of emerging and established biofuel technologies which use biomass to provide commercial sources of energy in the form of electricity, heat and/or transport fuels. Such biofuels can offer significant benefits, in the form of reductions in fossil fuel resource depletion and carbon dioxide and other greenhouse gas emissions, which are implicated in global climate change. However, all technologies, including biofuel options, have some associated consumption of fossil fuels and emissions of greenhouse gases, directly and/or indirectly. Hence, the actual benefits which can, in practice, be realised by biofuels depend, crucially, on their energy and carbon balances. These indicate the magnitude of fossil fuel inputs (and related greenhouse gas emissions) relative to subsequent fossil fuel savings (and avoided greenhouse gas emissions) resulting from their use as alternatives to current commercial sources of energy. A considerable number of studies have been conducted for evaluating such energy and carbon balances for a range of biofuel options. However, these studies have been performed in a variety of ways to achieve diverse objectives, and are presented with different degrees of transparency.

Nevertheless, given an appropriate approach, these existing studies present the opportunity to formulate a consistent, coherent and comprehensive assessment and comparison of the energy and carbon balances for a range of important biofuel options in the United Kingdom (UK).

THE WORK PROGRAMME

The process of selecting biofuel technologies was based on consultation with scoping advisors. The resulting 18 separate biofuel technologies consisted of the following:

- biodiesel from oilseed rape
- biodiesel from recycled vegetable oil
- combined heat and power (large-scale with an industrial load) by combustion of wood chip from forestry residues (large- scale)
- combined heat and power (small-scale) by gasification of wood chip from short rotation coppice
- electricity (large-scale) by combustion of miscanthus
- electricity (large-scale) by combustion of straw
- electricity by combustion of wood chip from forestry residues (large-scale)
- electricity by combustion of wood chip from short rotation coppice
- electricity by gasification of wood chip from forestry residues (large-scale)
- electricity by gasification of wood chip from short rotation coppice

- electricity by pyrolysis of wood chip from forestry residues (large-scale)
- electricity by pyrolysis of wood chip from short rotation coppice
- ethanol from lignocellulosics
- ethanol from sugar beet
- ethanol from wheat
- heat (small-scale) by combustion of wood chip from forestry residues (large-scale)
- heat (small-scale) by combustion of wood chip from woodland residues (small- scale)
- oil from oilseed rape.

Application of a modular structure for describing biofuel technologies determines that nine biomass provision modules and 12 biomass processing modules were required to evaluate baseline carbon and energy balances for 18 selected biofuel technologies. A review of 43 existing studies on these selected biofuel technologies enabled the most suitable existing studies to be selected for the preparation of baseline carbon and energy balances.

Flow charts were formulated to represent the essential stages of the production of biomass and its conversion into relevant biofuels, as well as the prominent inputs and outputs for each process chain.

RESULTS AND CONCLUSIONS

- There is a substantial collection of existing studies on the energy inputs and greenhouse gas outputs of a range of biofuel technologies which could be potentially important in the UK.
- Although these studies vary in relevance, detail and transparency, it was possible to identify those which could provide a suitable basis for deriving baseline energy and carbon balances for selected biofuel technologies.
- Complete estimates of primary energy inputs and carbon dioxide, methane, nitrous oxide and total greenhouse gas outputs, qualified by indications of uncertainty, were calculated for selected biofuel technologies.
- These estimates were recorded in spreadsheets, supported by flow charts and detailed notes to provide a high degree of standardisation and transparency.
- Results were derived in the form of energy, carbon dioxide, methane, nitrous oxide and total greenhouse gas requirements, and these baseline results demonstrate that all the biofuel technologies considered achieve, in varying degrees, positive energy and greenhouse gas benefits, which would offer savings in the consumption of fossil fuel resources and associated emissions of greenhouse gases.

A summary of the energy, carbon, methane, nitrous oxide and total greenhouse gas requirements for the selected biofuel technologies is presented in Table 1 at the end of this abstract.

POTENTIAL FOR FUTURE DEVELOPMENT

As part of recommendations for further work, the following additional data requirements were identified:

- Agricultural activity data for estimating the primary energy inputs and greenhouse gas outputs of the manufacture, repair and maintenance of agricultural machinery used in the production of oilseed rape, miscanthus, sugar beet and wheat.

- Agreed evaluation of the effect of removing straw from fields for fuel use on fertiliser use and yields for subsequent crops.
- Direct methane and nitrous oxide emissions from the operation of a combined heat and power plant based on the gasification of wood chips, power only plant based on the combustion, gasification and pyrolysis of wood chips, and an ethanol plant based on lignocellulosics (straw).
- Physical inventories of plant components for calculation of the primary energy inputs to the construction of a combined heat and power plant based on the combustion of wood chips, power only plant based on the combustion of miscanthus, straw and wood chips, and ethanol plant based on lignocellulosics (straw), sugar beet and wheat.
- Direct methane and nitrous oxide emissions factors for the combustion of liquid biofuels and their equivalents, such as diesel oil, petrol and fuel oil derived from crude oil, on an agreed and comparable basis.
- A set of equivalent reference results for conventional fuels, electricity and heat supplies for consistent and comprehensive comparison with results for biofuel technologies.

FURTHER INFORMATION

A separate project report on “Carbon and Energy Modelling of Biomass Systems: Conversion Plant and Data Updates” (B/U1/00644/REP, URN 01/1342) is also available from the DTI publications Web site.

Table 1: Summary of Energy, Carbon, Methane, Nitrous Oxide and Total Greenhouse Gas Requirements for Selected Biofuel Technologies

Selected Biofuel Technology	Energy Requirement (MJ/MJ)	Carbon Requirement (kg CO_2/MJ)	Methane Requirement (g CH_4/MJ)	Nitrous Oxide Requirement (g N_2O/MJ)	Total Greenhouse Gas Requirement (kg eq CO_2/MJ)
Biodiesel from oilseed rape	0.437 ± 0.024[(a)]	0.025 ± 0.001[(a)]	0.028 ± 0.002[(a)]	0.048 ± 0.006[(a)]	0.041 ± 0.002[(a)]
Biodiesel from recycled vegetable oil	0.188 ± 0.018[(a)]	0.013 ± 0.002[(a)]	0.007 ± 0.001[(a)]	-	0.013 ± 0.002[(a)]
Combined Heat and Power (large scale with industrial load) by combustion of wood chip from forestry residues	0.139 ± 0.012[(b)]	0.007 ± 0.001[(b)]	0.002[(b)]	0.005[(b)]	0.008 ± 0.002[(b)]
Combined Heat and Power (small scale) by gasification of wood chip from short rotation coppice (Option A)	0.102 ± 0.019[(b)]	0.005 ± 0.001[(b)]	0.001[(b)]	-	0.005 ± 0.001[(b)]
Combined Heat and Power (small scale) by gasification of wood chip from short rotation coppice (Option B)	0.092 ± 0.016[(b)]	0.004 ± 0.001[(b)]	-	-	0.004 ± 0.001[(b)]
Electricity (large scale) by combustion of miscanthus	0.272 ± 0.019	0.018 ± 0.001	0.008	0.021	0.026 ± 0.001
Electricity (large scale) by combustion of straw	0.607 ± 0.038	0.029 ± 0.002	0.025 ± 0.003	0.111 ± 0.011	0.066 ± 0.004
Electricity by combustion of wood chip from forestry residues (large scale)	0.309 ± 0.023	0.016 ± 0.001	0.004	0.019	0.022 ± 0.001
Electricity by combustion of wood chip from short rotation coppice (Option A)	0.381 ± 0.056	0.018 ± 0.003	0.004	0.025 ± 0.003	0.025 ± 0.003
Electricity by combustion of wood chip from short rotation coppice (Option B)	0.352 ± 0.048	0.016 ± 0.002	0.003	0.023 ± 0.003	0.023 ± 0.003
Electricity by gasification of wood chip from forestry residues (large scale)	0.133 ± 0.009	0.007	0.003	-	0.007
Electricity by gasification of wood chip from short rotation coppice (Option A)	0.169 ± 0.027	0.008 ± 0.001	0.003	0.001	0.008 ± 0.001
Electricity by gasification of wood chip from short rotation coppice (Option B)	0.154 ± 0.023	0.007 ± 0.001	0.003	-	0.007 ± 0.001
Electricity by pyrolysis of wood chip from forestry residues (large scale)	0.284 ± 0.022	0.014 ± 0.001	0.014 ± 0.002	-	0.014 ± 0.001
Electricity by pyrolysis of wood chip from short rotation coppice (Option A)	0.331 ± 0.040	0.016 ± 0.002	0.014 ± 0.002	0.001	0.016 ± 0.002
Electricity by pyrolysis of wood chip from short rotation coppice (Option B)	0.312 ± 0.035	0.014 ± 0.002	0.014 ± 0.002	0.001	0.015 ± 0.002
Ethanol from lignocellulosics (wheat straw)	- 0.028 ± 0.037[(a)]	0 ± 0.002[(a)]	- 0.024 ± 0.005[(a)]	0.043 ± 0.005[(a)]	0.013 ± 0.002[(a)]

Ethanol from sugar beet	0.496 ± 0.044[a]	0.034 ± 0.003[a]	0.013 ± 0.001[a]	0.018 ± 0.002[a]	0.040 ± 0.003[a]
Ethanol from wheat	0.464 ± 0.032[a]	0.024 ± 0.002[a]	0.028 ± 0.003[a]	0.012 ± 0.001[a]	0.029 ± 0.002[a]
Heat (small scale) by combustion of wood chip from forestry residues (large scale)	0.100 ± 0.006	0.005	0.017	0.005	0.007
Heat (small scale) by combustion of wood chip from woodland management (Option A)	0.092 ± 0.006	0.005	0.017	0.005	0.007
Heat (small scale) by combustion of wood chip from woodland management (Option B)	0.094 ± 0.006	0.005	0.017	0.005	0.007
Rapeseed Oil from oilseed rape	0.291 ± 0.018[a]	0.015 ± 0.001[a]	0.020 ± 0.002[a]	0.046 ± 0.006[a]	0.031 ± 0.002[a]

Notes

(a) Based on the net calorific value of the biofuel.

(b) Per unit of electricity or heat.

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Report Ref. B/U1/00627/REP (URN 04/961) Publication date: May 2004

ARBRE MONITORING – ECOLOGY OF SHORT ROTATION COPPICE

The Game Conservancy Trust (with The Central Science Laboratory)

OBJECTIVES

- To monitor appropriate flora and fauna within and around a suitable number of commercially managed Short Rotation Coppice (SRC) plantations established as a fuel source for Project ARBRE.
- To use this information to assess the impact of the SRC plantations on wildlife in the area.

SUMMARY

The project aim was to describe the ecological impact of planting commercially managed SRC plots on arable land. Four wildlife groups (birds, plants, butterflies and general invertebrates) were monitored over a four-year period. In order to properly quantify the ecological impact on these chosen groups, arable control plots representing the previous land use were also monitored. Monitoring was carried out at various distances from the edge of the crops to determine the importance of edge habitat.

The data also provided information on weed and insect pest populations within commercially planted SRC plots contributing to the efficient management of SRC.

The results obtained show that commercially managed SRC plots contain a higher diversity of wildlife

Figure 1. Fieldfare within SRC (courtesy of The Game Conservancy Trust)

than the arable fields being replaced, although some species are also displaced.

COST

The total cost of the project, £91,393, was met by the Department of Trade and Industry (DTI).

DURATION

51 months – January 2000 to March 2004

BACKGROUND

SRC is a crop grown to produce wood chips for subsequent conversion, to provide heating or power generation. The development of commercially planted SRC plots represents a significant step towards the UK government's commitment to renewable energy production and the reduction of greenhouse gases. The ARBRE electricity-generating plant was to have been the first commercial plant of its type in the UK using wood chips from forestry and purpose-grown SRC plantations. It is anticipated that commercially planted SRC could become a widespread feature of the countryside, representing a major change in land use.

At present there is very little information on the impact of large-scale SRC plantations on the countryside and its wildlife. The planting of large scale SRC plots creates a new habitat that could potentially provide opportunities for colonisation by many plant and animal species. Previous studies carried out on non-commercial SRC have already shown the crop to be beneficial to wildlife. However, these previous studies were carried out on SRC plots that tended to be smaller in size, with a more varied age structure and fewer agricultural inputs than the commercially planted plots used in this study.

Replacing existing arable land with SRC could also be potentially detrimental to some species preferring open habitats. Recent declines in bird species associated with farmland habitats have been of concern to conservation groups. In this study, paired arable control plots were also monitored in order to document both gains and losses in wildlife resulting from the change in land use associated with planting SRC.

In order to facilitate the objectives of the project a further four-year study began in May 2002 to determine the conservation value of SRC plots planted on grassland sites. This is also being funded by DTI. As SRC planted on grassland sites does not differ fundamentally from SRC planted on arable land, the same wildlife groups are being monitored using the same methodology. This new study can be viewed as an extension of this project and on completion will provide even more information on the impact of commercial SRC on wildlife, as well as allowing the effect of previous land use to be examined.

THE WORK PROGRAMME

A total of 12 sites (along with 12 nearby arable fields to be used as control plots) were identified as suitable for use in the project. Four wildlife groups were monitored during the project: birds, plants, general insects and butterflies. Birds and butterflies were specifically chosen due to their conspicuous nature, which makes them easy to monitor. Many other groups (such as small mammals) were considered to require additional effort that could not be adequately undertaken within the broad constraints of the project.

The breeding birds of SRC

Breeding birds were monitored using a point count methodology on two separate occasions in the spring during each year of the project. This enabled the density of birds to be estimated within both SRC plots and arable control fields. Bird densities were estimated both at the edge and interior of the crop, as well as in the boundaries adjacent to the crop

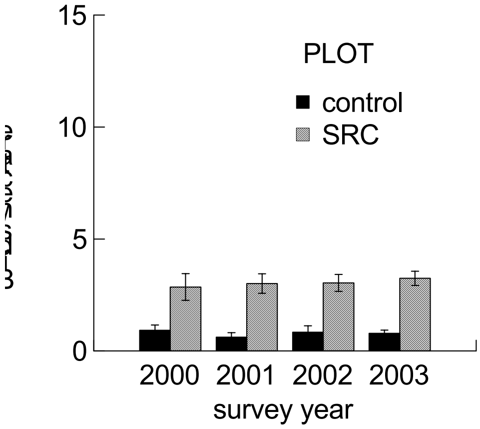

Figure 2. Density of birds within SRC and arable control plots during each year of the project

Wintering farmland birds of SRC

In order to provide a more complete study of wildlife use in commercial SRC plots throughout the year, wintering birds were also monitored (by walking transects through the plots). Four visits were made to each site (during the last three years of the project) to take account of the high mobility of birds during the winter in response to weather conditions and food supply.

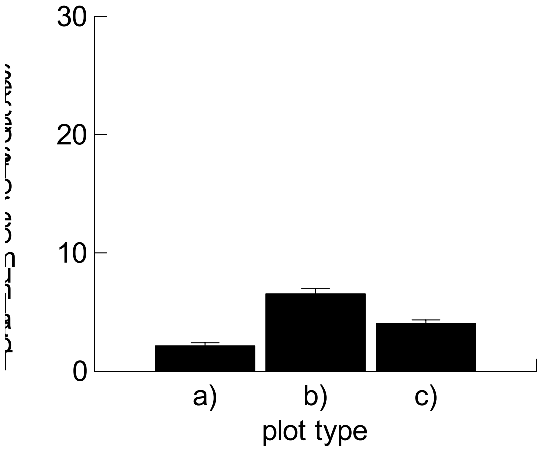

Figure 3. Total number of bird species recorded per visit wintering in a) arable control plots b) recently harvested or cut SRC c) established SRC

Vegetation within SRC and arable control plots

Vegetation was monitored annually throughout the study from a number of quadrats positioned at various distances from the crop edge along two transects in each SRC plantation and arable control field. Vegetation was also monitored from the surrounding headlands. Both percentage vegetation cover and the total number of species present and relative abundance were recorded. Plant species were separated into annuals, invasive perennials and long-lived perennials, which enabled succession to be documented within the SRC plantations.

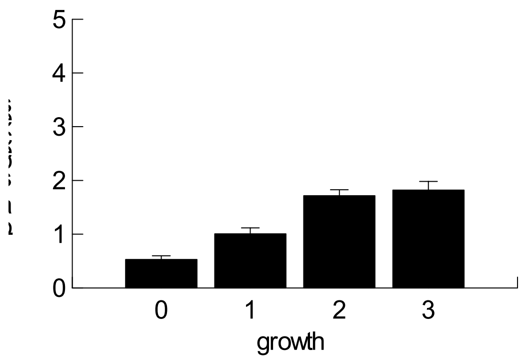

Figure 4. Total number of plant species recorded per 1x10 metre quadrat with a greater than 10% cover at various stages of willow growth (years) within SRC plots

Butterflies of SRC

Butterflies were monitored along transects around the edge of the SRC and arable plots using standard methodology involving timed counts. Monitoring was carried out three times during the summer to allow for seasonal variation between different species.

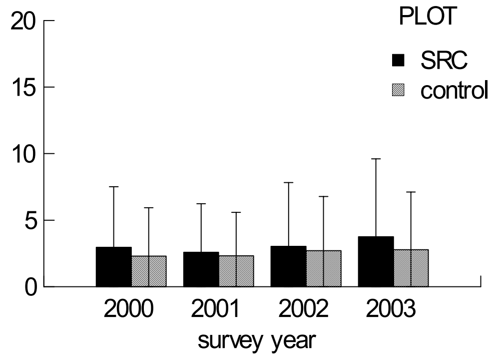

Figure 5. Mean number of butterfly species recorded per visit in SRC and arable control sites during each year of the study

General invertebrates of SRC

General invertebrates were sampled twice a year within the SRC only using standard beating techniques. Samples were taken at various distances from the crop edge

CONCLUSIONS

- Higher densities of birds and more bird species were recorded during the summer in the SRC plots than in the controls. The SRC plots also contained more bird species than the controls. Densities of migrant bird species, such as warblers were as high in the edge of established SRC as they were in the surrounding hedgerows and adjacent boundaries. Resident bird species tended to prefer the hedgerows to the SRC. Bird density was higher at the edge than the interior of the plantations.
- The bird community changed in response to increased willow growth. Densities of tits, finches and warblers increased over the study. Thrushes reached a maximum density in two year-old SRC, and game birds in one-year old SRC. Those species identified as preferring open habitat (such as skylarks and wagtails) declined as the willow became established.
- Recently planted and cutback plots support higher numbers of skylarks and lapwings than the arable fields.
- The density of birds in the commercially managed plots was lower than had previously been recorded in non-commercial SRC, perhaps reflecting the larger size, more uniform age structure and higher levels of agricultural inputs in commercially managed plots.
- In the winter there were on average more species of birds in the SRC plots than in the arable controls. Recently planted SRC was especially attractive to buntings, with several yellowhammer and reed bunting flocks recorded. Many groups of birds preferred younger coppice, although tits were more abundant as the plots became more established. Both snipe and woodcock were regularly flushed from SRC in the winter, but were only rarely recorded from arable plots.
- The majority of plant species found both in arable fields and recently established SRC plots were annuals, characteristic of disturbed ground. There was a significant decrease in the proportion of annuals as the SRC became established and higher proportions of both invasive and long-lived perennials. The number of species present with a greater than 10% cover increased with each successive year's growth. The amount of vegetation cover varied between sites. In recently established plantations vegetation cover was higher at the edge of the

plots. Vegetation cover increased for the first year after planting, but then remained fairly constant. Although vegetation height was not measured, it is predicted that the levels of vegetation cover recorded are generally not sufficiently high enough to significantly reduce yield.

- The butterfly community of both the SRC plantations and arable controls was dominated by relatively common species, with the meadow brown being the most abundant species. However, more butterflies were recorded in the relatively unmanaged and sheltered headlands of the SRC plantations than the arable control headlands. Both the number of individual butterflies and number of species increased over the four-year period of the study as the willow coppice became more established.
- The mean number of invertebrate orders also increased with subsequent growth of the willow coppice. There was a tendency for the edge of the plots to have higher numbers of invertebrates than the interior. The blue willow beetle (*phyllodecta vulgatissima*, a pest species) formed a high proportion of the total number of invertebrates recorded.

POTENTIAL FOR FUTURE DEVELOPMENT

The results of this study are able to provide guidance on the ecological impact of future commercial SRC developments.

Maximum conservation benefits can be obtained by continuing to retain hedgerows and open rides within the crop. Plots containing a variety of different growth stages are recommended.

The results of this study show recently planted SRC plots to be better than arable plots for open species such as skylark and lapwing. These are species of high conservation concern that have undergone declines in recent years. Additional, more extensive research is probably needed to determine whether or not these species are able to breed successfully on recently established SRC plots before the rapid growth of the willow crop.

Vegetation within the established commercial plantations was a mixture of invasive perennials and long-lived perennials, especially grasses. In contrast, vegetation in arable plots consisted primarily of annual species, which is characteristic of disturbed ground. The longer-lived, more stable plant communities are to be encouraged, as they have lower transpiration rates and consequently are less likely to compete with the SRC crop for moisture.

The presence of long-lived perennial species on headlands and rides is of value not only in terms of conservation but also provides a nectar source for beneficial insects, such as parasitic wasps with the ability to control pest outbreaks.

Further research would be valuable in determining the best management strategies within commercial SRC to encourage more stable perennials rather than invasive weeds. High levels of fertiliser applications may encourage species such as nettles to dominate.

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Report Ref: B/W1/00788/REP (URN 04/1080) Publication date: July 2004

ENVIRONMENTAL IMPACT OF THE EXTRACTION OF FORESTRY RESIDUES

Cranfield University (with Macaulay Land Use Research Institute and Canopy Consulting, a division of TRADA).

OBJECTIVES

- To review current forestry practices for the treatment of residues and production of wood fuels and their impacts on air, land, water, flora and fauna, including soil and landscape. The review would adopt a UK focus but would also consider international experience.
- To develop scenarios of how practice may change to develop and maintain sustainable supplies of forestry residues over a timeframe to 2020. The quantity of forest land from which residues may be available would be indicated.
- To consider how current environmental impacts may change as a result of the removal of forestry residues.
- To identify gaps in knowledge.
- To propose guidelines for the monitoring of a scheme to test the conclusions.
- To report in ways accessible to the layperson.

Figure 1. Woodchip pile at Thetford Forest (courtesy of Cranfield University)

SUMMARY

Biomass will play an important role in meeting the target of generating 10% of electricity from renewable energy by 2010. The implementation of this policy could lead to the use of significant volumes of forest residues and the establishment of between 100,000 and 150,000ha of energy crops in England and Wales. However, there are potential environmental impacts from the removal of forest residues, for the UK. The issues to be considered are:

- preservation of sustainable forest productivity
- protection of soil
- maintenance of water quality, through the control of sediment transport

- maintenance of bio-diversity
- carbon sequestration
- woodland amenity and access.

COST

The total cost of the project, £102,830, was met by the Department of Trade and Industry (DTI).

DURATION

21 months – April 2002 to December 2003

BACKGROUND

Published material on the environmental impacts of residue removal, under UK conditions, was inadequate to assess the limits to a change of practice. Information may be supplemented from two sources. The first is the understanding of the issues and constraints within the UK forestry profession and the timber harvesting skill-base. The second is the creation of geographic information system (GIS) models employing soil, topography, forest area, and climate data. These models can be used to consider scenarios, based on impact thresholds, to produce assessments on the proportion of forest areas from which residues may become available.

The model is not intended as a site management tool. Nonetheless, the soil parameters on which the models are based provide a checklist of environmental considerations for managers, providing a decision support mechanism. The incorporation of yield data in the models of environmental impact, and development of the tool nationally would serve policymakers and investors in biomass energy.

THE WORK PROGRAMME

A review of the knowledge base on whole- tree harvesting and the environmental impacts was conducted using published sources and discussions with the forestry and biomass energy industries. UK literature on this topic was scarce and the relevance of international literature to UK conditions was weak for many of the impacts. This enhanced the importance of the discussions with industry. These discussions embraced a wide geographic spread within Great Britain, but the results were considered to be relevant also to Northern Ireland.

The selection of case study areas on which GIS models were tested was similarly broad, but not random. Each of the seven study areas was 20km x 20km. These were located at:

- Clashindarroch
- Morven and Aros
- Southern uplands
- Clocaenog
- Thetford
- South Downs
- New Forest.

Significantly, the selection covered a wide climatic and edaphic range, where forestry was a major land use. A number of datasets, based on 1:250,000 soil maps, and common to Scotland, England and Wales have been adopted. These were:

- critical loads of acid deposition
- erosion risk, based on topography
- groundwater vulnerability, based on geology and soils
- soil compaction risk based on soil moisture retention characteristics, integrated with climatic parameters

- soil fertility for tree growth, which employs soil pH.

Only the physico-chemical impacts associated with whole-tree harvesting, listed above, can be modelled. Carbon sequestration and biodiversity impacts were excluded. The policy/management drivers behind decisions to harvest forest residues were irrelevant to the model.

Thresholds for each data layer have been selected, representing an assessment of each individual impact on the suitability of a site for residue extraction. In practice the terms ‘highly’, ‘moderately’ and ‘marginally suitable’ may refer to the likely degree of impact (for example, acidity load) or to differing periods of time in which site conditions permit residue extraction (such as soil wetness). The term ‘unsuitable’ is applied to those areas where typically there is no opportunity during the year to traffic the soils without environmental damage, or at a very limited number of sites which have an exceptionally high acidification risk.

Harvesting of residues which have been used as brashmats and trafficked is not a realistic prospect because of soil contamination. Currently, the model is insufficiently sophisticated to enable division between non-harvested brashmat material and surplus harvestable residues.

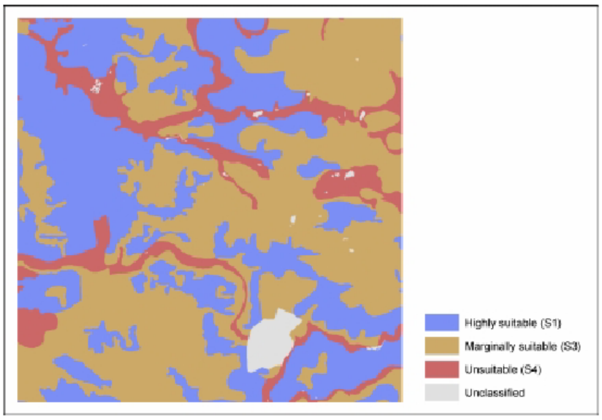

Figure 2. Suitability classification for residue extraction in Thetford, based on critical loads of acidity (courtesy of MLURI and Cranfield University)

The case study areas represented only 2.8% of the forest area of Great Britain. It was decided not to include a simple numerical extrapolation of the model outputs to estimate the resource for the whole country. It was possible, however, to consider the model outputs against a national survey, derived from expert opinion and reported by forest district, of the potential woodfuel resource from traditional forestry (McKay *et al,* 2003), available at http://www.woodfuelresource.org.uk].

Study area	**% high/ moderate suitability**	**% marginal suitability**	**% un-suitable**	**% residues available in district** (McKay)
Clashindarroch	7.6	73.9	18.5	0
Morven and Aros	12.7	23.0	64.3	13-21
Southern Uplands	0.2	70.0	29.8	0-40
Clocaenog	0.3	93.0	6.7	20-59
Thetford	34.9	55.9	9.2	19-62
South Downs	65.3	23.6	11.1	46-61
New Forest	70.9	14.2	14.9	16-38

Table 1. Comparison of availability of forest residues determined by geographical model (from this project) against expert knowledge (reported in McKay et al, 2003).

The GIS models tended to under-estimate the proportion of forest land unsuitable for residue extraction, relative to the expert system, and the models appeared insufficiently sensitive in considering sites such as the Southern Uplands and Clocaenog. Nonetheless, the project team was reassured by this comparison.

CONCLUSIONS

- The model outputs differentiate between limited opportunities for residue harvesting from upland forest sites in the north and west of the UK and greater potential from lowland forestry in the south. This reflects the different physio-chemical conditions.
- Whilst the distinction between upland and lowland forestry is reasonably clear, in fact there was considerable variation in the way these cumulative impacts were derived.
- The contrast in the soil compaction assessment between case sites in the west and those in the east was very marked. Poorly drained soils (peaty gleys and peat) in the west of Scotland contributed principally to the large area deemed unsuitable for residue extraction. However, soil wetness class assessment assumes no tree cover, and so the assessment presented here is the worst case. Adjustment to the classification would require further information.
- The absence for the most part of any areas highly suitable for residue extraction was principally a result of the classification relating to soil fertility. The relationship between surface soil pH and fertility is weak for forest soils but this approach was adopted. Furthermore, the thresholds within the adopted dataset were not ideal. As a result, the model outputs were considered particularly precautionary regarding the adverse impacts of residue removal on soil fertility.
- Since the adopted dataset was developed originally to provide data to the Forestry Commission on soil fertility and tree growth the broad categorisation requires further consideration.
- The limitations imposed by the scale of the data, on which the models were based, meant that the approach adopted is not appropriate for the creation of a site management tool.
- The basis of a system, which stands comparison with an expert system, has been developed. It is considered that one of the problems of comparing the expert and modelled systems is simply one of nomenclature. Land which has been termed ‘marginally suitable’ for residue extraction may conjure different reactions in the minds of different users. The project team was supportive of the expert system as a mechanism for audit of forest residue stock in 2003, which may be projected some years hence. The team sees no need, therefore, to try to extrapolate its own data and would instead direct readers to the report of McKay *et al* (2003). However, we contend that the modelling approach is potentially much more flexible and would enable direct, true geographic interpretation.

POTENTIAL FOR FUTURE DEVELOPMENT

National development of the model is advocated, to enable user-friendly investigation of forest residue availability within a selected radius of any grid reference. The advantage of scenario setting using digital models is that this development would be relatively straightforward. Some further research is needed to underpin the setting of threshold values for classifying site suitability for residue extraction. Inclusion within the model of yield prediction, for different tree species, and therefore of the associated residues, would be of considerable benefit to policy makers and to those proposing to invest in biomass energy generation.

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Report Ref. B/CR/00783/00/00 (URN 04/1600) Publication date: October 2004

THE HYDROLOGICAL IMPACTS OF ENERGY CROP PRODUCTION IN THE UK

Centre for Ecology and Hydrology, Wallingford

OBJECTIVES

- To determine the effects on water availability at the catchment and sub-catchment scale, of production of energy crops, across England and Wales.
- To indicate areas where the crops will be most productive, which will be largely determined by water availability.
- These have been achieved through a combination of measurements and the application of validated models, in conjunction with a GIS, to allow the change in water use accompanying the replacement of existing land cover with energy crops to be calculated.

SUMMARY

With the recent surge in favour for renewable energy, there has been steady progress in the development of energy crops, such as Short Rotation Coppice (SRC) and Miscanthus. These are viewed as environmentally beneficial since, when compared with fossil fuels, burning them would reduce CO_2 emissions. Additionally they would provide new habitats and ecosystems.

These energy crops, however, have a high demand on water. Therefore before planting any new sites, consideration must be given as to whether the environment around it can provide that water. The outcome of this report was to provide the modelling tools that would enable this consideration efficiently and effectively.

COST

The total cost of the project, £126,976, was met by the Department of Trade and Industry (DTI).

DURATION

31 months – January 2002 to August 2004.

BACKGROUND

Over the last decade there has been steady progress in the development of energy crops across the UK, with increasing areas of land planted with SRC, especially willow. Other crops, in particular certain grasses, are potential energy crops and have been the subject of research for several years and are now approaching the stage where commercial plantation is starting, eg *Miscanthus.* In many respects energy crops are thought to be environmentally beneficial, most importantly in providing a fuel that, when used to replace fossil fuels, would reduce CO_2 emissions to the atmosphere, but also in providing habitats and ecosystems that support increased biodiversity.

However, along with the rapid growth that characterises and qualifies particular plants as energy crops, there is the high water use. This has been shown in several studies on trees grown as SRC eg willow and poplar species (Hall *et al.*, 1996), and also in a few studies on energy grasses (eg Beale *et al.*, 1999). Although the water use for irrigation of *Miscanthus* is similar to the water use by SRC, it has a higher water use efficiency so that the production of dry matter is substantially larger. For this and other agronomic reasons they are seen as a potentially very useful source of biomass energy. Bullard (1999) estimates that the UK would need energy crops to be grown on in excess of 110,000ha (assuming a yield of 18 tonne ha^{-1}) if 5% of energy generation is to be produced from energy crops.

Nevertheless, if biomass conversion is to make a significant contribution to the national energy supply, large areas will need to be planted around purpose-built power stations. Careful consideration must be given to the location and scale of these plantations if adverse impacts on the water resources are to be avoided. This is particularly true in the south-east of the country where high population density and small differences between the precipitation and the evaporation, ie low effective precipitation, makes southern England particularly sensitive to any reduction in groundwater recharge or river flow.

THE WORK PROGRAMME

The first phase of the project was the production of guidelines for siting individual plantations. These were published in May 2003:

'Grasses for energy production – hydrological guidelines URN 03/882'

'SRC for energy production – hydrological guidelines URN 03/883'.

Models for water use of energy crops grown in the UK were produced. This involved significant fieldwork that was required to provide the data essential for developing, running and testing the models. This fieldwork component focused on measurements at Roves Farm, on willow SRC, and at Rothamsted, Woburn and Richard's Castle on the energy grasses *Miscanthus* and switchgrass (*Panicum virgatum*). The Met Office Surface Exchange Scheme (MOSES) is the model that was used as the basis for this work.

Sub-catchment level modelling of hydrological impacts of energy crop production in the UK was then carried out. The first model was used in conjunction with gridded sets of the driving data. These data comprise rainfall, climate, soils, land cover, and elevation for England and Wales at a range of resolutions. Some of these data were transformed to grids at different spatial (and temporal) resolutions and some variables were determined from others; eg in the weather driving data, sunshine hours were used to derive radiation values.

Once the appropriate driving variables were calculated they were used, with the model, to calculate the water use of a selected energy crop at a selected location. Monthly coverages of the virtual additional abstraction for each of the energy crops were produced for a typical, a wet and a dry year. These will be required for accurate assessment of the resource balance in sub-catchments and the Water Resource Management Units (WRMU) of the EA Catchment Abstraction Management Strategy (CAMS).

Other output products from this project include:

- hard-copy maps of additional abstraction for England and Wales;
- a demonstration GIS data set, supplied on CD, operational within a restricted 60 km by 60 km area of the country and hydrological data, eg run off, and drainage on a restricted area of 60 km by 60 km;
- A Visual Basic program to extract data from the system.

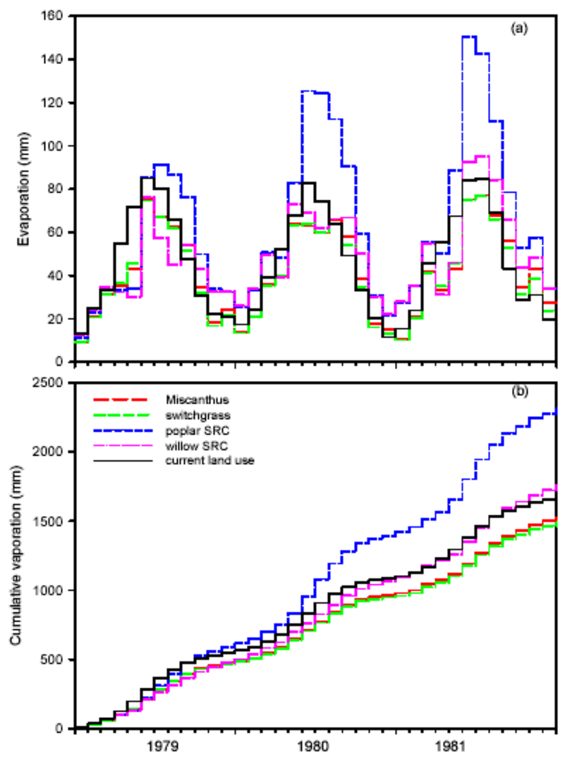

Figure 1 Comparison of the predicted monthly water use of the energy crops and current land use 1979-1981

CONCLUSIONS

- The effect of enhanced evaporation at the edges of SRC plantations is localised and so will have the greatest impact on small plantations. For plantation greater than 10ha the effect is certainly comparable or less than other factors, eg the nature of the soil.
- More measurements are needed on poplar SRC varieties to determine whether the high water use is a consistent feature and, if not, the model should be run using the new information.
- Additional measurements are needed on the energy grasses in order to reduce the uncertainty arising from the model parameter values.
- For the same rainfall and soils, the water use of the energy grasses is likely to be less or comparable to that of the existing land cover where it is grass or tilled land and less if the existing land cover is woodland or heathland.
- In the final year of the three year cropping cycle, the water use of SRC is likely to be greater than the existing land cover if it is grass or tilled land and comparable or greater if it is woodland or heathland. However, in the first year it is likely to be less than existing land cover types.
- The results for poplar SRC show a very high water use. These results should be interpreted with caution as it is likely that varieties could be or are available that would have lower water use. In which case the water use is likely to be comparable to that of willow SRC.
- In areas of high annual average rainfall (greater than around 800 mm), the nature of the soil has little impact on the water use of the energy crops, or the existing land cover. However, in other areas, the soil hydraulic properties, particularly the ability to store water that can then be

used by the plants for transpiration, can be important because of the higher transpiration rates of the energy crops.

- When the rooting depth of the energy crop is deeper than the existing land cover, there is the possibility that, after a period of drought, the soil water deficits will be greater resulting in a reduction in recharge and/or runoff in the following winter.
- During years with above average rainfall, when transpiration rates are not constrained by soil water, the energy crops tend to use more water than the existing land cover, mainly due to the higher interception losses.
- The predicted indicative yield from the energy crops is a function of air temperature and the amount of sunshine. The energy grasses are predicted to be more sensitive to these factors than the SRC and so show a more marked trend of decreasing indicative yield with increasing latitude and altitude.
- There are strong indications that, in areas of low annual average rainfall (less than about 700mm), the indicative yields of all the energy crops are reduced by soil water stress.

POTENTIAL FOR FUTURE DEVELOPMENT

An operational system for the whole of England and Wales is the likely extension of this project but is not within its current scope.

Report Ref. B/T1/00582/01/00 REP (URN 04/1978) Publication date: December 2004

MONITORING OF GASIFIER UNIT AT THE BLACKWATER VALLEY MUSEUM

B9 Energy Biomass Ltd

OBJECTIVES

There is a significant lack of credible data available on the operation of small scale downdraft gasifiers, as such the main objective of this monitoring programme was:

- To develop data on the operation of the Blackwater Valley demonstration project.

SUMMARY

The Blackwater Valley Museum project was commissioned in 1998, heat is supplied by a small district heating network to the adjacent museum and electricity to the National Grid under a NI-NFFO contract. The initial capacity of the plant was designed for 100kWe and this report details the monitoring work undertaken of this unit.

The project has been continually monitored by B9 Energy Biomass Ltd since 1998. A combination of written and remotely monitored process data was gathered and analysed over this period of time. In addition independent monitoring of the unit has been undertaken by NICERT during June 2001. This report details the results of this work. Following the success of this demonstration project it is to be expanded to 200kWe incorporating the use of a spark ignition engine. Installation started in October 2001.

COST

The total cost of the project, £10,000 was met by the Department of Trade and Industry (DTI).

DURATION

40 months – June 1998 to October 2001.

BACKGROUND

B9 Energy Biomass Ltd won a generating contract under NI-NFFO 2 to supply 200kWe of electricity to the National Grid from wood fuel at the Blackwater Valley Museum in County Armagh. The plant design is based on core Swedish gasification technology which was developed by SMP and Exergetics for automotive power as part of the Swedish Government's National Defence policy. This technology was adopted and significantly modified by B9 Energy Biomass Ltd into a fully automated stationery power plant.

The installation at the Blackwater Valley Museum is the first demonstration of a fully automatic zero liquid and tar waste downdraft CHP unit operating on wood chips.

Wood chips are delivered to an enclosed area and fed automatically to a drier by an overhead crane. Waste heat from the engine cooling system is used to dry the wood chips before feeding them into a gasifier. The chips are heated in a restricted flow of air which converts them into a combustible gas, this gas is then cleaned and cooled and fed to a compression ignition engine, the ignition source in the engine is currently supplied from diesel. The engine shaft is coupled to a generator, producing electricity at 415V. The electricity is stepped up to 11kV and fed to the National Grid.

The engine exhaust contains a considerable amount of heat which is recovered by diversion through a heat exchanger. The resulting hot water is then pumped via underground pipes to the museum for space heating purposes.

Heat is also recovered from the engine jacket and is used to dry the wood chips, from their initial moisture content of approximately 50%, prior to feeding to the gasifier. The plant is able to operate 24 hours per day unmanned, however, a manual de-ashing system necessitates that the plant is shut down regularly for ash removal.

The initial capacity of the plant was designed for 100kWe, this report details the monitoring of this unit. Manufacture of a larger 200kWe unit incorporating a spark ignition engine is underway, installation is due to start on site in October 2001.

THE WORK PROGRAMME

A monitoring study of the Blackwater Valley demonstration project was undertaken for which part support was received from the DTI for the following activities:

- Purchase of a portable CO monitor for measuring environmental conditions in the engine house and gasifier and drier areas.
- Purchase of CO measurement equipment for analysing the percentage of CO in the producer gas.
- The purchase of an oven and balance for establishing wood chip moisture content.
- Programming of a data acquisition system at B9 Energy offices to enable a database to be compiled for reporting.
- After 1000 hours of stable operation the employment of an independent organisation to monitor the environmental and technical performance of the unit.

RESULTS

Summary of operating experience

August 1998 – December 1998

Main areas of work carried out and achievements:

- Functionality testing of major plant items of equipment was completed.
- Control and PLC programming modifications were undertaken.
- Elimination of engine leaks - oil, water, diesel and exhaust.
- Installation of air inlet and outlet silencers to provide additional noise reduction.

- Design of feed valves were modified to improve reliability and reduce leakage.
- Optimisation of lagging thickness to achieve process and mechanical design temperatures.
- Smooth engine operation was achieved on wood gas.

Total operating time - 63 hours.

<u>January 1999 – December 1999</u>

Main areas of work carried out and achievements:

- Gas substitution rates of >90% established.
- Aqueous waste production eliminated through process modifications.
- Engine operating conditions established for smooth operation on wood gas.
- Zero tar production.
- Bridging in drier and gasifier feed mechanism was resolved.
- Slippage of drier belt after extended operation was resolved.
- Elimination of EMC interference on control panel instruments.
- Significant levels of downtime were due to unreliable level detection within the gasifier and the need to test out new devices.
- System over pressurisation resulted in high levels of downtime. Causes of the incidents have been resolved.
- Damage to engine head gasket occurred in establishing optimum engine conditions, causing long period of downtime.
- Development of plant operating procedures.
- Optimisation of plant operating conditions.

Total operating time - 202 hours.

<u>January 2000 – December 2000</u>

Main areas of work carried out and achievements:

- After testing several types of level switches reliable level detection was finally achieved.
- Data acquisition system and pager system fully operational.
- The extended periods of testing and unreliable level switch operation resulted in warping of the grate causing poor reliability of the grate drive. The grate bearings and drive were modified to resolve this issue and reliable operation was consequently achieved.
- Unreliable level detention resulted in 'melting' of several hearths. A new high temperature hearth material was selected, hearths manufactured and put under test. Testing was still in progress at the end of the year.
- Unmanned operation of the plant was achieved.
- Wood fuel supplier was changed to improve quality of wood chips.
- Reliability of all systems was significantly improved.
- Efforts to eliminate bridging by using a rotary valve to promote smoother feeding to the gasifier were unsuccessful.

Total operating time - 643 hours

<u>January 2001- June 2001</u>

Main area of work carried out and achievements:

- The first new hearth material was unsuccessful in withstanding conditions in the gasifier, as such additional new materials of construction of the hearth were selected, manufactured and tested. 'Melting' and thermal shock issues were finally resolved.
- PLC programming improvements undertaken.
- Particulate emissions analysis of the unit were undertaken.
- A diesel quality problem resulted in injector failure and problems of piston erosion, which resulted in a significant amount of downtime of the unit.
- Distortion of two flanges in the high temperature zone of the gasifier caused considerable downtime due to gasket leakage. Inspection of the rest of unit has indicated, however, that the hearth issue has been resolved, gasifier, air nozzles and grate are in excellent condition.
- Bridging in top section of the gasifier remains an issue and cannot be resolved with the existing design.
- Design of 200kWe unit and raising finance to expand the capacity at the Blackwater Valley Museum has been completed. Manufacturing is underway.
- NICERT monitoring of the plant (assessment of the average power generation efficiency and assessment of emissions and mass and energy balance).

Total operating time - 749 hours.

CONCLUSIONS

Significant delays in the NFFO, planning and permitting processes were experienced as a result of the fact that the project was the first of its type within the UK.

The costs to build and commission the Blackwater Valley Museum project were higher than anticipated this was due to a number of factors:

Initial cost estimate was too low.

- Additional costs were incurred due to the need to contract in labour on-site.
- An element of learning was required as to how best control, operate and maintain the process.
- Testing of new ideas in order to develop the company's knowledge of the process its limitations and to reduce future build, and operating and maintenance costs.

The core technology was based on a (manned) vehicle as such substantial design and development work had to be carried out to produce an unmanned automatic CHP unit. Not everything worked exactly as initially planned and significant time and effort was spent in 1998 and 1999 resolving these problems. After resolving the level detection problems in the gasifier in Q1 2000 the extra time and effort required started to payback as steady operation has been achieved within the design conditions.

The plant is operating safely, unmanned and fully automated. Extended periods of operation have been hindered by bridging in the top section of the gasifier this prevents fuel dropping into the burning zone, thus gas production stops causing a plant shutdown. Bridging occurs frequently requiring an operator to go to the site on a daily basis to restart the machine. Attempts to resolve the issue by changing the feed mechanism were unsuccessful. Modifications to the top section of the gasifier are needed to resolve this issue (this will be undertaken as part of capacity expansion).

The 90:10 gas substitution rates were achieved, however, a change in the method of setting up the diesel flow to the engine (2000) has resulted in higher than anticipated diesel consumption.

Emissions to air measured by NICERT are different to those previously measured on such systems and in particular on a sister plant in Sweden, and contact with the instrument manufacturer is being undertaken. These results are therefore not considered valid. Further research in this area is required.

A lack of resources has been the largest cause of downtime at the plant. Priority in allocating personnel was given to the design, installation and commissioning of the Swedish R&D unit and the Beddington Zed project to the detriment of run time at the Blackwater Valley Museum. B9 Energy Biomass Ltd is in the process of recruiting additional personnel to resolve this issue.

Zero liquid and tar waste design has been proven.

The design of certain elements has been modified which has greatly improved the mechanical and electrical integrity of the plant. These modifications have been included in the new design for the Blackwater Valley Museum.

Personnel costs are higher that expected as there has been a much larger element of testing and product development carried out at the Museum than initially anticipated. This short-term cost will result in long term benefits as future build, operating and maintenance costs have been reduced. Excluding personnel costs all other costs are within the budget.

Feed back from visitors and customers to the Blackwater Valley Museum has been very positive indeed. Being able to demonstrate the technology and know how the company has built up over the years is a very good selling point. The company's attitude is that it has not just been developing a project but a technology for the market place.

POTENTIAL FOR FUTURE DEVELOPMENT

The installation of the 200kWe unit will allow the bridging issue to be resolved, and will also take account of the capacity losses caused by the zero liquid waste design.

B9 Energy Biomass is also undertaking a further Research and Development project part funded by the DTI at the Blackwater Valley Museum. The aim of this project is to help eliminate fossil fuels from the system and research the effect of using catalytic converters on the engine exhaust.

Installation of the new unit, and the results of the R&D programme are expected to significantly improve the availability and operability of the Blackwater Valley Museum CHP unit.

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SECTION 2

SHORT ROTATION WILLOW AND POPLAR AS ENERGY CROPS

PROJECT SUMMARY LISTING

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Report Ref: B/W2/00579/REP01 Publication date: November 1999

FERTILISER REQUIREMENTS FOR SHORT ROTATION COPPICE

ADAS Consulting Ltd

OBJECTIVES

- To carry out a review of the current literature and guidance on the fertiliser requirements for short rotation coppice (SRC), including work on sewage sludge carried out by WRc and work carried out in Northern Ireland and in Scandinavia.

SUMMARY

A review of published and unpublished information on the nutritional requirements of SRC and related crops has been used along with the underlying principles of fertilisation of crops to suggest a programme of fertiliser use for this crop.

COST

The work was one of 15 'call off' tasks carried out under a master agreement 'Coppice Establishment - Consultancy' (July 1998 to July 2003).

The cost was £4,500 from a total project cost of £78,515, which was met by the Department of Trade and Industry (DTI).

DURATION

11 months – January 1999 to November 1999

BACKGROUND

With the growing interest in SRC and related crops, there is a related growth in interest in the fertilisation of these crops in order to achieve the best results.

There are three main considerations for encouraging plant growth:

- Soil pH – all plants have their favoured pH range for the soil they are growing in.
- Phosphate, potash and magnesium.
- Nitrogen.

All three of these must be taken into consideration throughout the life cycle of the respective plants and it should be remembered that it is possible for the requirements to change at different stages of the plant's life.

THE WORK PROGRAMME

The programme of work involved looking at the life cycle of SRC and related crops in order to determine the requirements of these plants throughout their lives.

Organic manure was investigated to determine the effects and benefits of its use as a fertiliser.

CONCLUSIONS

- Soil pH should be corrected where it is low. pH recommendations are summarised below:

Species	Optimum pH range
Salix reticulata	6.0-8.0
Salix retusa	6.0-8.0
Salix serpyllifolia	6.0-8.0
Populus alba	6.0-8.0
Populus tremula	5.5-7.5

- Base fertiliser (phosphate, potash and magnesium) is only required where soil levels of these nutrients are low. Using the UK soil index system, suggested base nutrient requirements of coppice (kg/ha) are:

Nutrient	Index 0	Index 1	Above Index 1
Phosphate	100	50	0
Potash	140	50	0
Magnesium	50	0	0

- Following establishment these nutrients should be applied to balance the expected offtake in the harvested crop except at low soil levels where extra additions may be justified or at higher levels where none are required.
- Nitrogen should not be applied in the establishment year, as there will be adequate soil supplies, thereafter nitrogen rates can be slowly increased. Unless there is knowledge that the soil has anything other than a normal mineral N content (owing to high residual levels from previous cropping or high organic matter levels) a simple scheme for N applications could be:

Year of establishment	0kg/ha
First year after cutback	40kg/ha
Second year after cutback	60kg/ha
Third year after cutback	100kg/ha

- Bulky organic manures will be beneficial when applied pre-planting and the nutrients contained in them should be taken account of when planning base manufactured fertiliser applications.
- Organic manures containing high levels of available nitrogen, such as slurries and poultry manures should not be applied prior to planting because most of the nitrogen will be lost to the environment.

FURTHER INFORMATION

For further information on this project see project report reference number B/W2/00579/REP 01.

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Report Ref: B/W2/00579/REP02 Publication date: November 1999

SHORT ROTATION COPPICE: A GUIDE TO COLD STORAGE OF PLANTING MATERIAL

ADAS Consulting Ltd

OBJECTIVE

- To produce a report on the availability of cold stores in which coppice planting material can be stored.

SUMMARY

This guide has been written to introduce growers of Short Rotation Coppice (SRC) to the principles of and need for cold storage of planting material. The main types of cold store are described. It also provides assistance in the selection of suitable stores and how these are located nationally.

COST

The work was one of 15 'call off' tasks carried out under a master agreement 'Coppice Establishment - Consultancy' (July 1998 to July 2003).

The cost was £6,500 from a total project cost of £78,515, which was met by the Department of Trade and Industry (DTI).

DURATION

11 months – January 1999 to November 1999

BACKGROUND

Biomass SRC is propagated vegetatively from stock beds, and involves the taking of plant material from hardwood during the period of dormancy. The plant material is planted out in spring at the start of the growing season, which should be late enough to avoid the damaging effect of frosts upon the growing plant.

<u>The need for cold storage</u>

Storage is required to see the plant material through the winter period. If demand for rooting material is low, then harvest of the plant material can be delayed, so that there is a relatively short period between harvest and replanting of new SRC areas. Traditionally, planting material is harvested while dormant (which in the UK is normally from late November), packed, dispatched and planted out without delay. The harvesting window will also be restricted by ground conditions, and as larger-scale production becomes more widespread, earlier harvesting may predominate. Poor storage practice is often the cause of planting failures.

As new projects for power generation from biomass are developed, greater areas of coppice will be planted (planting of coppice currently takes place from late February). The Government is working towards a target of renewable energy providing 10% of UK electricity supplies by 2010. It is considered that energy crops will play an important role in meeting such renewable energy targets and it has been estimated that over 125,000 hectares of coppice might well be required. For larger areas of planting to be supplied with material at the optimum time, production of planting material will need to be carried out over a longer period in order to meet demand. As harvesting is likely to need to start earlier, cold storage will be required in order to ensure survival of viable planting material. This also ensures that customer demands for material will be met on time.

THE WORK PROGRAMME

The tasks involved and the information contained in the report include:

- a summary of the temperature and other relevant specifications necessary for storage of coppice planting material
- notes for users on the selection of suitable sites
- a review of the wrapping and packaging required for the storage of all types of coppice planting material including billets, cuttings and rods
- an assessment of the seasonal demand for cold stores for coppice planting material
- a comprehensive list of cold stores available in England, Wales, Scotland and Northern Ireland which meet the specifications, with contact details and an indication of likely availability at the relevant time of year.

Company	Location	Telephone	Facility Description
	Midlands		
Scott Newman Group	Shrewsbury	01743 235551	Potato store
M. Warner Esq.	Nescliffe, Shropshire	01743 741211	Potato store
Lubstree, Park Farm	Telford, Shropshire	01952 604320	Soft fruit store
M. Crozier Esq.	Evesham, Worcester	01386 750269	Vegetable stores
Red Star Growers	Pershore, Worcester	01386 750670	Vegetable stores
	North West		
W. H. Mawdsley Ltd	Warrington, Cheshire	01925 763174	Vegetable stores 0.5oC
J.&T. Cropper	Preston, Lancashire	01772 812536	Vegetable stores 0.5oC
Grosvenor Farms Ltd	Chester	01244 620333	Ice - bank potato stores
	Anglia		
G's Fresh Vegetables	Cambridgeshire	07971 155222	Onion stores -2oC
Progrow	Gt Yarmouth	01493 383206	Wet air vegetable stores
	Scotland		
East of Scotland Growers Ltd	Cupar, Fife	01334 654047	Members , Vegetable stores
M Robson Farms	Kelso , Scotland Morpeth, Northumberland	01890 850207	Potato Stores
	South West		
Growers Marketing Services	Hayle, Cornwall Pershore, Worcester	01736 850190 01386 552131	Vegetable Stores
Univeg Ltd	Penzance Cornwall	01736 711884	Wet air cooler vegetable Stores 4 oC
AE Langdon Packers Ltd	Exeter	01392 873661	Vegetable Stores
	South		
Bedfordshire Growers	Biggleswade, Beds	01767 312403	Onion Stores
Wye College	East Malling , Kent	01233 812401	Fruit Stores
	North East		
P.G. Moor Esq.	Morpeth Northumberland	01890 820389	Potato Store from February
J. Parks Esq.	Warkworth Northumberland	01665 711244	Potato Stores
	East Midlands		
S. White Esq.	Doncaster	01427 890 224	Humidified stores -2oC

Figure 1. Cold store contacts

FURTHER INFORMATION

For further information on this project see project report reference number B/W2/00579/REP02.

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Report Ref. B/W2/00579/REP03 Publication date: November 1999

WEED CONTROL IN SHORT ROTATION COPPICE CROPS: A Review of recently published literature and current guidance for farmers

ADAS Consulting Ltd

OBJECTIVE

- To carry out a review of the current literature and guidance on weed control for short rotation coppice, including work carried out by Long Ashton, Banks Agriculture, ARBRE Energy Ltd and in consultation with UK industry and relevant Scandinavian organisations.

COST

The work was one of 15 'call off' tasks carried out under a master agreement - 'Coppice Establishment - Consultancy' (July 1998 to July 2003).

The cost was £3,000 from a total project cost of £78,515, which was met by the Department of Trade and Industry (DTI).

DURATION

11 months – January 1999 to November 1999.

BACKGROUND

Effective weed control, particularly in the first few months after planting, is vital to the success of short rotation coppice (SRC) plantations. However, failure to achieve this remains the biggest single cause of poor crop establishment and low yields.

THE WORK PROGRAMME

An analysis of the current weed control options for SRC growers was undertaken. Product strengths and weaknesses were identified both in terms of weed spectrum and cost. Approval status, timings and application methods were also identified.

The report reviews establishment methods and the recognition of the need for weed control during the crops establishment phase is clearly identified.

Suggestions for areas of further research are also discussed.

CONCLUSIONS

All products, with either a full label or specific off-label approval for use in forestry or farm woodlands, may also be used in SRC plantations on arable land or improved grassland. Products in this category include *Laser* (cycloxadim), *Roundup Pro* (glyphosate), *Challenge* (glufosinate-ammonium), *Flexidor 125* (isoxaben), *Butisan S* (metazachlor), *Falcon* (propaquizafop), *Kerb 50 W* (propyzamide) and *Alpha Simazine 50 SC* (simazine).

Current Government off-label approvals also permit, in SRC established on land which was previously under arable cultivation, or improved grassland:

- any herbicide which has full (or provisional) approval for use on cereals to be used in the first five years of establishment, and

- herbicides approved for use on cereals, oilseed rape, sugar beet, potatoes, peas and beans to be used, in the first year of regrowth after cutting.

Most SRC growers in the UK depend upon a small number of herbicides - including the residuals pendimethalin and simazine and the foliar-acting herbicides amitrole, clopyralid and glyphosate - but the above rules for off-label approvals permit the use of a wide range of agricultural herbicides.

Efficient weed control starts with the destruction of existing vegetation, prior to SRC planting. This normally involves application, in autumn, of a foliar-acting herbicide, such as glyphosate or glufosinate-ammonium, before ploughing; followed by further cultivations or another herbicide spray in spring, shortly before planting. The relatively late planting of most SRC crops provides a good opportunity for use of the 'stale seed-bed' technique to reduce post-planting weed pressures.

Inversion of the soil during ploughing assists weed control by burying weed seeds. Deep ploughing, to depths of >50 cm, enhances weed control benefits but is probably too expensive an option at present.

Approved herbicides for weed control in the first year after planting include:

<u>Atrazine</u> - Both residual and some foliar activity; generally effective against a broad spectrum of weeds. Some phytotoxicity possible. Very low cost.

[Note: Atrazine was removed from the usage list on ARBRE1999 plantings due to its poor environmental profile and damage risk on light soils.]

<u>Clopyralid</u> - Foliar, translocated activity; mainly for effective post-emergence control of weeds in the Asteraceae family (eg thistles, sowthistles, dandelions and groundsel). Generally safe, even when applied well after crop growth has commenced.

<u>Cyanazine</u> - Contact and residual activity against a broad spectrum of weeds. Only safe in sprays applied before crop emergence. Medium cost.

<u>Cycloxydim</u> - Translocated, foliar activity; for effective post-emergence control of annual and perennial grasses (but not annual meadow grass). May possibly damage some poplars, if applied in summer. High cost.

[Note: cycloxydim is more widely used commercially than claimed in the report, especially for control of couch, rye grasses, and volunteer cereals.]

<u>Fluazifop-P-butyl</u> - Foliar activity against annual and perennial grasses. May possibly damage some poplars, if applied in summer. Only to be applied through tractor-mounted sprayers. Very high cost.

<u>Lenacil</u> - Residual activity against annual broadleaved weeds and annual meadow grass. No reported phytotoxicity problems in willow or poplar crops.

<u>Metazachlor</u> - Residual and some (limited) foliar activity against a wide range of annual grasses and broadleaved weeds. Good results from two-way mixtures of metazachlor with metamitron, pendimethalin or propyzamide [*but note that metamitron and propyzamide are not approved for post-planting sprays*]. Applications of the normal recommended rate, shortly after planting are unlikely to cause any damage to crops. Medium-high cost.

Napropamide - Residual activity against annual broadleaved and grass weeds. Should be applied before end of February. No evidence of crop damage from normal usage. Medium-high cost.

Pendimethalin - Residual activity annual broadleaved and grass weeds. Commonly used in commercial plantations, alone or in mixtures, notably with isoxaben (Flexidor 125). No phytotoxicity likely if applied before or at bud-break, but possible phytotoxicity to poplars if applied later.

Propaquizafop - A relatively new foliar-acting graminicide, for post-emergence control of annual meadow grass, blackgrass, common couch, ryegrass, volunteer cereals, wild oats and other grass weeds. High cost.

Simazine - Residual activity against a broad range of annual dicotyledons and grasses. Commonly used in commercial plantations, alone or in mixtures with pendimethalin. Applications at recommended rates are likely to be safe in most conditions; but poplars (in particular) might be damaged on light soils where heavy rainfall follows application. Very low cost.

[Note: Simazine was removed from the usage list on ARBRE1999 plantings due to its poor environmental profile and damage risk on light soils.]

Other herbicides with the appropriate off-label approval that might be considered for use on SRC crops during year 1 include:

Diflufenican (DFF) - Only available in mixtures (eg with isoproturon). Contact and residual activity against a broad spectrum of grass and broadleaved weeds. Limited research suggests that normal rate applications of diflufenican, in mixtures with isoproturon, are likely to be safe and potentially very useful to SRC growers.

Isoproturon (IPU) - Residual herbicide, with pre- and post-emergence activity against annual grasses and broadleaved weeds. Limited research suggests that normal rate applications of isoproturon, in mixtures with diflufenican, are likely to be safe, but high rates of isoproturon (eg 2.5kg a.i./ha or more) are very damaging.

[Note: rates of IPU at 2.5kg a.i./ha are required for full control of grass weed species, which have been proven to be damaging to willows in previous published DTI reports (Dixon & Clay 1996a). The damage is exacerbated on light soils where rates of no more than 0.5kg a.i./ha have damaged cereal crops and would therefore be highly likely to do the same to SRC. The report identifies the damage levels, but not the fact that this amount of active is required for weed control. These factors effectively rule out the use of IPU on SRC. This would not immediately exclude the use of DFF in alternative mixtures, however, this would need to be tested for crop safety.]

Pyridate - Contact herbicide with post-emergence activity against annual dicotyledons. Generally safe to willows and poplars, even when applied well after bud-break. Potentially very useful for the control of broadleaved weeds in SRC crops.

After cut-back, at the end of year 1, herbicide options include all of those listed above plus a few additional ones. These include:

Metamitron - Residual and limited contact activity against annual broadleaved weeds and grasses. A sugar beet herbicide with off-label approval for use in the year following cut-back or harvest.

Propyzamide - Residual and contact activity against grasses and annual dicotyledons. Particularly effective against grasses, both pre- and post-emergence. Fully approved for forestry use, but restricted to winter applications to crops established for at least one growing season. Generally safe to willows and poplars.

Cut-back weed control is generally practiced through the use of propyzamide where the timing of cut back fits in with the legal product timings. The use of amitrole over dormant stools is also practiced, and is very effective where emerged weed burden is high, and is often mixed with residual products to provide persistence control.

As with cut-back, the period following harvest provides a good opportunity to 'clean up' existing weed problems, and to re-apply residual herbicides. The value of post-harvest herbicide applications is not, however, always clear-cut. Decisions should take into account both economic and environmental considerations. If herbicides are considered appropriate the possible options include those chemicals listed previously, and others including:

Amitrole - Translocated, foliar-acting, non-selective herbicide. Generally safe if applied as an overspray to dormant stools of willow or poplar (or shortly after bud-break), but may cause transient yellowing of new growth in some instances. Very late applications (eg July) are very damaging. Much safer than oversprays of glyphosate. Widely used against thistles, bent grasses, common couch and other 'problem' perennial weeds. Less effective than 2,4-D, glyphosate or paraquat in the long-term control of creeping buttercup. Specific off-label approval for use in farm woodlands.

Diquat + paraquat - Non-selective, contact herbicide for the control of annual grasses and broadleaves, perennial non-rhizomatous grasses and volunteer cereals. There is little research work on diquat + paraquat mixtures for SRC, but trials with paraquat alone have shown that overall sprays must be applied no later than just after bud-break. Full label approval for forestry use.

Dichlobenil - Granular herbicide, with pre- and post-emergence activity against a wide spectrum of annual and perennial weeds. Very effective in controlling nettle patches, but ineffective against bramble. Generally safe when applied up until the 'buds swelling' stage. Not permitted for use within first two years after planting.

Glufosinate-ammonium - Non-selective contact herbicide, with some systemic action. Recommended for use as oversprays to deeply dormant SRC crops, but should be used as a directed spray at all other times. Not effective against creeping buttercup. However, research evidence suggests that sprays up until bud-break, whilst causing symptoms of phytotoxicity, are likely to cause no yield reduction.

Asulam, glufosinate-ammonium, glyphosate, paraquat or triclopyr may all be applied as carefully directed sprays (avoiding the crop) to control weed patches in growing crops. Glyphosate and triclopyr are, however, particularly damaging if they accidentally drift onto crop plants. Asulam is recommended for the control of bracken and docks. Triclopyr is effective against a broad spectrum of perennial weeds, and performed very well against common nettle and bramble in an experiment.

It is possible to adapt various row-crop cultivators for use in SRC crops; mechanical weed control has been undertaken in the UK, albeit on a small scale at present.

Plastic mulches are too expensive for use in SRC.

SRC provides useful areas for the disposal of organic manures, including FYM and sewage sludge, but to apply these manures to the depths required for weed control purposes is likely to be impossible within the guidelines of the current MAFF Codes of Practice. Other, less rapidly degradable, organic ‘wastes’ might offer better prospects as mulches for weed control.

All ground cover plants compete with SRC crops for moisture, nutrients and (in some cases) light - to a greater or lesser degree. Crops will inevitably perform most efficiently under weed-free conditions, although total weed control might sometimes be considered unsatisfactory for environmental reasons. One experiment found that 'cover crops' of winter wheat, winter rye, perennial rye-grass or annual weeds, established in the autumn before planting SRC, caused big reductions in year 1 shoot growth (in comparison with residual herbicide-treated, bare soil plots) even when the cover crop was killed with glyphosate shortly before planting. Later removal of grass covers with cycloxydim resulted in reductions of approximately 95% in shoot fresh weights.

POTENTIAL FOR FUTURE DEVELOPMENT

Research needs are described in the report, under the following headings:

- **Weed competition (relevant where narrow spectrum contact herbicides are available. Of little benefit where broad spectrum residual herbicides are applied)**
  - quantification of weed competition
  - time of removal of weeds.
- **Further evaluation of residual and foliar-acting herbicides**
  - cereal herbicides for SRC
  - safe herbicides for new planting systems
  - screening of new cultivars for herbicide sensitivity
  - selection of herbicides for specific weed problems
  - weed resistance to herbicides.
- **Vegetation management without chemicals - non-herbicide methods for weed control**
  - mulches (although these require much energy input in the case of forest/SRC residue, and organic manures/sewage sludge actively encourage weed growth):
  - ground flora management - less competitive species
  - further work on mechanical weed control in SRC crops.
- **Quantifying the need for post-harvest herbicide applications.**

Research priorities for the future are on contact and residual herbicides, but this needs to be commercially based, once crop safety has been established.

dti

Report Ref: B/W2/00633/REP Publication date: March 2000

AN EVALUATION OF HERBICIDES FOR POST-EMERGENCE USE IN SHORT ROTATION COPPICE

Biomass Energy Services Ltd (with ADAS and CSC Crop Protection Ltd)

OBJECTIVE

- To evaluate the safety and efficacy of a range of herbicides and mixtures of herbicides, with both contact and residual activity, for the post-emergence control of weeds in newly planted willow short rotation coppice (SRC).

SUMMARY

Eleven herbicide treatments, all with current weed control recommendations that may be of benefit as post-emergence treatments were compared with a standard control. The crop safety for willows of these treatments was not known, and although most of the treatments caused varying degrees of phytotoxicity, including leaf and stem scorch and some stunting of the apical growing point, no willows died from herbicide treatment at any site. The biomass productivity assessments at the end of the growing season indicated that most treatments gave dry matter yields greater than those of the unsprayed control.

The best results in combined crop safety and weed control were from treatments Reflex T (fomesafen+terbutryn), Lexone (metribuzin) and Lexone + Titus (metribuzin + rimsulfuron).

This report provides growers and advisers on short rotation coppice with important (but still limited) information on how to achieve improved weed control of problem weeds increasingly prevalent in SRC fields. This may provide guidance for often essential emergency treatments when the crop establishment is under considerable pressure, and the potential safety, or otherwise, of certain weed-specific herbicides.

COST

The total cost of this project was £40,926 with the Department of Trade and Industry (DTI) contributing £22,630, and industry the balance.

DURATION

9 months – June 1999 to February 2000

BACKGROUND

Weed control continues to be one of the most common causes of poor crop establishment and total crop failure in newly planted SRC crops. The current best practice for weed control is to apply a pre-emergence (of crop and weeds) residual herbicide as soon as possible after planting. However, this option can often be delayed by adverse weather or alternative workload commitments on the farm. Consequently, this opportunity can be missed before bud burst on the willow cuttings, by which stage there is often a first germination of weed seedlings. In addition, drying soils result in reduced residual life of the herbicide and further flushes of weed seedlings can maintain weed competition on the crop. Under normal arable cropping conditions, a grower usually has a considerable array of herbicides to apply post-emergence to the crop that can be broad spectrum or target-specific and dose rate- specific. Although there are a few weed-specific herbicides available, the grower has very limited options with SRC.

Although growers can legally use a wide range of herbicides, relatively few have been tested. Recent research and field recommendations have been based on herbicides approved for use in forestry and can provide reasonable weed control of the weed species typically occurring in a forestry situation. The market expansion of SRC means that crops are now planted on typical arable fields that often contain different weed species. These weeds are usually not susceptible to control by the standard forestry herbicides and consequently, severe weed competition can occur.

A major factor in obtaining satisfactory weed control is the relative non-competitiveness of the crop in the first year of establishment. The relatively low planting density (typically 15,000 cuttings/ha), compared with wheat (typically 4-5 million seeds/ha), provides considerable open ground and increased resources of water and nutrients for germinating weeds. Coupled with this, the residual activity of the standard herbicides may be as little as 4-8 weeks under good conditions. Some of the most serious weed problems are volunteer oilseed rape and cleavers (*Galium aparine*). Oilseed rape, as a crop, is an accepted part of the arable rotation throughout the UK, and seed losses to the soil present a formidable seed reserve for germinating as a weed in subsequent crops. There are adequate herbicides available for control in cereals, but none recommended for use in SRC. Cleavers are a major weed problem in oilseed rape crops, with very few adequate control options, and consequently, with the seed return, cleavers are a major weed problem in arable rotations throughout the UK. There are no recommendations for herbicides that will give good cleaver control in SRC. Other weed species that can present serious competitive problems are *Polygonum* spp. and fat hen (*Chenopodium album*). Again, there are no satisfactory control measures available. Generally, the weed species that present the greatest problems are those with an upright growth habit rather than species with a prostrate, ground covering habit.

The most recent review of herbicides for use in SRC was published in 1996 (Forestry Commission Field Book 14). Since then, several new herbicides have been marketed in the UK, which have been shown to provide consistent control of these problem weeds (as well as a wider weed spectrum), in a range of arable crops. These products have not been tested for efficacy and safety in SRC.

THE WORK PROGRAMME

The project was designed to test a range of new and existing herbicides on trial fields where these problem weeds are likely to be present. The products, which either have full label approval, or off-label clearance for use in SRC, were tested at different dose rates, or in mixtures and at different timings out with their normal recommendations. The objective was to provide an updated list of herbicides that will control these increasingly important weeds and give advice on timing and appropriate dose rates.

The trial sites were installed within five commercially planted fields established in 1999. The fields were located throughout the UK providing a broad representation of soil types, climatic conditions and weed flora. Two sites were subjected to extensive investigation, which included quantitative assessments of crop and weed biomass, as well as the visual, qualitative assessments to which the intensive sites were subjected.

Site no.	Site location	Soil type	Intensive/ extensive	Date of planting
1	MAFF, Drayton Warwickshire	Clay	Intensive	15.4.99
2	East Lilling Farm Flaxton, York	Sandy loam	Extensive	12.6.99
3	Parkburn Farm Fyvie, Aberdeenshire	Sandy clay loam	Intensive	3.5.99
4	Burngrains Farm Dyce, Aberdeenshire	Sandy loam	Extensive	17.5.99
5	Barony, Auchinleck Ayrshire	Re-claimed coal Spoil	Extensive	8.10.99

Figure 1. Site installation details

A total of 11 herbicide treatments were applied, as a post-emergence treatment, across six willow varieties. There was also an untreated control. The plots were randomised across the trial with three replicates for each treatment. The total area occupied at each site was approximately 0.37ha (116m x 32m).

At the time of spraying, the crop and weed growth stages were noted by visual observation and the weed species present were recorded. The level of weed cover was recorded at the time of spraying and again 6-8 weeks after spraying at all sites. The weed frequency was measured at the two intensive sites during the same inspection visits.

The crop phytotoxicity was assessed visually 14-21 days after application of the herbicide treatments at all sites. The assessments were made to six (6) plants per plot, on all 216 sub-plots in each trial. An overall score of phytotoxicity was made on each plant, and other observations were made to include any interveinal chlorosis, bleached foliage, necrotic spots on leaves, shoot distortion or stem marking.

The weed biomass was collected and measured, 6-8 weeks after application at the two intensive sites.

The plant survival and crop height within the treatments was measured at the end of the growing season at all sites, and the crop biomass was measured, at the same time, at the two intensive sites.

	Product	Active ingredient(s)	Dose rate (l or g product /ha)
1	Untreated control		
2	*Sovereign + Gesatop*	Pendimethalin (400 g/l)	5.0 l
		Simazine (500 g/l)	2.2 l
3	*Sovereign + Gesatop + Eagle*	Pendimethalin (400 g/l)	5.0 l
		Simazine (500 g/l)	2.2 l
		Amidosulfuron (75%w/w)	40 g
4	*Sovereign + Gesatop + Titus*	Pendimethalin (400 g/l)	5.0 l
		Simazine (500 g/l)	2.2 l
		Rimsulfuron (25% w/w)	40 g
5	*Panther*	Diflufenican (50 g/l)	2.0 l
		+ IPU (500 g/l)	
6	*Javelin Gold*	Diflufenican (20 g/l)	4.2 l
		+ IPU (500 g/l)	
7	*Panther + Eagle*	Diflufenican (50 g/l)	2.0 l
		+ IPU (500 g/l)	40 g
		Amidosulfuron (75% w/w)	
8	*Panther + Titus*	Diflufenican (50 g/l)	2.0 l
		+ IPU (500 g/l)	40 g
		Rimsulfuron (25% w/w)	
9a	*Reflex T*	Fomesafen (80 g/l)	2.0 l [1]
		+ terbutryne (400 g/l)	
10	*Ingot*	Diflufenican (27 g/l)	3.75 l
		+ IPU (400 g/l)	
		+ flurtamone (67 g/l)	
11	*Lexone 70DF*	Metribuzin (70% w/w)	1.0kg
12	*Lexone + Titus*	Metribuzin (70% w/w)	1.0kg
		Rimsulfuron (25% w/w)	40g

Figure 2. Herbicide treatment list

CONCLUSIONS

Further work is required to test the more The crop productivity data from these trials would indicate that weed control benefits provided by most of the herbicide treatments compensated for, or in some cases, clearly outweighed any adverse phytotoxic effects. Since the importance of good weed control in the year of establishment plays a crucial role in the long-term productivity of the crop, then some of these treatments may have potential future use to SRC growers by providing effective, safe weed control of problem weeds during periods of crop growth.

The products which gave the most encouraging results were Reflex T and Lexone, which overall combined good crop safety and good weed control with concomitant reductions in weed biomass and increases in crop productivity. These products were applied at crop growth stages beyond their normal crop recommended timings, causing some scorch symptoms, from which the plants recovered and produced further healthy growth.

The two sulfonyl-urea herbicides tested, Eagle and Titus, produced the most severe phytotoxic symptoms with bleaching and die-back of the growing points. Eagle was the more severe of the two products, with the Titus in combination with Lexone producing acceptable results. These products are very weed-specific (eg cleavers), and so their use could be considered if the field infestation problem warranted an application.

The diflufenican mixtures (Panther, Javelin Gold, Ingot) gave reasonable weed control, and the crop safety from the Panther and Javelin Gold was acceptable. The Ingot caused crop scorch, reduced height and yield, although not significantly. This was probably due to the additional component, flurtamone, and will probably only be of use in a field situation where resistant strains of blackgrass (flurtamone susceptible) were of concern to the SRC. These products also contain isoproturon that had previously been considered unsafe and in this set of trials have shown little crop damage. These products are normally used in the early post-emergence stages of crop and weeds and should be re-tested in the field situation. They are available in many mixtures and are relatively inexpensive.

The treatment Stomp/Gesatop has been used as a standard field treatment for several years. Its recommended timing is pre-emergence of crop and weeds. Under such circumstances this mixture can provide broad spectrum, inexpensive weed control. The products have little effect in controlling mature weeds as encountered in these trials, but are relatively safe to the crop. The restrictions on the use of simazine (Gesatop) will probably minimise its use in future.

This series of field trials suggests that various herbicides offer potential as conventional post-emergence or 'emergency treatments' in situations where pre-emergence residual herbicide treatments have failed, or been delayed, or secondary flushes of weed seedlings have emerged. However, the products in the three most promising treatments – Reflex T, Lexone 70DF and Titus are currently not approved for use in SRC until after cutback or harvest. Furthermore, additional research is needed to study the effect of different spray timings, efficacy against a broader weed spectrum and crop safety on different soil types before firm recommendations can be made.

The results from these trials may assist in formulating future herbicide strategies for SRC. Very few of these products had been tested previously in field trials of SRC. Their inclusion was an attempt to identify safe effective weed control for post–emergence use, with the presumption that pre-emergence applications are usually satisfactory. The reality is that very few pre-emergence treatments either control the weeds satisfactorily within their label recommendations, or are persistent enough to control later weed seed germination.

The evidence from the weed frequency assessments indicates that weed seeds can germinate from the initial post-cultivation, pre-planting stage and can continue to germinate throughout the summer period. Most of the weed species produced fresh germination as long as ten weeks after the time of the pre-emergence herbicide (Site 1). The effective residual life of most (spring/summer) residual herbicides is 4-6 weeks, which would mean that there was little or no herbicide remaining to control the secondary flushes of weeds.

Under normal arable cropping conditions, this germination would still occur, but usually the competitiveness of a dense crop canopy would prevent weeds from establishing. However, SRC is a very open crop in its year of establishment and continuing weed germinations are able to obtain moisture and nutrients to establish and grow, and consequently some weeds are able to compete with the crop and hinder its establishment and productivity.

Therefore, it might be considered prudent to adopt a two-spray strategy based on a pre-emergence application followed by an appropriate post-emergence treatment. This would allow clear identification of the weed problem and allow for an application within the correct timing. This strategy, of course, has increased cost implications for establishment of the crop, but the grower would be better served if the strategy was in place before planting, than having to resort to emergency treatment at a later date, or no treatment at all.

POTENTIAL FOR FUTURE DEVELOPMENT

Further work is required to test the more successful treatments in this project and more accurately define the timing of application and dose rate. The treatments should be applied within their current label timings for weed control and the persistence against later germinating weeds should be observed, as well as observing any symptoms of phytotoxicity. Successful control from these herbicides applied, as a pre- or early post-emergence treatment would greatly expand the choice available to the SRC grower as well as providing guidance on treatments available as a 'last chance' measure.

Increased and refined data on the post-emergence herbicide options will form the basis of improved herbicide recommendations and better crop establishment.

Report Ref: B/W2/00622/REP (URN 00/1609) Publication date: June 2000

ADVICE ON RABBIT MANAGEMENT FOR GROWERS OF SHORT ROTATION WILLOW COPPICE

The Central Science Laboratory

OBJECTIVE

- To produce an advisory leaflet on rabbit management for growers of SRC and to provide a scientific report on the evidence behind the recommendations in the leaflet.

SUMMARY

Rabbit numbers are currently increasing throughout Great Britain at a rate of 2% a year, mainly because of the reduced effects of myxomatosis. It is estimated that the rabbit population in this country could double. As rabbit numbers increase, the threat of extensive damage to the establishment of new areas of Short Rotation Coppice (SRC) could become significant.

The Central Science Laboratory (CSL) was commissioned to produce an advisory leaflet for growers and developers with information relating to preventing and managing rabbit problems. The leaflet contains information on rabbit biology and behaviour, factors for consideration when siting plantations of SRC, details and costs of techniques for rabbit management and advice on planning and managing rabbit control programmes.

A copy of the leaflet *'Advice on Rabbit Management for Growers of Short Rotation Willow Coppice'* (URN 00/1609) can be obtained free of charge via the DTI publications Web site.

Figure 1. The European wild rabbit (Oryctolagus cuniculus)

COST

The total cost of the project, £10,743, was met by the Department of Trade and Industry (DTI).

DURATION

11 months – May 1999 to March 2000

BACKGROUND

Rabbits are increasing in numbers throughout Great Britain at about 2% a year, mainly because of the waning effects of myxomatosis and it is estimated that the national population could well double from current levels.

Previous DTI-funded projects, specifically the 'Farm Woodfuel and Energy Projects', have shown that one of the main factors that could affect the economic success of commercially grown SRC is rabbit damage. This effect will be enhanced as rabbit populations increase.

When considering establishing or managing new areas of coppice, growers need to have access to the latest information on all aspects of rabbit management and be made aware of the potential environmental and economic problems that rabbits can cause. In addition, such information will also be of value to industry, whose key concern at present is to reduce establishment and maintenance costs of SRC plantations.

The scope, addressing the key issues identified above, for an advisory leaflet on rabbit management for growers of SRC was developed through discussions between DTI, CSL and ARBRE Energy Ltd.

Figure 2. Wire netting fence supported with high-tensile spring steel straining wire

THE WORK PROGRAMME

The advisory leaflet covered the following areas:

- **Introduction:** this section reviews the background to the increasing rabbit problem and presents the current relevant information on the biology, behaviour and ecology of rabbits. The susceptibility of willow varieties to rabbit browsing and recommendations on the siting of SRC is also presented.
- **Management:** this section reviews the timing, material suppliers and cost of the available control techniques. Recommendations on the most cost-effective techniques are presented.
- **Legislation:** the current laws prescribing the use of control techniques were reviewed and presented at Annex 2 in the leaflet.
- Many of the control measures described use specific pieces of equipment, which are available commercially. The names and addresses of manufacturers or suppliers are listed in Annex 3 of the leaflet.

Figure 3. Electrified wire fence

CONCLUSIONS

A copy of the leaflet *'Advice on Rabbit Management for Growers of Short Rotation Willow Coppice'* (URN 00/1609) can be obtained free of charge via the DTI publications Web site.

POTENTIAL FOR FUTURE DEVELOPMENT

One of the main concerns of the industry is to reduce the establishment and maintenance costs of SRC plantations. At present it is recommended that a permanent rabbit-proof fence, which forms 40% of the establishment costs, is used to protect new SRC plantations.

Research could be undertaken to quantify and reduce the costs of establishing and maintaining plantations by:

i) developing a rabbit management decision support system that will enable reliable predictions of the likely costs of rabbit damage to be made prior to establishment of the SRC and provide advice on the most cost-effective response

ii) developing new fencing regimes (electric and wire netting) that will protect SRC against rabbit damage at a significantly reduced cost compared with current fencing techniques.

dti

Report Ref. B/W2/00548/21/REP Publication date: July 2000

A STUDY OF SRC PRODUCTION IN THE SECOND ROTATION AT THE "FARM WOOD FUEL AND ENERGY PROJECT" SITES

Writtle College

OBJECTIVES

- To obtain estimates of the annual productivity that can be obtained from semi-mature short rotation coppice (SRC) crops of poplar and willow, grown under commercial conditions.
- To compare the productivity of later harvest cycles with the productivity data obtained through the 'Farm Wood Fuel and Energy Project' (Ref. B/W2/00917/00/00) in the initial harvest cycle (1993 to 1996).
- To attribute reasons for any major differences in productivity.

SUMMARY

Productivity of the poplar variety Beaupré and the willow variety Dasyclados were assessed annually, by destructive sampling, at six sites in southern England, in the winters of 1997/98, 1998/99 and 1999/2000. The study continued the productivity assessments undertaken in the 'Farm Wood Fuel and Energy Project' between 1992 and 1996, of crops planted between 1992 and 1994.

At the best-performing site the average annual productivity of the three plantings of Beaupré averaged 12.4 oven dried tonne (odt) ha^{-1} y^{-1}. Three years previously the annual productivity had been slightly lower, at 11.1odt ha^{-1} y-^{1}.

The highest yielding Beaupré crop, at the best-performing site, attained annual productivity of 16.1odt ha^{-1} y-^{1}.

At the five other sites the annual productivity of Beaupré averaged only 3.6odt ha^{-1} y-^{1}. The very low levels of productivity were attributable, in part, to the incidence of the E4 race of poplar rust.

Productivity of Beaupré was lower in the second rotation than in the first rotation. However, this may be attributable to the incidence of rust.

At sites that were severely affected by poplar rust, there was a die back of stems and death of stools. Consequently, there was a reduction in the standing biomass of Beaupré at some sites during 1999.

At the best-performing site the average annual productivity of the three plantings of Dasyclados averaged 9.5odt ha^{-1} y^{-1}, an increase on the yields of 8.4odt ha^{-1} y-^{1} attained three years earlier.

The planting of Beaupré is no longer recommended, due to its susceptibility to rust, and Dasyclados is now classed as 'Becoming Obsolete'. Consequently extreme caution should be exercised in extrapolating the results of this study to the potential performance of

more recently introduced poplar and willow varieties.

COST

The total cost of the project, £14,350, was met by the Department of Trade and Industry (DTI).

DURATION

39 months – March 1997 to June 2000.

BACKGROUND

Knowledge of the yield potential from commercial crops of SRC is required by developers of heat and electricity generation schemes and by farmers contemplating production of the crop. However, productivity data is very limited, especially from commercial crops. The area of SRC within the UK is still small, and in 1999 was estimated to be only about 520ha. The majority of the commercial planting has been planted in Yorkshire for the ARBRE scheme, with just under 500ha planted by 1999, of which 200ha was planted between 1996 and 1998. Almost all of these commercial sites have yet to be harvested, and hence there is no information on initial yields. Furthermore, the crops are only in their first rotation and hence cannot provide information on how the productivity may change in subsequent rotations.

Consequently, estimates of potential production under UK conditions have, to date, been based on the results of a limited number of crops grown under experimental conditions. In the majority of cases, the data are restricted to yields recorded in the first harvesting cycle after cutback. The only published UK data for 'commercial' crops are for the first rotation at the 'Farm Wood Fuel and Energy Project' sites. This work continued the productivity assessments at those sites for a further three years.

The 'Farm Wood Fuel and Energy Project' ran from 1991 to 1997 and entailed the production of a total of 51ha of SRC at six farms in southern England. The crops, of both willow and poplar, were planted over a three-year period between 1992 and 1994 and comprised the first large-scale commercial production of SRC in the UK.

At the start of the Project, in 1991, UK experience of field-scale production was very limited and consequently it was not known what agronomic practices would prove to be the most suitable. A deliberate decision was therefore made that, in contrast to research trials, the growers should not follow a standard method of production, but should be free to make their own decisions about how to grow the crop, appropriate to their individual location and circumstances.

Full details of the husbandry at each site, including planting method, varieties, weed control, harvesting and rotation length were reported in the final report of the Project in 1997 (Ref. B/W2/00199/REP).

The six sites, located near Colchester, Oxford, Bristol, Exeter, Tiverton and Truro, were representative of a range of farming enterprises from arable farming in eastern England to grassland farming in southwest England.

At each farm, a total of 10ha were established over a three-year period between 1992 and 1994, with the sole exception of Frankford Farm, where a single planting of 1ha was established in 1992. At most sites the Beaupré and Dasyclados were grown either as the sole variety in the field or as a large single block within a range of varieties. The exception was at Knowle Farm where the Dasyclados plantings were restricted to two rows between adjacent rows of poplar in the 1992 planting and several rows between poplar in the 1993 planting.

No crop husbandry, apart from limited harvesting, was undertaken in the Beaupré or Dasyclados crops at any of the six sites between 1997 and 1999.

At the commencement of this study it was assumed that the growers would be undertaking field scale harvesting of the crops, either as first or second harvests. However, in the absence of either suitable energy markets or the opportunity to host harvesting trials, the growers chose to leave the majority of their crops uncut. Where harvesting took place, the areas were generally small, and harvested by hand. The products were used for non-energy markets. No large-scale harvesting took place in the Beaupré crops between 1997 and 1999, other than the thinning of part of the 1992 planting at Tregothnan. Similarly, there was no large-scale harvesting of Dasyclados, other than the 1992 planting at Friars Court, which was harvested in late 1999.

THE WORK PROGRAMME

This study continued, for a further three years to winter 1999/2000, the productivity assessment of the crops that were undertaken in the Farm Wood Fuel and Energy Project each winter between 1993 and 1996. At several sites, additional productivity assessments of Beaupré were made where crops had been thinned, or only partly harvested, leaving both cut and uncut areas. Assessments of Dasyclados productivity were discontinued in three plantings during the study. The details of these additional and discontinued assessments are as follows.

In 1996, the majority of the 1993 planting of Beaupré at Loyton Farm was harvested, but the eastern edge of the crop was left intact. The opportunity was therefore taken to assess and compare the productivity of both the cut and uncut areas of the field during the winters of 1997, 1998 and 1999. Similarly, at Knowle Farm only the western half of the 1994 Beaupré crop had been harvested in 1996, and hence the productivity of the cut and uncut crops were assessed separately in the winters of 1997, 1998 and 1999.

At Tregothnan Estate an area of the 1992 Beaupré was thinned during the winter of 1996 from a density of 10,000 per hectare to 1,667 per hectare, with the intention of growing the crop for forestry rather than short rotation coppice. Productivity was assessed in both the thinned and un-thinned areas of the crop in the winters of 1997, 1998 and 1999.

Productivity assessments in the 1992 Dasyclados at Loyton Farm and in the 1992 and 1993 plantings at Knowle Farm were discontinued in 1998. At Loyton there were only a few short rows of the variety at the edge of the field. Part of the area had been harvested in 1996 and the remaining area had many small stools that were subject to deer grazing, plus a few larger stems. It was not possible to obtain a meaningful yield estimate. At Knowle Farm the Dasyclados was grown as a break between other varieties. In the 1992 planting the crop was only two rows wide, and was strongly out competing the adjacent stools. Consequently the productivity was unrepresentative of a larger block of the crop. Similar problems of competitive growth occurred in the 1993 planting.

The 1992 Dasyclados at Friars Court was harvested during 1999 and hence there was no crop to assess during the winter of 1999.

Destructive sampling took place each year after leaf fall, between December and February. At each site 12 stools were randomly selected per variety and per planting, according to a pre-determined sampling plan. The stems were cut to stool height and the total fresh weight of the stems in each stool determined with a spring balance. The moisture content was determined by oven drying a 1kg sub-sample of material at 80°C in a forceddraft oven.

The dry weight per stool was obtained from the product of the fresh weight and the dry matter percentage. The yield estimate of the crop, expressed as odt ha^{-1} ± SE, was calculated from the mean DM yield per stool and the plant density. The estimate assumed full crop establishment and was based on cropped area rather than field area; no allowance being made for the field headlands. In practice, establishment was very good at all sites, generally in excess of 95%.

The productivity was also expressed in terms of average annual dry matter production (odt ha^{-1} y^{-1}). This was calculated each year as the dry matter yield divided by the number of years since coppicing or the last commercial harvest, as appropriate.

CONCLUSIONS

The key yield results are summarised in the table below:

Site and Planting	Beaupré Years after coppicing							Dasyclados Years after coppicing						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Ashmans '92	9.1	n.d.	11.1	15.0	13.6	12.8	10.9	14.2	12.4	11.6	11.5	8.7	9.2	11.3
Friars Court '92								n.d.	2.0	4.5	5.1	4.0	5.7	n.d.
Knowle '92	4.7	9.0	8.0	4.7	5.7	5.1	4.6	n.d.	13.8	n.d	10.7	18.5	n.d.	n.d.
Frankford '92	6.4	7.1	6.2	7.3	8.2	6.2	7.8	n.d.	10.1	7.6	8.8	10.7	8.2	10.1
Loyton '92	3.5	8.8	8.1	5.5	4.2	4.4	2.7	n.d.	1.1	1.4	2.4	4.7	n.d.	n.d.
Tregothnan '92	2.0	3.7	3.7	3.8	4.0	4.1	3.5							
(area thinned in '97)	-	-	-	-	1.0	1.2	0.8							
Ashmans '93	8.2	14.2	12.2	13.5	14.3	16.1		7.7	7.7	8.3	7.4	7.6	8.7	
Friars Court '93	0.8	2.4	3.4	8.5	9.3	9.2		3.3	3.7	4.8	5.8	4.2	5.9	
Knowle '93	3.5	6.2	7.5	5.3	3.0	2.1		9.9	9.6	n.d.	10.8	n.d.	n.d.	
Loyton '93	4.1	5.9	6.8	1.4	0.9	0.2								
(area not cut in '96)	-	-	-	4.3	4.5	3.1								
Tregothnan '93	3.5	4.1	7.3	6.5	5.2	3.6								
Ashmans '94	4.5	6.0	7.1	8.7	10.1			2.8	5.5	6.8	6.6	8.5		
Knowle	3.6	6.7	3.4	2.2	2.1									
(area not cut in '96)	-	-	6.7	6.4	5.5									
Loyton '94	1.3	4.3	2.4	1.8	1.6									
Tregothnan '94	4.7	4.4	6.7	3.6	3.0									

Figure 1. Comparison of productivity of Beaupré and Dasyclados (odt ha^{-1} y^{-1}), calculated at each year of the growing cycle as the average annual productivity since coppicing or commercial harvest, as appropriate).

Underlined values denote commercial harvest of entire crop after assessment. n.d. No data

The study has shown that high productivity (ca. 11-15 odt ha^{-1} y^{-1}) of both willow and poplar can be maintained when the crop is grown on an appropriate site that is well managed, provided that it is not seriously affected by rust. However, where growing conditions were adverse, productivity remained low. Important factors that contributed to high productivity were good weed control, resulting in a low weed burden; a soil with high water availability; and either low levels of disease or a late onset of disease.

The average productivity of the three Beaupré crops at the highest yielding site, Ashmans Farm, was 12.4odt ha^{-1} y^{-1}, at the end of this study. Three years previously the average productivity of the same crops was 11.1odt ha^{-1} y^{-1} (Figure 1). These high values compare with an average productivity of only 3.6odt ha^{-1} y^{-1} for the assessed Beaupré plantings at the other five sites, at the conclusion of the study.

The average productivity of the Dasyclados crops at Ashmans Farm was lower than the Beaupré, at 9.5odt ha^{-1} y^{-1}. This showed an increase from the average of 8.4odt ha^{-1} y^{-1} achieved from the same plantings three years previously.

Due to the absence of commercial harvesting at most sites it was only possible to compare productivity in first and second rotations in three plantings of Beaupré at Knowle Farm and three at Loyton Farm. In all cases the productivity of the second rotation was lower than that of the first rotation. This is consistent with the observation of Mitchell et al.(1999), from a review of experimental data, that, contrary to the generally held view, yields do not increase in the second rotation. However, it must be borne in mind that the crops at both Knowle Farm and Loyton Farm were severely affected by rust in the second rotation, but not in the first.

The planting of Beaupré is no longer recommended, as a consequence of its susceptibility to poplar rust, and Dasyclados is now classified as 'Becoming Obsolete' (Tabbush and Parfitt, 1999). Consequently extreme caution should be exercised in extrapolating the results of this study to the potential performance of more recently introduced poplar and willow varieties.

POTENTIAL FOR FUTURE DEVELOPMENT

No further yield monitoring was recommended at these sites.

dti

Project Ref: B/W2/00643/01/REP | Completion date: January 2001

AN IDENTIFICATION OF SUITABLE NUTRIENT SOURCES FOR SHORT ROTATION COPPICE

Coppice Resources Ltd

OBJECTIVE

- To identify a range of possible sources of nutrient for fertilisation of commercial short rotation coppice (SRC).

SUMMARY

The primary objective of the project was to identify a range of possible sources of nutrient for fertilisation of commercial SRC. The most suitable materials identified would be put forward for further evaluation and analysis. SRC is no different to any other crop in that it requires a source of food or nutrient to allow it to develop and realise its maximum potential.

The report provides the starting point for a larger project to determine the response of SRC to applied nutrients, to set standards to which growers of SRC and suppliers and appliers of nutrients can work.

The report considers both inorganic and organic forms of nutrient. Materials are identified and analyses of nutrient values are provided as accurately as possible. The list encompasses by-products as well as specially produced nutrients for agriculture. An estimate of cost is included as well as a rating of ease of application to a growing crop of SRC.

COST

The work was one of three 'call off' tasks carried out under a master ' SRC Consultancy' agreement '(April 2000 to April 2002). The total cost of all tasks, £13,417, was met by the Department of Trade and Industry (DTI).

DURATION

9 months – April 2000 to January 2001

BACKGROUND

Agricultural crops are typically fed with mixtures of both organic (manures) and inorganic (bag) fertilisers. Within the two groups there are many different types of materials with many different levels of inherent and artificial nutrients. There is also a range of different costs and of application techniques required.

For established agricultural crops there are set standards which are applied to nutrients, both for environmental and economic/yield maximisation criteria. For SRC, the situation is less certain. There are no set standards in terms of the amount of nutrient required for yield maximisation and so no recommended guidelines for growers to follow. With no standard figures for crop uptake of nutrient, it is not known how much nutrient a growing crop will remove from soils. The standards applied to SRC from the environmental angle are based upon work with general agricultural crops and therefore do not take account of possible increased uptake levels and 'cleansing' properties of the crop.

Nutrition of SRC is an inexact science. There are many nutrient sources, all with different properties and strengths and weaknesses. One certainty is that SRC crops will fail without nutrition. Recent work from Germany and Northern Ireland (Dawson, M) has shown that over the longer lifetime of a crop the inherent nutrients from the soil are used up, and in later years the crop fails to reach its maximum yield potential. It is therefore vital to identify a suitable range of nutritionally valuable materials to apply to SRC.

THE WORK PROGRAMME

The report considers both inorganic and organic forms of nutrient. Materials are identified and analyses of nutrient values are provided as accurately as possible. The list encompasses by-products as well as specially produced nutrients for agriculture. An estimate of cost is included as well as a rating of ease of application to a growing crop of SRC.

RESULTS AND CONCLUSIONS

When considering which nutrient sources are most effective overall, a ratings system needs to be employed. The table opposite summarises the relative properties and the practicalities of applying the various nutrient forms to SRC.

The four criteria chosen were nutrient value, ease of application, availability of product, and cost of product applied. However, the key criterion of nutrient value was weighted to make this value twice as important as any other factor. This results in the products that provide the most nutritional value being generally placed higher in the league table, and so meets the key need of fertilising growing SRC.

Therefore in rank order Bio-liquids and agricultural fertiliser come out as most suitable overall. They do, however, have different ratings, with agricultural fertiliser gaining on nutrient and availability, but losing out on application and cost. In pure costs terms, on a nutrient unit for unit comparison, the bio-liquids and bio-solids come out on top. However in the longer term, when linked with steeply rising demand, it is the availability of bio-products across the whole of the country that may prove to be a problem.

Material	Nutrient Rating	Application Rating	Availability Rating	Total Cost Rating	Total Score
Solid Ag. Fertiliser	20	7	10	6	**43**
Liquid Ag. Fertiliser	20	7	10	6	**43**
Bio-liquids	14	9	10	10	**43**
Bio-solids	14	6	9	10	**39**
Liquid Industrial Wastes	10	9	4	10	**33**
FYM Slurry	8	9	7	8	**32**
FYM solids	10	6	7	8	**31**
Solid Industrial Wastes	10	6	4	10	**30**
Green Manures	8	5	10	7	**30**
Micronutrients	4	8	10	8	**30**
Composts	10	6	4	6	**26**

KEY: Nutrient availability rated out of 20. All other factors rated out of 10.

FYM & slurry can be applied by the same methods and would be ranked higher in the list but for their decreasing availability and an inherent value. In agriculture FYM/slurry is generally used on high-value root crops, and so has a value in this context. Therefore, when looking at an SRC application a cost must be put against SRC to reflect this.

Industrial wastes fall into a similar frame, but with availability being the major limiting factor on their use.

Micronutrients appear where expected, with the low nutritional value overriding the other factors of ease of application. This is a fair reflection of their value and usage in SRC. They are best employed where a specific historical problem is known, rather than as an overall source of major crop nutrition.

The composted materials are placed bottom of the list as they are less readily available than most, and also have problems in nutrient value and application. They are seen to be more of a soil conditioner and organic matter improver than a high value source of nutrition, and so at present have limited value to SRC.

What is essential to take into account is the situation of each individual holding. For instance, a large dairy farm will find it more cost effective to apply dairy slurry and FYM to its crop as there is a large availability on site at low cost, which serves to outweigh other factors. Similarly, an SRC plantation based around an industrial process will rely heavily upon the nutritionally valuable by-product for its nutrient.

As a general rule the following principles should apply:

- Use materials that require a muck spreader application exclusively as seedbed fertilisers.
- Use materials that require a fertiliser spreader/sprayer application in the first half of the first year of growth.
- Use bio-liquids or industrial liquids that require boom irrigator application from the first to the mature years of growth.

In all cases an application plan is vital both on a small farm scale and also a larger regional scale to ensure that the best use is made of all available sources of crop nutrition.

POTENTIAL FOR FUTURE DEVELOPMENT

A recommendation system based upon the requirements of SRC and the crops uptake characteristics is required. In order to take crop nutrition forward in terms of cost effective application of nutrient this information must be applicable to varying situations of SRC growing, just as MAFF RB 209 is for all general arable and forage crops. Research work that measures and identifies these relationships within the confines of environmental regulations is invaluable to SRC becoming a more commercially viable crop.

dti

Report Ref: B/W2/00615/REP Publication date: February 2001

A DYNAMIC INFORMATION STRUCTURE TO IMPROVE CO-ORDINATION ON WILLOW BIOMASS FOR ENERGY ('REGROW')

The Scottish Agricultural College (with the Swedish University of Agricultural Sciences and the Netherlands Energy Research Foundation)

OBJECTIVES

- To improve co-ordination at national, regional and local level, in the creation of a willow energy industry.
- To encourage the exchange of experience and know-how between the UK, Sweden and the Netherlands.
- To disseminate relevant, dynamically updated information on the feasibility of energy from willow, nationally and internationally.
- To create a new opportunity for learning, education, and training on energy from willow.

The intention was to provide a complete picture of the whole chain of production, transportation and conversion to energy, with information on all the different stages and the anticipated obstacles, allowing decision makers to evaluate the advantages and problems with willow plantations at full scale as a renewable energy source.

SUMMARY

A guide has been written to give an overview of energy production from willow which is now available on the internet at http://www.sac.ac.uk/willowpower. Most of the text is drawn from experience in Sweden, the UK and the Netherlands, but the information will be applicable to other parts of the world.

COST

The REGROW project was carried out as part of the ALTENER II programme of the European Commission (EC).

The total cost of this project was £107,000, with the Department of Trade and Industry (DTI) contributing £43,000, and the EC and the Netherlands Energy Research Foundation the balance.

DURATION

17 months – August 1999 to December 2000

BACKGROUND

Biomass for energy is a high priority at EU and UK national government level for meeting targets on greenhouse gas reductions and renewable energy supplies, and for jobs and exports. A successful willow industry will greatly benefit farming and rural development.

In Northern Europe, willow is one of the most efficient crops for converting the radiation energy in sunlight to chemical energy in the form of organic compounds that can be used as fuels. (Only sugar beet and wheat can compete, but they need better soils and higher inputs of agro-chemicals). In addition, willows can be used in bio-remediation of contaminated water by taking up nitrates and phosphates, and in contaminated soils by taking up heavy metals.

In Sweden, where there is more experience of willow plantations than in any other EU country, around 16,000 hectares are already in production. At present, 10-12 dry tonnes per hectare per year is seen as the potential for commercial production of biomass from willow, but only about 25 per cent of Swedish growers achieve these yields. It is reported that Swedish farmers actually ploughed up 1000 hectares of willow during 1998. It was seen as important for new biomass power station projects, particularly those heavily dependent on willow for fuel, that this type of setback should be avoided.

It has been estimated that 15 jobs are created in the fuel supply chain, at the power plant, and in secondary employment, for every megawatt of electricity capacity generated from wood fuel. This compares with targets in an EC White Paper exceeding 50 gigawatts of electricity capacity from biomass, with the potential to create over 100,000 permanent full-time jobs.

However, weaknesses in understanding do exist, and these create barriers to coord-ination at different levels. Decision makers, planners, investors and others are often familiar with some parts of the emerging industry, but may lack knowledge of other critical parts and the interdependence between them. As a result, bad decisions can be taken and early projects can fail.

THE WORK PROGRAMME

The programme of work comprised three main actions:

- To complete a **Technical Review** of the entire production chain for energy from willow, including a bibliography, on the following areas:
  - willow production in the field
  - willow fuel supply systems
  - willow fuel conversion into energy
  - environmental analysis of energy from willow
  - economic analysis of energy from willow.
- To write and publish an **Energy from Willow Guide** covering the whole production chain, from field to end use, based on the Technical Review and bibliography.
- To design and install a prototype **Active Learning Centre** on the internet about Willow Power, based on the Guide.

The Energy from Willow Guide

The partners carried out literature searches in the agreed specialist areas:

1 Willow breeding and cuttings material

2 Cultivations, planting and establishment

3 Plantation management, pests and diseases

4 Harvesting and storage

5 Transport and supply systems

6 Fuel analysis and pre-processing

7 Fuel conversion processes, liquid fuels, gas cleaning

8 Energy production, heat, CHP, electricity

Structured bibliographies were then prepared and written technical reviews were drafted, providing a critical appraisal of relevant up to date knowledge (ECN published their review as a technical brochure [Dinkelbach, L *Thermochemical conversion of willow from short rotation forestry*. ECN-C--00-028, Petten, February 2000]).

The original intention had been to issue the Guide as hard copy, but it was later agreed that publishing the information through the internet was preferable.

The files have been installed on the SAC Web site http://www.sac.ac.uk/willowpower. The Guide can be downloaded in the industry standard Adobe PDF file format, which maintains the document layout regardless of what computer hardware is being used to view or print the document. Two versions have been made available, the smaller file optimised for viewing on screen and a larger file that allows high quality printed output.

The Active Learning Centre

The foundation material available was the content of the new Guide. This was incorporated into a new learning routine designed for the dedicated Active Learning Centre.

The Learning Centre can be treated simply like a book that is read from start to finish, but internal links allow the user to navigate around the document and study the material in either a random or a more structured manner.

A computer-based learning package can provide information in ways that are not possible with printed text, and two examples have been incorporated in the Active Learning Centre:

- a calculator has been provided so that plant population per hectare can be instantly derived when the user enters between-row and along-the-row spacings
- the action of a cut-and-plant machine, which is difficult to describe adequately in words, has been shown in an animation sequence.

Self-assessment questions have been provided at the end of each section, allowing users to check their understanding of the subject matter and, if in doubt, return directly to the relevant passage in the text.

Access to the Learning Centre is currently free to all internet users. This system allows much more complex interaction with the user, and more sophisticated assessment procedures, than can be achieved through the public-access areas of the internet.

CONCLUSIONS

This project delivered two new specific aids to understanding:

- The *REGROW* Guide, "Energy from Willow", is an entirely new guide to sustainable energy from willow. It is written in a clear, readable and informative style, published via the internet.
- The *REGROW* Learning Centre is a new flexible learning course on the internet, providing easy interactive learning and tuition, using source material from the Guide.

The Learning Centre can be accessed, and copies of the Guide downloaded, through the internet at www.sac.ac.uk/willowpower.

POTENTIAL FOR FUTURE DEVELOPMENT

The Guide has been published as a downloadable file on the internet, which allows the content to be revised much more easily than with a conventional printed document. The biomass energy industry is still in a stage of rapid development, and some of the information may become outdated relatively quickly. If funding were secured, the Guide could be updated on a regular basis.

The project contract involved production of a prototype Active Learning Centre, and this has been achieved. There is clearly scope to enhance the current version. Some of the options are:

- establishment of more links to external Web sites (eg biomass energy development projects, research programmes, equipment manufacturers)
- greater use of animation to explain the operation of machines, material flow through gasifiers, etc
- additional calculation facilities (eg for economic assessment of willow production).

The Active Learning Centre should be further developed into a more comprehensive Flexible Learning facility. For example, the scope for self-assessment by the learner is at present somewhat limited. As the biomass energy industry develops, there will be a requirement for tutored learning, educational qualifications and certificated training. These will help to underpin the UK and EU programmes of expanding the power generation capacity based on willow fuel.

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Report Ref. B/W2/00577/00/00 Publication date: February 2001

THE GIANT WILLOW APHID (*Tuberolachnus salignus*) ON SHORT ROTATION COPPICE WILLOW

The Game Conservancy Trust (with Imperial College of Science, Technology and Medicine)

OBJECTIVES

- To survey populations of stem-feeding aphids occurring naturally in short rotation coppice (SRC) willow crops.
- To discover more of the biology and ecology of these species.
- To estimate the effects on yield of any of these aphid species that appeared to have a pest status.

SUMMARY

Tuberolachnus salignus and *Pterocomma salicis* are both aggregative aphids that have been noted within SRC crops. Experiments with willows grown in soil and in hydroponic culture reveal that *T. salignus* can reduce the above-ground yield of biomass willows, have severe negative effects on the roots and reduce the survival of both newly planted and established trees. *Pterocomma salicis* can also reduce yield and negatively affect the roots of host trees, but its effects are less marked. Both species can lead to plant stress and increase the vulnerability of host trees to other factors. Field observations indicate that *T. salignus* may be increasing in abundance in SRC crops.

As yet we understand little of the population dynamics of these aphids and long-term monitoring within extensive SRC crops is required to determine the frequency and abundance of their occurrence.

COST

The total cost of this project was £16,500 with the Department of Trade and Industry (DTI) contributing £5,831 and the project partners balance.

DURATION

41 months – October 1997 to February 2001.

BACKGROUND

Insect pests can have adverse impacts on SRC yield and thus on the economics of production. Previous entomological studies have concentrated on the more obvious damage to SRC caused by defoliating insects. The damage caused by both leaf and stem-feeding aphids is largely invisible; other than in their roles as viral vectors and gall inducers they rarely cause obvious alterations to leaf structure and function. However, aphid presence is an energy and nutrient drain due to their phloem-feeding habit. The energy and nutrient loss caused to sycamore trees (*Acer pseudoplatanus*) by the sycamore aphid (*Drepanosiphum platanoidis*) has been shown to lead to earlier leaf fall, to reduce the size of leaves by 40% and the production of stem wood by 62% (Dixon, 1971). The sycamore aphid is much smaller than the giant willow aphid, *Tuberolachnus salignus,* which has been shown to ingest the photosynthetic product of 5-20 cm^2 of leaf per day (Mittler, 1958). The magnitude of this drain has the potential to affect significantly the yield of willows by altering the source-sink relationship within the plant. There may also be potential impacts on the long-term development and fitness of the rootstock left *in situ* after coppice harvesting as a result of changes in root health, density and architecture.

The study focused on two aphid species: *Tuberolachnus salignus*, the giant willow aphid and *Pterocomma salicis*, the black willow aphid. Both species aggregate and occur in dense colonies on the stems of infested plants, but have contrasting ecologies.

Tuberolachnus salignus (Gmelin), Lachninae, Lachnini

The Giant Willow-aphid is one of the largest aphids ever recorded (BL 5.0-5.8 mm) (Blackman & Eastop, 1994). It feeds almost exclusively on willow, but has very occasionally been recorded on poplar (*Populus sp.*). Its distribution reflects that of willows; it is virtually cosmopolitan, only being absent from Australasia. The species is apparently parthenogenetic; no sexual morphs have ever been found and recent DNA studies support this (Blackman & Spence, 1996).

The species is strongly aggregative, forming vast colonies on infested trees. These colonies can cover much of the 1-3 year old stem surface of a tree. Other than its large size the most distinctive features of this aphid are a large dorsal tubercule (function unknown), the reddish stain it makes when squashed and synchronised waving of the hind legs over large areas of infestation. Many entomological texts note this insect as being capable of much damage, even of killing willows up to 40 feet tall (Buckton, 1881; Das, 1918; Swirski, 1963), but until now little attention has been paid to its ecology and host relationships.

Pterocomma salicis (Linaeus), Aphidinae, Pterocommatini

The Black willow-aphid is another large aggregative aphid (BL 2.7-4.5 mm). It also feeds exclusively on willow (Blackman & Eastop, 1994), and is common in the northern hemisphere. Although the species is parthenogenetic for much of the year, a sexual generation is produced in autumn and the overwintering egg is found in the buds and on the stems of willows. The species is often attended by ants, which may protect it from predation.

THE WORK PROGRAMME

Effect of temperature on fecundity and development of *Tuberolachnus salignus*

This study investigated the thermal requirements, nymphal development rates and the fecundity (the number of young produced) of both alate (winged) and apterous (without wings) adults of the giant willow aphid, *Tuberolachnus salignus* at several temperatures.

Host selection and performance of the giant willow aphid – implications for pest management

The recent increase in planting of selected willow clones as energy crops for biomass production has resulted in a need to understand the relationship between commonly grown, clonally propagated genotypes and their pests.

This work studied the interactions of six willow clones and the previously unconsidered pest, the giant willow aphid.

The impact of the aphids *Tuberolachnus salignus* and *Pterocomma salicis* on willow trees

The effect of two species of stem-feeding aphid on the yield, phenology and water-use of soil grown and hydroponic-cultured willow were investigated.

Ant-mediated dispersal of the black willow aphid *Pterocomma salicis;* does the ant *Lasius niger* judge aphid-host quality?

Many species of aphid have intimate associations with species of any. These relationships are often considered mutualistic and the benefits to both parties are widely appreciated. The benefits to the ant partner stem largely from the ready supply of carbohydrate available in aphid honeydew and in certain cases from the protein of aphids themselves, whist aphids may benefit in terms of protection from natural enemies, improved colony hygiene, increased feeding rate, transport and dispersal.

RESULTS

Effect of temperature on fecundity and development of *Tuberolachnus salignus*

Nymphal development rates increased linearly with temperature. It was estimated that 196± 4 degree-days above a threshold temperature of 5.5 ± 0.3°C were required for apterae to complete development from birth to final ecdysis.

The alate morph was significantly less fecund than the apterous morph and its fecundity did not vary with temperature.

The apterous morph displayed highest fecundity at 20°C.

Survival to reproduction was lower in the alate morph, but temperature had no effect on the proportion reproducing in either morph.

Host selection and performance of the giant willow aphid – implications for pest management

Tuberolachnus salignus alatae displayed no preference between the clones, but there was genetic variation in resistance between the clones; Q83 was the most resistant and led to the lowest reproductive performance in the aphid.

Maternal effects buffered changes in aphid performance. On four tested willow clones fecundity of first generation aphids on the new host clone was intermediate to that of the second generation and that of the clone used to maintain the aphids in culture.

In the field, patterns of aphid infestation were highly variable between years, with the duration of attack being up to four times as long in 1999 when compared to the previous year. In both years there was a significant effect of willow clone on the intensity of infestation. However, while Orm had the lowest intensity of infestation in the first year, Dasyclados supported a lower population level than other monitored clones in the second year.

The impact of the aphids *Tuberolachnus salignus* and *Pterocomma salicis* on willow trees

The effects of *Pterocomma salicis* were less marked than those of *Tuberolachnus salignus*. The latter reduced not only the above and below-ground growth of trees made during and subsequent to infestation, but also altered the mass of previously developed woody tissue.

The negative effects of *T. salignus* on the shoots and roots of established and establishing trees were drastic and were both quantitative and qualitative. They were observed also to reduce the survival of infested trees.

P. salicis had negative effects on the growth of roots and shoots during infestation, but the influence of this species did not persist nor did it influence previous growth.

Ant-mediated dispersal of the black willow aphid *Pterocomma salicis;* does the ant *Lasius niger* judge aphid-host quality?

Pterocomma salicis and *Lasius niger* benefit from the presence of each other. The presence of *L.niger* increased the numbers of *P. salicis* in colonies, but not the adult dry weight. *L.niger* was seen to carry late-instar *P. salicis* between plants. Results indicate that this ant-borne dispersal of aphids may take into account host quality. In a crop context, the presence of ants may not only increase the impact on yield of these aphids by aiding an increase in their numbers, but may also lead to their wider dispersal within the crop.

CONCLUSIONS

Both these aphid species do adversely impact the yield of SRC willows. The black willow aphid's effect is less marked than that of the giant willow aphid, which can reduce not only the growth of the plants subsequent to infestation but also alter previously developed woody tissue. The negative effects of the giant willow aphid on the shoots and roots of established and establishing trees are drastic and are both quantitative and qualitative. Impoverished roots can reduce the survival of infested trees as well as increasing the vulnerability of the host to other potentially detrimental factors. It is likely that mortality previously attributed to drought or frost may have been exacerbated or increased by the presence of these stem-feeding aphids.

POTENTIAL FOR FUTURE DEVELOPMENT

Large scale monitoring of aphid populations is underway at trial sites around England (ref. DTI project B/W2/00624/00/00). A preliminary glance at the data arising from this indicates that, although there is much variation, mean numbers of aphids present in the autumn survey are rising. These aphids, while not identified to species level, are highly likely to be the giant willow aphid, *Tuberolachnus salignus.* As this species is likely to be the most substantial aphid threat to SRC yields, further investigations of it's ecology with a view to gaining sufficient understanding to contribute to its control are warranted.

Prospects for Biocontrol

The black willow aphid is predated and parasitised in this country and populations may well be maintained at levels below those of economic impact by cultural methods that promote natural enemies.

The giant willow aphid has no parasitoids, few predators and its numbers only seem to be reduced by a mysterious ‘black death’. It is not known if this disease is fungal, bacterial or viral in origin and further research is required to determine its dynamics and impact, and thus whether it could be used to control numbers to reduce the impact of this aphid on crop yield.

Willow Clonal Resistance

As there is now evidence that some willow clones are more resistant to the giant willow aphid than others, an expanded screening that includes a larger selection of willow clones is advised. With increased planting of willow SRC crops and an increased abundance of this aphid in trial plots around the country it is vitally important to identify which clones may be promoting high populations and to monitor these in the field.

FURTHER INFORMATION

The report summarises the findings of a PhD thesis (C.M. Collins, 2001) and the reader is referred to that for fuller details of methods, results and discussion.

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Report Ref. B/M4/00532/13/REP Publication date: August 2001

THE SILVICULTURE, NUTRITION AND ECONOMICS OF SHORT ROTATION WILLOW COPPICE IN THE UPLANDS OF MID-WALES

Cardiff University

OBJECTIVES

- To determines the silviculture of short rotation coppice (SRC) in upland sites in Wales, the influence of animal manures on growth and the economic potential of SRC as an alternative land use.

SUMMARY

The potential of SRC as a biomass crop on land over 250m (the uplands) of mid-Wales was studied.

At an altitude of 255m on a clay loam, with fertiliser application in establishment year only, the highest yielding variety, *Salix* Delamere, produced six oven dry tonnes (odt) ha^{-1} yr^{-1} after five years. The optimum planting date on this site was determined as being from January to mid-March.

After three years, at an altitude of 365m on a peaty gley, yield was found to be doubled by the addition of cattle slurry ($100m^3$ ha^{-1}) in years one and two. With fertiliser application, production of the best yielding varieties, *Salix viminalis* Bowles Hybrid, Gigantea and Q683 ranged from 1.37 to 2.25odt ha^{-1} yr^{-1}. Cut back after one year was found not to influence biomass production in year three, but did lower survival. Survival rates were generally high, from 91-98% in establishment year.

In addition to increasing foliar nutrient concentrations, glasshouse studies demonstrated that yield increases were due to the slurry acting as a mulch. Further glasshouse trials showed that poultry and pig manure also increased growth, although for poultry manure this was dependant on the addition of a mulch. Root growth was influenced by fertiliser application, with increased surface rooting under liquid fertiliser additions.

Non-destructive estimates of standing biomass were produced, and although weight was successfully predicted from diameter, inaccuracies were recorded when scaling up to field level.

An economic model was written (assuming a market in the form of a local electricity plant) and in terms of Net Present Value (NPV) over 25 years, returns were found to be similar to those from sheep production at a production level of 8odt ha^{-1} yr^{-1}

The results found in this study indicate that growing short rotation coppice willow in the uplands is a viable proposition with regard to establishment success and yields. In the event of a secure wood chip market in Wales, returns to the grower would be comparable to those from sheep production.

COST

The total cost of this project was £35,964 with the Department of Trade and Industry (DTI) contributing £3,000, and DEFRA, ADAS and LRZ Ltd the balance.

DURATION

42 months – January 1996 to June 1999.

BACKGROUND

Ideally willow should be grown as close as possible to where it will be utilised, in order to minimize transport costs. In Wales this could result in upland land being planted (land above 250m altitude) as 62% of Wales falls into this category. One third of all farm holdings are solely in this area, and many more farmers have a proportion of land in the uplands (Welsh Office, 1997).

Currently the primary land-use in these areas is sheep production, which is heavily subsidized. With the uncertainty surrounding agricultural support for livestock farming in these areas, farmers are keen to diversify. Farmhouses and buildings are a suitable size for small-scale woodfired heating units using short rotation coppice as a fuel. Additionally there are potential markets in the form of several proposed wood-fuelled electricity plants in mid-Wales.

In general upland soils are acidic and nutrient poor. Studies of growing willow on organic soils such as those found in the uplands have all shown a need for fertilisation (Elowson & Rytter, 1988; Firm & Hytonen, 1988; Hodson, 1995; Kanetsu, 1983) and if economic yields are to be obtained then fertilisation is likely to be essential. Organic fertilisers such as sewage sludge and slurry have benefits over inorganics in that they are readily available, cheap, enhance soil structure and also have mulching properties (Granhall, 1994).

THE WORK PROGRAMME

The effect of cattle slurry on establishment and biomass production.

A 1ha field trial on a seasonally waterlogged peaty gley soil was set up at ADAS, Pwllpeiran in mid-Wales. The site had an altitude of 365m and is believed to be the highest site under SRC in the UK. Average rainfall was 1760mm year^{-1}.

Six willow varieties were planted (at a density of 20,000ha^{-1}) by hand in Spring, 1996, on the Swedish double row system:

- S. *x dasyclados* – a (*caprea* x *cinerea*) x *viminalis* variety, found to grow well in previous upland trials.
- S. *viminalis* Mullatin, Q683, Gigantea and Bowles Hybrid – all found to produce good yields and remain fairly insect and rust resistant.
- S. *viminalis* Jorunn – a newly released Swedish clone found in Forestry Commission trials to perform well over a whole range of sites (although all below 200m).

Slurry from a herd of beef cattle was applied in Spring, 1996 and 1997 at a rate of 100m^3 ha^{-1} based on the maximum recommended quantities of slurry in the Code of Good Agricultural practice (MAFF, 1991).

Standard practice is to cut back the shoots after the first year, although there is no evidence to support the benefits of this. It was decided to cut back half of each plot in December 1996, and examine the influence of this on subsequent growth.

The effect of animal manures and mulches on the establishment and biomass production of *Salix* x. *dasyclados* grown in pots under glasshouse conditions.

Two pot experiments were set up to assess the variation in growth and nutrients of willow in response to different types of animal manure. In 1996 a one year trial was set up with poultry, pig and cattle manure applied to willow at three rates. Two types of plant material were used, new unrooted cuttings and established stools. In 1997 an experiment was set up to examine the influence of mulching as well as cattle slurry, cattle manure and poultry manure on tree growth.

Root production in biomass tree crops grown under an effluent disposal system.

A visit was made to Massey University, Palmerston North, New Zealand, to utilise equipment and expertise in root studies.

A lysimeter study had been set up to ascertain the nutrient and water balance of the trees by monitoring all inputs and outputs. One mini-rhizotron had been installed in each lysimeter. A mini-rhizotron system consists of a camera which runs up and down a clear tube inserted into the soil. Three varieties were studied, *Salix kinuyanagi*, *Eucalyptus nitens* and *E.saligna.*

Assessments were made at approximately two-week intervals, and the data (root branches and intersections with the edge of the frame) were analysed by the author.

In 1994 a field trial was set up by researchers at Massey University to investigate the response of *Eucalyptus nitens* and nine *Salix* varieties, to dairy farm effluent irrigation.

In June 1994 field trials were planted. In May 1996 the trees were cut-back, and in September 1996 an investigation of the root growth of *E. nitens* and *Salix viminalis* PN386 and NZ1295 was carried out.

The influence of fertilisation at establishment on longer term yields in the uplands.

Cardiff University began short rotation willow coppice field trials in the uplands of mid-Wales in 1992. The main trial site, called Carnau, at an altitude of 255m on a stony silty clay loam of the Cegin association is believed to be the only upland SRC site in Britain other than those set up at ADAS Pwllpeiran as part of this study.

After being ploughed and harrowed the site was planted with the following varieties in January 1992:

- *Salix* x. *dasyclados*
- *Salix viminalis* Bowles Hybrid
- *Salix cinerea* McElroy
- *Salix* Delamere.

Two fertiliser treatments and a control of no treatment were applied:

- Potassium (100kg ha^{-1}) + Phosphorus (60kg ha^{-1}).
- Potassium (100kg ha^{-1}) + Phosphorus (60kg ha^{-1}) + Magnesian Limestone (10t ha^{-1}).
- Control - no treatment.

The survival was recorded and the trees were cut-back and weighed in January 1993. In January 1997 all plots except Bowles Hybrid were harvested and weighed. In summer 1997 it was noticed that the Dasyclados plots were not growing well in comparison to the other two varieties. It was thought that the fast-growing Dasyclados may have exhausted the soil nutrient supply and soil samples were taken of each plot of Dasyclados and *S. cinerea.* In January 1998 the plots were harvested and weighed again.

The influence of planting date on the establishment and growth of stored and freshly cut willow cuttings.

An upland site, 255m, on a stony silty clay loam of the Cegin association was used for this experiment.

Willow was planted every 28 days throughout 1996, using one year old cuttings of Dasyclados which had been cut in December 1995, loosely wrapped in polythene and stored at –4°C. At the same time fresh cuttings were taken from existing plantings at the site and planted. All cuttings were soaked in water for 24 hours prior to planting.

Soil and meteorological data were recorded, and the trees harvested and weighed in December 1997.

The economics of growing short rotation coppice in the uplands of mid-Wales and an economic comparison with sheep production.

An economic spreadsheet was written in Microsoft Excel, comprising cashflows for the two enterprises (SRC and sheep). The model represents standard cashflows for different silvicultural regimes and allows other factors to be considered, such as chip price and government subsidy level. Output from the model is in the form of NPV at four different discount rates (r); four, six, eight and ten percent.

In order to provide the farmer with annual incomes, the model assumes planting will be on a sustained yield system that is to have as many areas of coppice as there are years in the rotation, so that annual harvests can be made. A four-year rotation was assumed for this upland scenario. The model assumes the market of a woodfuelled power station, sited ten miles away, and accepting wood chips at delivered prices ranging from £30 to £40 odt^{-1}. All costs of planting, management and harvesting were included, and discounted over 25 years, the assumed productive life of SRC stools.

CONCLUSIONS

Silviculture of willow in the uplands.

In Wales it is primarily upland land that is likely to be available for planting SRC in the foreseeable future, due to farmers' reluctance to plant the better lowland. The uplands offer several advantages for growing willow in comparison with the lowlands. The cold damp climate has been seen to prevent excessive insect and rust attacks. The high rainfall means that water stress is not a problem, and the low nutrient status of the soil can be seen as an advantage, enabling the application of slurry which can otherwise present problems of disposal.

Disadvantages are the shorter growing season, exposure and strong winds, all of which are detrimental to growth. The shallow soils could also be a problem in the future, facilitating wind throw of older trees. The wet ground leaves the soil intractable for much of the year and, generally, the climate is not cold enough for the ground to be frozen in the winter to facilitate harvesting access. Another problem for harvesting are the hillside gradients, which are unsuitable for tractor access. Weeds are less competitive than in the lowlands but rush (*Juncus effusus*) can be problem and is difficult to eradicate. Hares can cause grazing damage, although in the lowlands the problems of rabbits can be much worse.

The main field experiments in this study were carried out at altitudes of 255m or greater, and thus are believed to be the highest altitude SRC trials yet documented. Soils of the Cegin and Wilcocks series are both subject to seasonal water-logging and together total 11.5% of total land in Wales. Temperature sum ranged from 2517 to 2876 at 255m and 2337 to 2606 at 365m. Rainfall during the growing season varied considerably between the sites, with a range of 423-761mm at 255m and 850-1982mm at 365m. Duration of the growing season was similar for both sites, ranging from 209-245 days. The following guidelines are based on these climatical conditions.

Variety choice

Different varieties perform differently at different sites so general prescriptions for variety choice are hard to make. It is advisable to plant several varieties, and determine which grows best. First year results are not always reliable in predicting long term yields and so stools should be left for several years before a decision is made to grub up and replant with a different variety. In the longer term with little nutrient inputs *S.* Delamere and *S. cinerea* (McElroy) have produced moderate yields, and in the shorter term with fertiliser addition *S. viminalis* Gigantea, 683 and Bowles Hybrid have all done well.

Planting Date

In the uplands the planting season should be earlier than in the lowlands, with best results obtained by planting from January to mid-March. There is no need for costly cold storage facilities if trees are cut just prior to planting.

Cut-back

Generally if the shoots are small and performing badly then the stools should not be cut back as doing so will lower second year survival and exposes the shoots to further hare grazing damage. This decision may be revised if there is a lucrative market for the cuttings, but otherwise the cost of cutting back is not returned by higher yields later in the rotation.

Yield production

Production in these upland trials was much lower than found on lowland sites, being approximately 6 odt ha^{-1} yr^{-1}. There is potential for far greater yields with regular fertilisation and also yields will increase as the stools mature. Although prediction of yield (standing biomass) is not yet adequate for the commercial environment, the preliminary results were encouraging and indicate further research areas. In combination with scientists at the Forestry Commission the study presented here should help predict yield production across a range of different site types.

Nutrition of willow in the uplands.

Contrary to accepted practice, fertilising in establishment year produces significant increases in yield. Cattle slurry, cattle manure, poultry manure and pig manure all increased growth in establishment year when applied at a rate equal to 250kg N ha^{-1}. Poultry manure has the best balance of nutrients, but was found only to work well in conjunction with an additional mulch. Of the manures tested, cattle slurry had the best natural mulching properties, and was also seen to suppress weeds in a field situation.

The soil pH was found to decrease in all fast growing plots on both upland field trials, indicating the need for liming before establishment, and possibly between harvests. There is also a need to fertilise older stools between harvests, as additions of manure at rates equivalent to 250kg N ha^{-1} produced increased yield of the three year old stools. Yields of Dasyclados decreased annually in the field, and regular fertilisation may have overcome this.

It may be necessary to apply phosphorus in addition to the manures as generally phosphorus levels in the foliage were low. Rates of inorganic phosphorus alone of 60kg ha^{-1} have been found to increase production (Hodson, 1995), so for cattle slurry a supplement of 40kg ha^{-1} would be advisable in addition to the approximately 20kg supplied by cattle slurry when applied at a rate of $100m^3$ ha^{-1}.

All the manures tested were high in potassium, and the foliar concentrations of this nutrient reflected this, being higher than recommended (Ericsson, 1994). However, no problems such as abnormal growth or chlorotic foliage were recorded.

Nitrate leaching should not be a problem, as it is likely that denitrification is occurring in the wet cold soil of the uplands. However, more work should be carried out to quantify this. Fertilisation was found to influence root spatial arrangement, with more roots near the soil surface. This has implications for machine harvesting, which could damage these surface roots by soil compaction or physical damage.

Economics and the future of SRC in the uplands.

With all subsidies removed the returns from SRC, although low are greater than for sheep production (assuming £35 odt chip price, yield 8 odt ha^{-1} yr^{-1}), a realistic target for the uplands. The economic climate is changing rapidly, and since the model was written the subsidies for sheep have risen and the price of lambs dropped, resulting, on a level basis, in SRC appearing even more favorable. The results presented from this study are being used by the National Assembly of Wales, Agriculture Department (NAWAD) to determine the viability of SRC in relation to other novel alternatives of farmers. This may lead to a new system of support to replace the current Woodland Grant Scheme and offer greater financial incentives to plant SRC in Wales.

Yield, odt ha^{-1} yr^{-1}	**Chip Price**		
	£30	£35	£40
6	4858	4517	4176
8	4426	3971	3516
10	3994	3426	2858
12	3563	2881	2199
Current government sheep subsidy = £4190			

Figure 1 Proposed discounted SRC subsidy ha^{-1} (discount rate 6%, no lime)

The results found in this study indicate that growing short rotation coppice willow in the uplands is a viable proposition with regard to establishment success and yields. In the event of a secure wood chip market in Wales, returns to the grower would be comparable to those from sheep production.

POTENTIAL FOR FUTURE DEVELOPMENT

The future for biomass crops is encouraging, with NAWAD perceiving biomass as a key alternative crop for farmers, and short rotation willow coppice as the crop with most potential in the uplands. Developments in energy markets for biofuels will be crucial, for example, it is fully expected that approval will be granted for wood powered electricity plants in Wales in the near future.

FURTHER INFORMATION

This report summarises the findings of a PhD thesis (Heaton, 2000) and the reader is referred to that for fuller details of methods, results and discussion.

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DEVELOPMENT OF A COPPICE PLANTING MACHINE TO COMMERCIAL STANDARDS

J Turton Engineering Limited

OBJECTIVES

- To develop and produce a four-row version of the Turton coppice planting machine to a commercially acceptable standard of economical design and production consistent with quality of fieldwork and operational reliability.
- To develop and produce an electro-hydraulic service and control module for a six-row planting machine arrangement but using only four machines, with each machine planting one row of cuttings.
- To assess the field performance under commercial conditions.

SUMMARY

The Turton Engineering coppice planters use a modular system of construction not dissimilar to many conventional seed drills. Typically, several identical planting machines, each planting a single row of cuttings from rods, are arranged along a toolbar. A central service module provides each machine with hydraulic power to valves through supply and return lines. In addition, electrical timing and control functions are supplied from the central service module.

The report covers development work carried out between October 1998 and December 1999 with the objective of bringing the Turton Engineering coppice planting machine to commercial acceptability in the market place. In particular, it covers the redesign and development of a number of mechanical items giving rise to concerns and limitations evident during previous use.

Trials show the larger four- and six-row planters have a high sustained output capacity. The basic planting speeds per row are closely comparable with observed speeds for the four-row Step Planter.

However, the development of an automatic feeding apparatus would remove the present operator limitation on planting speed and would reduce the number of operators. Design work on an automatic feeder is advanced and some metal parts have been made. This work should continue.

The planting machines demonstrate significantly improved reliability although large-scale field trials are still required to confirm acceptable commercial reliability.

COST

The total cost of this project was £30,650 with the Department of Trade and Industry (DTI) contributing £14,240, and J Turton Engineering Ltd the balance.

DURATION

14 months – October 1998 to December 1999

BACKGROUND

From an initial towed machine (1994) powered by traction wheels, the Turton coppice planter evolved through to a single-row hydraulically powered prototype in 1995. This machine was tested and positively assessed by the Forestry Commission Technical Development Branch in 1995. In 1996, with the aid of DTI funding, a two-row pre-production planter, powered and controlled by electro-hydraulic means, was built and field-tested at several locations.

These tests showed promise, but revealed a number of problems requiring further development. This led to significant changes in 1997. Hydraulic distribution to the two individual machines, soil contamination of electrical sensors and a weak cam and follower arrangement were particular problem areas for which effective solutions were found. An electronic controller was developed to provide an internal 'trigger' signal to initiate each planting action as an alternative to an external landwheel input. This latter feature has proved to be useful in determining the planting pitch between cuttings to the extent of replacing the landwheel. With the above developments, a planting trial into wet, unprepared soil took place in November 1997 which demonstrated that the machine was capable of planting into hard, compacted soils.

In early 1998 the two-row coppice planter was provided with dual on-board hydraulic systems taking power from a tractor PTO shaft rather than the tractor hydraulic pump. This was a successful development. Tractor pumps were of variable output and were mainly of inadequate capacity for more than two machines. This change was considered to be essential for further development towards large multi-row machines.

The 1998 planting season saw the machine transported to Sweden where further field trials took place. The planting quality was considered by Swedish colleagues to be good and the method of planting to be particularly suitable for Swedish field preparation where the cultivation depth was generally less than in the UK. Over-running of the mechanism led to failure of one of the machines and an urgent but successful repair took four days. Swedish colleagues expressed an interest in a six-row version of the machine.

THE WORK PROGRAMME

Design for commercial use

All drawings were collated to relate to a number of discrete assemblies and sub-assemblies to facilitate the ordering of parts and assembly work. Special manufacturing processes required 'cross-assembly' drawings. These covered:

- laser cut parts
- small precision machine parts
- rods and shafts.

Design modifications were carried out to many components with the objective of:

- improving performance
- reducing production costs.

Several components were re-designed for bolted assembly and the use of welding was minimised. This reduced the production cost and avoided troublesome distortion of components due to welding. The parallel linkage, wheel frame and inclined frame were typical examples.

Particular attention was given to the problem of overrunning of the mechanism as experienced in Sweden and a double buffer arrangement to limit the hydraulic cylinder travel was devised. Robust magnetic sensors were used to communicate with a mild steel plate mounted directly onto the clevis end of the hydraulic cylinder rod and profiled to give required sensor signals.

The service and control module was designed to provide hydraulic power and electrical control functions for six planting machines. Dual on-board hydraulic systems followed those of the two-row system but having three times the capacity, each system capable of serving three planting machines via one-to-three-way gear flow dividers. Only four planting machines were connected but hydraulic circuits simulated two additional planting machines.

Production

Production of parts and of the welded and bolted assemblies was carried out by contractors. Assembly of modules was carried out by Turton Engineering. Much use was made of laser cut parts produced directly from Turton Engineering drawings in DXF file format. Small items such as bearing housings were generally welded into place. Otherwise, welding was kept to a minimum to avoid distortion problems.

Bolted assemblies using spacers and Binx nuts proved an economical and satisfactory assembly method.

Components and assemblies were inspected for quality of machining, accuracy and finish.

Owing to timing constraints and heavy involvement in other work by a particular contractor, several contractors were used for specific aspects of the production process. This led to the production process falling behind schedule.

Proving trials and commercial planting

Static trials took place at Turton Engineering. The work fell well behind schedule and proving trials were not carried out before transport to a commercial planting site was arranged. This occurred very late in the planting season. A number of faults became evident which would normally have been dealt with during the proving trials. These were:

- Excessive tightness of the sliding head bushes on the slidebars.
- Distortion of the anvil/shutter plate owing to heat treatment during production.
- Failure of one magnetic switch.

These faults, and the fundamental causes behind them, were quickly remedied as later proving trials in the field confirmed. An opportunity for extended field trials during the winter months of a single-row planting machine arose from the need for a machine to plant blackcurrant cuttings from rods. No further machine problems have been encountered during any of these trials.

The service module performed satisfactorily throughout the trials and demonstrated a full capability to service six machines.

Results

The planting machines were convenient in operation and in adjustment to the required operating parameters. These were:

- Planting pitch in the row over the range 200-2000mm.
- Planting depth, manually adjusted by 'top link' type members.
- Sliding head 'out-and-home' speeds, individually adjusted by hydraulic valves.

The required selection and preparation of rod material was minimal.

The quality of planting was excellent. Recent small design changes appeared to eliminate the very small amount of bruising which sometimes occurred previously. The inclined cut, combined with forced planting gave excellent soil contact and the machine has demonstrated historically an excellent cuttings 'take'. However, in stony soils cuttings can be damaged by stone contact.

Accuracy of planting was good. Pitch in the row was normally maintained within +/- 20mm.

Speed of planting was typically in the range 3600-4000 cuttings/hr for each row, the limiting factor being the skill and dexterity of the operator and the lengths of rods. The higher speeds of a sustained 4200 cuttings/hr and maximum 5000 cuttings/hr, attained in previous use with one and two-row machines should be possible.

An operators' guide giving routine maintenance instructions is in hand. Routine maintenance is confined to oiling and greasing of a few components and regular inspection of the cutting blade, with sharpening or replacement as appropriate. A pre-season check by Turton Engineering is required.

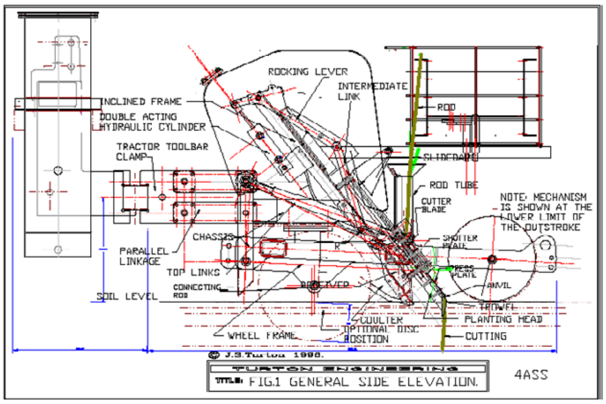

Figure 1 General side elevation of the Turton coppice planter

CONCLUSIONS

Four- and six-row arrangements of the Turton coppice planter are technically feasible.

The planting machines demonstrate significantly improved reliability although large-scale field trials are required to confirm acceptable commercial reliability. Extensive single-row planting of blackcurrant may give this confirmation.

Adjustment in the field of planting pitch in the row, planting depth and speed of planting is particularly convenient.

The larger four- and six-row planters have a high sustained output capacity. The basic planting speeds per row are closely comparable with observed speeds for the four-row Step Planter. Increased speed of operation per row may be possible, with the development of a rod feeding apparatus.

The capital cost of the larger four- and six-row Turton planters is a significant factor but is believed to be highly competitive with the Step Planter. The overall cost of operation in the field is expected to be comparable with the existing Step Planter on a four-row basis. However, six-row planters have potentially lower operating costs in establishing the larger plantations than corresponding four-row machines.

Larger four- and six-row planters may be unsuitable for very hilly terrain. Harvesting machinery may have a similar problem.

It is suggested that four- and six-row planters are likely to sell mainly to Farm Contractors or to be hired to end users. However, the economic constraint imposed by high transport costs is an important factor in overall planting costs, particularly for the smaller plantations. This has an important bearing on future development.

POTENTIAL FOR FUTURE DEVELOPMENT

Future construction and the possible arrangements of four- and six-row planters should be considered as primarily contractors' coppice planters or for hire to end users. In these markets the cost and convenience of transport between sites is an important consideration.

Integral four- and six-row planters require side-loading onto heavy vehicles such as low loaders. An option is to produce two-row machines designed to operate either as in the two-row mode for small sites or to combine as three two row machines to produce a six-row combination for larger sites. Two-row planters arranged for standard row spacing (0.75 and 1.5m) can be end-loaded onto a trailer, thereby giving a considerable reduction in transport cost. Further consideration should be given to this.

Although minor design improvements and additions such as soil rakes and press wheels are possible and may be desirable, the essential development of the planting machines is complete. However, the development of an automatic feeding apparatus would remove the present operator limitation on planting speed and would reduce the number of operators. Design work on an automatic feeder is advanced and some metal parts have been made. This work should continue.

The electronic controllers should be packaged unobtrusively and the controls should be limited to:

- on/off switch with warning light
- internal trigger frequency control
- selector switch for internal trigger or external landwheel control.

The hydraulic system and electrical wiring should be packaged unobtrusively, consistent with the requirements of ease of access for servicing.

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Report Ref: B/W2/00595/REP (URN 02/622) Publication date: January 2002

PROMOTION AND BEST PRACTICE DISSEMINATION FOR SRC IN THE PROJECT ARBRE AREA

Forestry Commission

OBJECTIVES

- To promote and disseminate best practice for planting Short Rotation Coppice (SRC) in an area surrounding the UK's first wood-fuelled power station at Eggborough, near Selby in Yorkshire.
- To encourage the establishment, within a 40-mile radius of the power station, of a reliable supply of SRC for use as fuel by the plant.

SUMMARY

This work was undertaken by the Forestry Commission as part of the Renewable Energy Programme, a programme managed by ETSU on behalf of the DTI. Co-ordinated by Forestry Commission project officers, the initiative was intended to support in two specific areas the UK's first wood-fuelled power station, built by ARBRE Energy Ltd and known as Project ARBRE. Firstly, it sought to promote and provide information about SRC and Project ARBRE and secondly, to help establish local growers by processing their funding applications and Environmental Impact Assessments (EIAs).

Use of both formal and informal 'networking' within the developing biomass industry was clearly important as a means of communication and building support. The network brought together interest groups, which included project developers, research organisations and existing or potential growers of SRC. It was through this network that advice and information were provided on topics ranging from progress reports on Project ARBRE itself, to technical information on how to grow SRC, grant availability, the costs of growing SRC and its environmental impact.

Specific promotional activities included specialist workshops and seminars for growers on the practical aspects of starting an SRC plantation, and the public launch of funding initiatives. More general promotion of the SRC initiative, Project ARBRE and the biomass industry as a whole was achieved by a Ministerial visit to the ARBRE plant.

It was recognised that the project was of interest to the biomass industry in general, so project officers reported progress at industry events and the SRC Promotional Strategy Group was established as a forum to allow the main partners to discuss key developments. As a consequence, additional research was undertaken to evaluate the views of local farmers and to address issues such as the effect of

SRC on local archaeology and the environment.

Financial incentives provided a significant boost to grower interest in SRC. Additional funding from the Forestry Commission, in the form of a locational supplement to the Woodland Grant Scheme, was made available to growers within a 40-mile radius of the Eggborough plant. Both this and the subsequent launch of the Energy Crops Scheme by the Ministry of Agriculture, Fisheries and Food (MAFF) resulted in a marked increase both in applications and in the area planted with SRC. Alongside the processing and implementation of funding, project officers accelerated the process by helping to prepare the EIAs, which had to accompany the applications for SRC planting schemes. Consultation and consensus-building with local authorities and other organisations ensured that reactions to proposed schemes were largely positive.

COST

The total cost of the project was £76,668, with the DTI and the Forestry Commission each contributing £38,334 (50%).

DURATION

3 years – May 1998 to April 2001

BACKGROUND

SRC is the name given to willow grown and repeatedly harvested every few years for use as a fuel. The growth and burning cycle is seen as providing an environmentally friendly energy source, so there is currently a great deal of interest in trying to exploit the technology commercially.

The purpose of the project was to promote and disseminate best practice for planting SRC, thereby helping to secure a fuel supply for the UK's first wood-fuelled power station at Eggborough, near Selby in Yorkshire. Land within a 40-mile radius of the plant was defined as the area to be targeted by the project. Additional financial incentives were applied to encourage farmers and landowners in parts of Yorkshire, Lincolnshire, Nottinghamshire and Derbyshire, which lay within the designated area, to establish SRC as a fuel crop.

The plant, which is now in early operation, was built by ARBRE Energy Ltd, the name being an acronym for ARable Biomass Renewable Energy. ARBRE Energy was formed as a joint venture by three companies. These were: First Renewables, part of the Kelda Group (previously known as Yorkshire Water plc), which had interests in developing a renewable energy source; TPS of Sweden, which developed the gasification technology and Royal Schelde Group of the Netherlands, which was responsible for plant design and construction but has since been replaced by UK-based engineering company Balfour Beattie.

Funding for the power station was obtained through the UK Government's Non-Fossil Fuel Obligation (NFFO) arrangements and the European Commission's THERMIE programme.

Eggborough is the first commercial plant of its type to use the gasification process. Once fully operational, it will produce 10MW of electricity, of which 8MW will be exported to the local grid – enough power to supply approximately 30,000 homes. The fuel supply will comprise around 43,000 oven dry tonnes (odt) of SRC and forestry material. Initially, the proposed fuel mix was 75% SRC, 25% forestry material, the intention being to plant 2000 hectares (ha) of SRC. The mix is now more likely to be 60% SRC, 40% forestry material, owing to pressure on fuel costs. Almost 1400ha of SRC has so far been planted within the ARBRE area.

Although initially financed by the DTI and the Forestry Commission, the SRC 'promotion and best practice' initiative has benefited from the start from the close co-operation of a range of partners. Representatives from the Forestry Commission, ETSU, the MAFF Agri-Industrial Materials Section (AIMS), the National Farmers' Union (NFU) and ARBRE Energy Ltd have been closely involved in all aspects of the project.

THE PROJECT

The project was set up to promote and disseminate best practice for establishing SRC as a fuel supply in the Project ARBRE area. Two Forestry Commission project officers were appointed to fulfil these objectives. In addition, they implemented funding schemes designed to encourage SRC growers within the designated area and helped smooth the way for applications, by preparing EIAs of proposed planting schemes.

The project officers co-ordinated a wide range of promotional and other activities, designed to inform and advise interested parties on many different aspects of SRC. They played an important role in publicising both SRC and Project ARBRE to individuals and organisations within and outside the biomass industry.

Formal and informal 'networking' was crucial to the success of the project, not just as a means of sharing information but also as a way of generating support. Opportunities were taken to promote the project widely. Contact was made with various groups, including biomass project developers, research organisations, growers and potential growers, British Biogen and other interested organisations and individuals.

Constant requests were received for advice and information on various topics. These included: updates on Project ARBRE required by someone working within the biomass industry; technical information on growing SRC and advice on grant aid and costs, needed by a potential grower; details on the ARBRE growing agreement and payments and information about the environmental impacts of SRC. Queries were either dealt with directly over the telephone, by e-mail or letter, or were referred on to the relevant partner organisation. The quality of this advice was enhanced by successful dialogue with key groups, such as county archaeologists, and by access to specialists within partner organisations.

Effective liaison with partners and other interest groups was vital as a means of keeping them informed of project progress. Project officers represented the project at key industry events, such as British Biogen conferences and seminars, ETSU research seminars, DTI research route mapping workshops and grower meetings.

The SRC Promotion Strategy Group was established as a forum for information exchange, so that the main partner organisations could receive reports on project progress from a project officer and members of ARBRE staff. Partners could in turn report on key developments within the wider industry. The Group, comprising the Forestry Commission, ETSU, MAFF, the NFU and ARBRE Energy Ltd, met several times a year and made occasional visits to ARBRE sites.

A series of promotional events provided a good opportunity to raise the profile of both the project and of the biomass industry as a whole. Activities included the launch of key financial incentives such as MAFF's Energy Crops Scheme and the Forestry Commission's locational supplement to the Woodland Grant Scheme. The latter was publicised by way of a press release from Mr Morley MP, at the Great Yorkshire Show.

Promotional stands were taken at the Yorkshire, Lincolnshire and other local, county and regional agricultural shows and partners publicised aspects of the project at the Royal Show. Visits to the ARBRE plant by Ministers and professional organisations generated considerable local interest. Forestry initiatives such as Yorwoods and Lincwoods, based in European 5b funding areas in North Yorkshire and Lincolnshire respectively, have actively promoted the project among their own contacts.

Workshops and seminars held for different interest groups were successful both in raising awareness of SRC and in highlighting any specific areas of concern. A series of five grower workshops, involving the Forestry Commission and ARBRE Energy, was organised by AIMS and the NFU. Held at different locations in Yorkshire and Nottinghamshire, the workshops were aimed at farmers, with invitations being sent to NFU members within the ARBRE area. Over 300 people attended the sessions, which explained Government energy policy, introduced the locational supplement and outlined SRC as a crop.

Another well-attended seminar was organised by the Forestry Commission for local authority archaeologists in the ARBRE area. It described the way SRC was established and maintained as a crop and explained the reasons for Forestry Commission support. Government energy policy and Forestry Commission policy on archaeology were outlined. Project ARBRE was also publicised. The meeting highlighted uncertainty about the possible effect of SRC on archaeological remains and established the need for further research into its rooting habit.

A two-day event, held on behalf of AIMS and the Forestry Commission informed Woodland Grant Scheme consultees and growers about technical and environmental issues surrounding SRC. Consultees included local planning authorities, English Nature, English Heritage, the Environment Agency, MAFF and local authority archaeologists. Other organisations such as the Country Landowners' Association, the Council for the Preservation of Rural England, Forest Enterprise and the Institute of Chartered Foresters were also invited. The first day focused on 'The Environmental and Ecological Aspects of SRC' and introduced consultees to SRC, its silviculture and the reasons for growing it. On the second day, existing and potential growers learned about use of SRC as a fuel and its economics as a crop. Information was given about the agreements offered by ARBRE Energy and about the Woodland Grant Scheme. There was also an opportunity to see a growing crop, bundles of harvested rods and a demonstration of the planting machine.

Throughout the project period, a number of articles and adverts were produced and placed in the local farming and forestry press. Project officers also contributed to articles about SRC in relevant industry and specialist publications. The Forestry Commission and MAFF jointly produced four issues of 'Willow Power', a newsletter which publicised opportunities in growing SRC for Project ARBRE and included advice on Government support, agronomy and silviculture. 'Willow Power' had a circulation of 500, which included farmers who had expressed an interest in cultivating SRC through grower workshops.

Workshops and seminars raised many useful points and clearly indicated a need for further research in some areas. For example, the Forestry Commission Research Agency undertook a preliminary assessment into the impact of SRC rooting habit on archaeological remains. The NFU carried out a questionnaire survey to determine attitudes of farmers and other individuals who had attended grower workshops in the previous year. The results highlighted perceived problems in establishing SRC as a crop, providing guidance for future policy trends.

The other main strand of the project was to implement funding schemes and to help growers make successful applications. Two main sources of funding were available to those wishing to establish SRC as a crop. The first one - the Forestry Commission's Woodland Grant Scheme - offered a rate of grant which was low in relation to the costs of establishing SRC. It was felt necessary to increase this in order to encourage more SRC planting within the Project ARBRE area. Thus, in 1998, the Forestry Commission agreed to pay an additional contribution to costs within an area of roughly 40 miles radius from the power plant. This was to encourage farmers and landowners in the designated parts of Yorkshire, Lincolnshire, Nottinghamshire and Derbyshire to grow SRC. The locational supplement was available between August 1998 and March 2001 and acted as a 'top up', raising the level of grant from an initial £400-£600 to £1000. A total sum of £1 million was available in each financial year on a first-come, first- served basis. Within Areas of Outstanding Natural Beauty, National Parks and Environmentally Sensitive Areas, planting was restricted to arable land only, to allow for landscape and conservation sensitivities. The minimum area for any one block of planting was 3ha; however, ARBRE Energy increased this to 5ha in 1999 and 10ha in 2000. Applications had to meet Woodland Grant Scheme environmental guidelines and could not involve removal of trees or hedgerows. Applicants also had to provide evidence of a contract to supply the power station with fuel. The second source of funding, MAFF's Energy Crops Scheme was launched in October 2000. It included funding for both establishment grants for SRC and for producer groups comprising SRC growers. Grants worth as much as £1600 were available, with eligible producer groups able to claim up to 50% of their set-up costs.

Success or failure of an application to grow SRC may depend on having an accurate assessment of the various impacts of a particular proposal. A project officer was closely involved in such assessments, advising potential growers and liaising with Project ARBRE staff to ensure a consistent approach to all proposals. The officer also engaged specialist advice where required and checked on the need for formal environmental impact assessment. Applications were assessed for compliance with the UK Forestry Standard and placed on a public register to invite comments. The local authority archaeologist was informed of proposed sites before full applications were completed; these and other early consultation exercises ensured a largely positive response to final proposals.

Introduction of the locational supplement resulted in a significant increase in both the number and average size of SRC schemes approved within the Project ARBRE area. Compared with 28 schemes approved in the whole of the three years before the supplement was introduced, 20 were approved in the first year of the supplement and 37 in the second. There were no applications in the third year, following a change in the rules for claiming the grant and pending the introduction of the new Energy Crops Scheme. Of the 25 applications for this new grant received during the first half-year, only 11 agreements were approved. This was due to a change in ARBRE's policy from 'grow and supply' to 'supply only' contracts.

CONCLUSIONS

Promotion

- The project effectively promoted and disseminated best practice for SRC in the ARBRE area.
- Networking and other liaison activities have proved worthwhile, as has the co-ordinating role of project officers.
- The most cost-effective way to reach potential growers is through workshops, where the audience can be targeted.
- Agricultural shows are important for informing the public and gaining their support. However, they are expensive and do not generally attract significant numbers of new schemes.
- Targeted media articles, specialist newsletters and advertising are important for attracting and supporting potential growers.

Implementation

- A combination of financial incentive and promotional work realised a doubling of SRC applications and a five-fold increase in the area under cultivation.
- Early environmental and technical assessment improved the success rate of applications.
- Uncertainties over grant funding, supply policies by ARBRE and the viability of the power station adversely affected take-up in the latter stages.

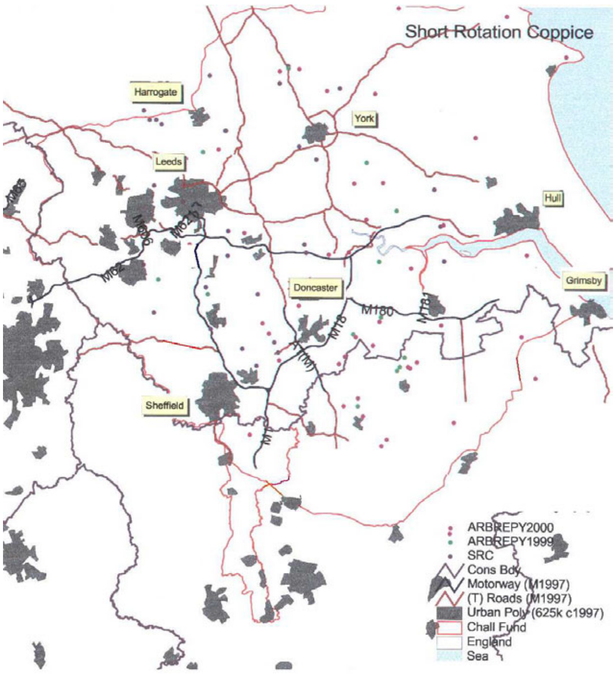

Figure 1. Map showing SRC planting under WGS (Courtesy of Katie Thorn, SRC Development Officer)

RECOMMENDATIONS FOR FUTURE PROJECTS

- Partnerships with other stakeholders should be developed from the outset.
- Potential growers should be targeted early, advised through effective use of workshops and kept informed of progress with the power plant.
- Newsletters are important to keep growers and others informed.
- Promotion at local level would be best organised by the end user, such as ARBRE. At national level, promotional work should be co-ordinated through Regional Development Agencies or Government Offices.
- The Energy Crops Scheme should be continued and broadened to include other categories of grower.
- Administration of the Energy Crops Scheme should remain with the Forestry Commission.
- Cost-effective harvesting must be practically demonstrated to potential growers.

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Report Ref. B/W2/00717/REP (URN 02/1561) Publication date: January 2003

A FURTHER EVALUATION OF HERBICIDES FOR POST-EMERGENCE USE IN SHORT ROTATION COPPICE

Biomass Energy Services Ltd (with The Scottish Agricultural College)

OBJECTIVES

- To review the commercial performance of standard herbicide treatments and associated weed control factors.
- To test a range of pre- and early post-emergence use herbicides, individually or in mixture, which are considered to have the potential to control problem weeds in Short Rotation Coppice (SRC).
- To demonstrate their crop safety, on a range of sites including a coal spoil site where the activity of herbicides may vary because of the potentially higher carbon content of the coal spoil and the higher organic matter from the incorporation of sewage sludge cake.
- To formulate robust recommendations for pre- and post-emergence herbicide use in spring-planted SRC.

SUMMARY

An initial evaluation of herbicides in 1999 (Report Ref. B/W2/00633/REP), provided useful data and information on the safety of some herbicides applied post-emergence to newly planted SRC. This project evaluated a total of 12 treatments, including the successful 'post-emergence' treatments from the previous DTI-funded project and a weed- free control.

The crop safety of these treatments for willows was not known, and although most of the treatments caused varying degrees of phytotoxicity, including leaf and stem scorch and some stunting of the apical growing point, there was minimal crop death from any treatment. Where crop losses occurred this was due mainly to the effects of severe competition from perennial weeds.

The products that gave the most encouraging results were Reflex T and Impuls, which overall, combined good crop safety and good weed control with concomitant reductions in weed biomass and broadly maintained crop productivity compared with the control. These products were applied at crop growth stages beyond their normal crop recommended timings causing some scorch symptoms, which the plants recovered from and produced further healthy growth.

The report provides growers and advisers of SRC with important (but still limited) information on how to achieve improved weed control of problem weeds increasingly prevalent in SRC fields. This may provide guidance on often essential emergency

treatments when the crop establishment is under considerable pressure and on the potential safety, or otherwise, of certain weed-specific herbicides.

Commercial field application of the more successful treatments in this project is now possible, although recommendations by advisers should be undertaken at ‘Growers Own Risk’ until sufficient field experience has accumulated. This is needed to define more accurately the timing of application and dose rate. The treatments should be applied within their current label timings for weed control and the persistence against later germinating weeds should be observed, as well as observing any symptoms of phytotoxicity. Successful control from these herbicides applied, as a pre- or early post-emergence treatment would greatly expand the choice available to the SRC grower as well as providing guidance on treatments available as a ‘last chance’ measure.

COST

The total cost of this project was £71,909 with the Department of Trade and Industry (DTI) contributing £28,400 and UK industry the balance of £43,509.

DURATION

18 months – June 2001 to November 2002

BACKGROUND

Poor weed control continues to be one of the most significant causes of poor crop establishment and complete crop failure with SRC. The reasons for poor weed control include: limited choice of effective pre-emergence herbicides and mixtures; dry soils in late spring/early summer reducing residual activity; and lack of safe and effective post-emergence herbicide recommendations. In addition, secondary flushes or germination of weed seedlings exacerbate the problem.

Current ‘best practice’ guidelines (FA SRC/4) recommend that a weed control programme should consist of a single pre-emergence herbicide, applied immediately after planting and before bud burst of the cuttings (this presumes that perennial weed control has been applied pre-planting). Another publication (Short Rotation Coppice for Energy Production-Good Practice Guidelines) provides very general guidance, emphasising the need for good weed control using “overall selective herbicides or directed sprays of contact herbicides”. Specific treatments, or dose rates are not stated.

Consequently, in commercial practice, SRC agronomists have often to apply experience gained in the weed control management of other crops to determine the appropriate product or mixture and dose rates.

An initial evaluation of herbicides in 1999 (Ref. B/W2/00633/REP), provided useful data and information on the safety of some herbicides applied post-emergence to newly planted SRC. This project evaluated a total of 12 treatments, including the successful ‘post-emergence’ treatments from the previous DTI-funded project and a weed-free control.

Previously, two herbicides in particular showed good broad-spectrum weed control and good crop safety (fomesafen+terbutryn and metribuzin). Two other herbicides that are target-specific showed visual damage to the crop, but no significant reduction in productivity (amidosulfuron and rimsulfuron). All of the herbicides were applied outside their normal timing for crop and weed growth stage. One important herbicide (isoproturon), which had previously been reported to cause significant damage to willow, gave minimal visual toxic symptoms and no reduction in productivity.

The achievement of full or off-label approvals for the successfully demonstrated treatments will increase the current pre- and post-emergence options as well as the possibility of a programmed approach.

THE WORK PROGRAMME

A review of the commercial usage of herbicides in SRC was undertaken, researching the most widely used herbicides, the dose rates applied and current commercial costs.

The primary protocol of the project was to build on the initial findings of the work in the 1999/00 project, by testing again the more successful treatments at a mid-season timing and also at their normal label timing for crop and weed growth stage.

The products, which either had full label approval, or off-label clearance for use in SRC, were tested at different dose rates, or in mixtures and at different timings outside their normal recommendations. The objective was to provide an updated list of herbicide recommendations that will give satisfactory control of these increasingly important weeds, coupled with good crop safety, and give advice on timing and appropriate dose rates.

The trial sites were installed within three commercially planted fields established in 1999. The fields are located across the UK providing a broad representation of soil types, climatic conditions and weed flora. All sites were subjected to extensive investigation, which included quantitative assessments of crop and weed biomass, as well as the visual, qualitative assessments to which the intensive sites were subjected. One of the sites was installed on a reclaimed coalfield site at Barony Colliery, Auchinleck, Ayrshire.

Eleven herbicide treatments were applied, as a post-emergence treatment, across three willow varieties. There was also an unsprayed control. The plots were randomised across the trial with three replicates for each treatment. The total area occupied at each site was approximately 0.37ha (116m x 32m).

Three willow varieties were chosen for this trial, representative of commercially planted crops. The varieties were Jorr, Tora and Ashton Stott.

At the time of spraying, the crop and weed growth stages were noted by visual observation and the weed species present were recorded. The level of weed cover was recorded at the time of spraying and again 6-8 weeks after spraying at all sites. The weed frequency was recorded during the same inspection visits.

The crop phytotoxicity was assessed visually 14-21 days after application of the herbicide treatments at all sites. The assessments were made to six plants per plot, on all 216 sub-plots in each trial. An overall score of phytotoxicity was made on each plant, and other observations were made to include any interveinal chlorosis, bleached foliage, necrotic spots on leaves, shoot distortion or stem marking.

The weed biomass was collected and measured, 6-8 weeks after application. The plant survival, crop height and crop biomass within the treatments was measured at the end of the growing season at all sites.

CONCLUSIONS

The evidence obtained, and discussions with the organisations interviewed, indicate that the predominant herbicide used for weed control in SRC is pendimethalin, either alone or in mixture with isoxaben or simazine. All of these products have full regulatory approval for use in SRC.

The inability to control perennial weeds, such as couchgrass, nettles, thistles and docks is cited as a major issue. The lack of control is usually the result of poor forward planning by farmers in their decision to plant the crop, which results in delayed application of glyphosate herbicide that is considered to be the standard pre-planting treatment for perennial weeds.

All of the agronomists interviewed acknowledged that effective and safe recommendations for post-emergence weed control were essential. The quality of agronomic experience and knowledge of field history are important factors in deciding good weed control and cost of treatments.

The crop productivity data from these trials would indicate that weed control benefits provided by most of the herbicide treatments compensated for, or in some cases clearly outweighed, any adverse phytotoxic effects. Since the importance of good weed control in the year of establishment plays a crucial role in the long-term productivity of the crop, then some of these treatments may have potential future use to SRC growers by providing effective, relatively safe weed control of problem weeds during periods of crop growth. This crop is open in nature in its first year of establishment, but in later years its growth pattern should shade out most weeds, without the necessity of further control. Unfortunately, two of the trial sites were infested with perennial weeds, for which none of the selected treatments could be expected to give reasonable control.

Most of the treatments gave a reduction in yield over the untreated standard, but this is a recognised factor with many herbicides in other arable crops. This is usually due to a de-waxing effect on leaves, slowing plant development. Therefore, the potential of a possible yield reduction in the first year of establishment has to be considered.

The products which gave the most encouraging results were Reflex T and Impuls, which overall combined good crop safety and good weed control with concomitant reductions in weed biomass, and broadly maintained crop productivity when compared with the control. These products were applied at crop growth stages beyond their normal crop recommended timings, causing some scorch symptoms, which the plants recovered from and produced further healthy growth.

The treatment Stomp/Gesatop has been used as a standard field treatment for several years. Its recommended timing is pre-emergence of crop and weeds. Under such circumstances this mixture can provide broad spectrum, inexpensive weed control. The products have little effect in controlling mature weeds as encountered in these trials, but while they are relatively safe to the crop applied pre-emergence, the treatments containing simazine showed enhanced levels of transient phytotoxicity, when applied post-emergence. The legislative restrictions on the use of simazine (Gesatop) will probably minimise its use in future. [European Council Directive 91/414/EEC is reviewing the registration for simazine].

Similarly, the Sovereign+Flexidor treatment contains primarily root-acting components, so its use should be restricted to pre-emergence applications only, as it should control a broad spectrum of annual weeds.

The addition of Impuls to these treatments improved weed control without any significant increase in phytotoxicity and no adverse effect on yield. The Impuls treatment as a single component provided relative crop safety and an improvement in yield.

The two Reflex T treatments indicated that the lower rate is safer to the crop, although there was little difference in yield response. In most other indicators these treatments produced better than average responses. The Panther treatment produced acceptable levels of scorch and was satisfactory in all the other indicators. Its crop safety was better than the related Javelin Gold treatment, indicative of the higher dose rate of isoproturon in the latter herbicide.

Although the Javelin Gold and Lexone treatments gave good weed control their levels of unacceptable crop scorch with a significant reduction in yield would suggest that they should not be considered for post-emergence treatment in SRC, because their label weed spectrum does not offer any advantages over the other, safer, treatments.

In conclusion, this series of field trials suggests that various herbicides have potential as conventional post-emergence or 'emergency' treatments in situations where pre-emergence residual herbicide treatments have failed or been delayed, or secondary flushes of weed seedlings have emerged. However, the products in the two most promising treatments – Reflex T and Impuls are currently not cleared for use in SRC until after cutback or harvest. Furthermore, additional research is needed to study the effect of different spray timings, efficacy against a broader weed spectrum and crop safety on different soil types before firm recommendations can be made.

Therefore, it might be considered prudent to adopt a two-spray strategy based on a pre-emergence application followed by an appropriate post-emergence treatment [Defra 'Good Practice Guidelines for Short Rotation Coppice']. This would allow clear identification of the weed problem and allow for an application within the correct timing. This strategy, of course, has increased cost implications for establishment of the crop, but the grower would be better served if the strategy were in place before planting, than having to resort to emergency treatment at a later date, or no treatment at all.

This report has identified the relative crop safety of the tested herbicides and mixtures. For advisers and growers, this will be the prime objective of a post-emergence herbicide recommendation. The levels of weed control achieved will depend mostly on the herbicide being applied within its label recommendations, although it is acknowledged that a non-competitive crop, such as SRC may not provide as much crop competition as a denser arable crop, so that overall weed control levels will be reduced.

POTENTIAL FOR FUTURE DEVELOPMENT

Increased and refined data on the post-emergence herbicide options will form the basis of improved herbicide recommendations and better crop establishment.

The biomass industry should develop herbicide strategies based on the information produced in these trials. This strategy would have the objective of improved targeting, improved timing and overall improved season-long weed control, and ultimately better establishment of the crop. An ongoing survey of the technical results from commercial field application should be collated and disseminated to provide improved and robust agronomic advice to advisers and growers involved in the market expansion of Short Rotation Coppice.

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Report Ref: B/W2/00643/02/REP (URN 02/1344) Publication date: March 2003

AN IDENTIFICATION OF POTENTIAL NEW HERBICIDES FOR SHORT ROTATION COPPICE

Coppice Resources Ltd

OBJECTIVES

- To identify a range of new herbicides for weed control in commercial short rotation coppice (SRC).

SUMMARY

Agrochemical, and in particular herbicide availability is limited in SRC. The number of compounds that are tested and found to be 'crop safe' is small, and the research effort by chemical manufacturers into this area is practically nil. Therefore growers with infestations of pernicious weeds often find themselves unable to control them with conventional chemical applications applied overall to a growing crop. New chemistry is needed at all stages of the crop growth, from planting, through first year growth and right up until the crop is cutback around 12 months into its life. At all stages there is a need to find more effective options and also to identify where there may be potential cost reductions that will enhance the overall economic viability of the crop.

This report considers the three main timings for application:

1. at planting
2. in the first year of growth
3. at cutback in the first winter.

The potential options for control are identified, based mainly on crop safety, along with an indication of the levels of weed control that can be achieved. An indication of the cost of successful treatments when compared with standards is also included.

These identified options can then be taken forward into larger-scale field trials and assessed in more detail for their crop safety and spectrum of weed control so that in the medium term they can be incorporated into an SRC grower's armoury.

COST

The work was one of three 'call off' tasks carried out under a master 'SRC Consultancy' agreement '(April 2000 to April 2002).

The cost was £10,951 from a total project cost of £13,417 which was met by the Department of Trade and Industry (DTI).

DURATION

24 months – April 2000 to April 2002

BACKGROUND

Mainstream agricultural crops enjoy the benefit of much research into new chemical compounds that can be applied to control, weeds, pests, diseases etc. SRC as a minor part of the worldwide cropping plan does not. Instead, arrangements exist that allow the 'off-label' use of pesticides permitted on other crops to be used in SRC. This reduces the cost to chemical manufacturers of providing chemicals for SRC, but does limit the grower in terms of chemical choice. Small-scale crop safety trials are therefore the way that chemicals are initially trialled on SRC crops.

Pot trials in laboratories can provide a base, but there are several steps prior to commercial introduction. Field trials must start small and then scale up as data and confidence is gained that the herbicide will be both safe to field crops and useful in its pattern of weed control. The process can take up to five years to complete, but by skipping the pot trials this can be cut to three.

THE WORK PROGRAMME

The primary task was to establish crop safety, with a basic examination of efficacy. The most suitable materials identified would then be put forward for further evaluation and analysis.

Residual at planting herbicides

Residual at planting herbicides are the first in-crop opportunity for weed control. They offer the chance to create a chemical seal on the soil surface that will prevent weed growth. As weed seeds germinate in the soil they take up the herbicide by root or shoot and are rendered dead before they emerge and so offer no competition to the establishing SRC crop. Standard practice at present revolves around mixtures of three chemical compounds pendimethalin (Stomp) isoxaben (Flexidor) and simazine (Gesatop). In these trials a mixture of 2000g ai/ha of pendimethalin and 250g ai/ha of isoxaben has been used as the control treatment. The main issues regarding current practice are the poor environmental profile of simazine and the high cost per hectare of isoxaben. Therefore, a range of alternative products that would help both to reduce cost and improve the environmental profile of the applied mixtures is desired.

Contact herbicides

Currently there is an extremely limited range of herbicides available for overall application to a growing SRC crop. The few options that are available are targeted at either the grass weed/volunteer cereal spectrum as in the graminicide family (ie Laser) or at thistles as in the use of clopyralid (Shield). Therefore if there are other weed species present the only control at present is to apply a total herbicide through a shielded sprayer that protects the crop. In this case, and also that of Shield, cost per hectare can be up to £75 when application charges are included. Therefore, a range of cost effective alternatives that control a wider range of species is desirable.

Residual at cutback herbicides

Currently it is standard practice to cutback an SRC crop at the end of its first season of growth. This encourages the plant to grow more stems (coppice) and allows access for weed control. In general, weed control has been carried out using contact-only materials but there is also a case for the addition of residual chemistry to prolong weed control through soil-activated herbicide. These trials give consideration to the choice of contact material and also to the residual partner that is most effective.

RESULTS

Residual at planting herbicides

The results in this sequence of trials show the following trends:

- Linuron (Linuron), Trifluralin (Treflan) and the cyanazine/pendimethalin mix (Bullet) resulted in crop death.
- Isoproturon-containing compounds (Panther & Encore) were damaging to the crop, and in addition weed control was no better than current standards.
- Propachlor (Ramrod) and chloridazon (pyramin) provided the best levels of crop safety and also, in the case of chloridazon, weed control.
- The control treatment of pendimethalin/ isoxaben was equalled by the best trial treatment in terms of efficacy. In cost terms the trial treatment is 85% cheaper than the control.

Contact herbicides

The results in this sequence of trials show the following trends:

- Hormonal-based compounds are generally unsafe.
- Broad spectrum sulphonyl urea-based herbicides are generally unsafe.
- Dosaflo (metoxuron) was safe and has reasonable weed activity.
- Ethofumesate is safe but has poor weed activity.
- Cyanazine at this timing is safe and particularly effective.
- Boxer (florasulam) is safe and effective.

Residual at cutback herbicides

The results in this sequence of trials show the following trends:

- When applied over a dormant SRC stool all selected treatments were safe to the crop.
- All contact materials were effective at killing weeds present.
- Contact materials worked at differing rates of speed of kill.
- Residual chemicals were reasonably effective despite the surface trash present.
- The choice of residual partner made little practical difference to weed control levels.
- All treatments were as effective as the control treatment of a contact material applied alone.

CONCLUSIONS

The trials highlighted several chemical compounds that may prove to be useful additions to the limited range of SRC herbicides that currently exists. As a note of caution they have as yet been tested only on small-scale plots albeit under normal field- based conditions. Further work is required to establish the safety of the compounds on a wide area.

The selected herbicides for further work are categorised in their usage periods as follows:

1. Residual at planting herbicides

- Pyramin DF (chloridazon)
- Ramrod (propachlor)
- in combination with each other and/or pendimethalin.

2. Contact herbicides

- Cyanazine (cyanazine)
- Boxer (florasulam).

3. At cutback combinations

- Gramoxone/Stomp (paraquat/pendimethalin)
- Weedazol/Stomp (amitrole/pendimethalin).

All of the highlighted products/combinations show benefit over current standards in terms of one or more of the following criteria: cost effectiveness, weed control, and environmental profile. They all have the potential to become standards in the longer term for SRC weed control. In particular the contact herbicides show the potential to control competitive weeds that are at present only checked by shielded inter-row applications of total herbicides.

When taken in terms of the overall benefit to the SRC industry they have the potential to play a part in reducing the production cost per tonne of SRC fuel crops. This will both open up more areas in which the crop can be grown and increase the profitability of establishing areas that are currently identified for cropping.

POTENTIAL FOR FUTURE DEVELOPMENT

The herbicides tested and identified as potentially beneficial, have proved safe in initial trials, but they do need to be tested on larger field-scale areas before they can be recommended as standard treatment options. There is always a risk in transferring knowledge from small plot-scale onto larger areas and so this will act as a safety buffer before they are recommended to the wider industry. It will also allow for extra experience to be gained on application timings and crop safety that are not allowed for in small plot trials.

Residual at planting herbicides

Chloridazon & propachlor are fundamentally crop safe and have good efficacy against a general range of broad-leaved and grass weeds. They are also cost effective compared with current standards. They both offer potential to be mixed as two- and three-way combinations with pendimethalin to increase levels of weed control without losing cost effectiveness.

There is no reason to suspect that they would be any more harmful to the crop in combination than individually although a series of small-scale field trials would confirm this. The follow-on trial work should concentrate on the efficacy of the combinations and also of any potential new partners once crop safety has been confirmed.

Contact herbicides

Florasulam & cyanazine would appear to be crop safe and offer useful weed species controls in SRC. Further trials on a larger field-scale and at varying timing should be employed to assert crop safety.

Potential for tank mixing or sequencing of the above compounds should be considered, as it will broaden spectrum of weed control.

Residual at cutback herbicides

Paraquat mixtures may provide an alternative contact product to Weedazol. More work is needed on the timing of cutback herbicide application targeted at the effectiveness of later applied mixtures. Trials involving comparisons of Weedazol/Stomp vs. Gramoxone/Stomp on a field scale would be valuable for this.

dti

Report Ref: B/W2/00643/03/REP (URN 02/1344) Publication date: March 2003

RESIDUAL PROVEN SRC HERBICIDE APPLICATION RATE TRIALS

Coppice Resources Ltd

OBJECTIVES

- To identify the application rates at which proven safe herbicides could be applied to SRC crops.

SUMMARY

Application rates at present are high in terms of the amount of active ingredient (a.i.) applied per hectare and in terms of cost. Reductions in the amount of chemical applied will bring both environmental and financial benefits.

In order to test this theory, field trials were organised on SRC crops. There were no issues with crop safety as only proven chemistry was being applied and that at rates lower than have been found to be safe for the SRC crop. The objective was to see how low application rates could be cut whilst still maintaining an adequate level of weed control.

The trials sequence was applied during a particularly inhospitable weather period, resulting in a set of trials that were totally inconclusive. Consequently, the report does not deal with final results and recommendations, rather it explains the process of selection and applications, with suggestions for future work in this area.

COST

The work was one of three 'call off' tasks carried out under a master 'SRC Consultancy' agreement '(April 2000 to April 2002).

The cost was £2,466 from a total project cost of £13,417 which was met by the Department of Trade and Industry (DTI).

DURATION

24 months – April 2000 to April 2002

BACKGROUND

Agrochemical, and in particular herbicide availability for use in SRC is limited. The number of compounds that are tested and found to be 'crop safe' is small, and the research effort by chemical manufacturers in this area is practically nil. Therefore, growers with infestations of pernicious weeds often find themselves unable to control them with conventional chemical applications applied overall to a growing crop. At all crop stages there is a need to find more effective options and also to identify where there may be potential cost reductions that will enhance the overall economic viability of the crop.

THE WORK PROGRAMME

An investigation was carried out on the common herbicides and weed control. A selection of herbicides was chosen in order to carry out field trials.

The report considers the reduction of application rates of, at planting, residual herbicides as a measure of achieving more effective options.

An indication of the cost of treatments when compared with standards is included in the report. The identified options are all proven to be crop safe and the measure by which they were assessed was herbicidal efficacy.

CONCLUSIONS

A significant factor influencing the results of outdoor field-scale trials is the weather. The weather conditions at the time of the trial rendered the results totally inconclusive. Following planting the site was rolled immediately behind the planter and chemical applications were timed for application in the next seven days. Following planting there was a period of heavy rain, which precluded herbicide application. The site itself flooded to a depth of six inches in the lower areas and machinery access, even when fitted with flotation type tyres, was not possible. Consequently the herbicide application was delayed until beyond the desired period.

The trials were applied 17 days after planting. At this time the crop was emerging in the drier areas of the field, but not yet in the wet zones as lack of aeration to roots prevented germination. There was also an element of small surface weed growth at the cotyledon to one true leaf stage but no species were beyond the controllable growth stage by residual chemical applications.

Following application there was a reversal in the weather and there was a long period of sustained drought conditions. The effect on crop growth was minimal but the major problem was the effect on the residual chemicals applied. Such chemicals work by contact with soil to control the emerging shoots and roots of selected weed species. Without moisture however residual chemicals are inactive. This was the case in the trials and so activity on weed species was very limited. Across all the sequence there was no difference whatsoever in the levels of weed control achieved, all of which were poor.

Moisture did eventually arrive some 14 days later, but by this stage the weeds had grown to a level where they were beyond the growth stage that could be expected to be controlled by the residual chemicals. They had grown rapidly as moisture was present underneath the crust on the soil that the roots could tap into and the warm conditions plus high light intensity sparked a period of rapid growth. The trials were halted at this stage.

POTENTIAL FOR FUTURE DEVELOPMENT

As the trial sequence was not completed, no recommendations for follow on work could be identified within the area of rate reductions trials. One option would be to repeat the trials starting from the site preparation phase through to the end of sequence.

dti

Project Ref. B/W2/00624/00/00 | Project Due for Completion: May 2005

YIELD MODELS FOR ENERGY COPPICE OF POPLAR AND WILLOW

Forest Research

OBJECTIVES

The overall objective of the 'Yield Models for Energy Coppice of Poplar and Willow' project (1993-2005) is to develop models relating the yield from energy coppice of poplar and willow to site factors and clonal characteristics. This objective is being achieved by:

- Managing 51 sites planted with 32 poplar and willow clones established to simulate commercial plantings of short rotation coppice (SRC) with no artificial irrigation, nutrition, fungicide or insecticide inputs.
- Monitoring growth and biomass accumulation and performance in the poplar and willow SRC clones over two 3-year rotation cycles using destructive and non-destructive techniques.
- Collecting detailed environmental data characterising site conditions and their relationship with growth and yield through physiological studies.
- Collecting qualitative data on the relative incidence of pests and diseases affecting SRC that will be used to assess the impact of insurgence on SRC yield, and in development of the empirical model.
- Developing two models, an empirical and a process-based model, to forecast biomass production of SRC species (willow and poplar) in the UK at the plot scale; the process model will operate at the daily timestep, summarising yield at the annual timestep. The process model will simulate relevant physiological processes determining the yields observed in field trials and any significant variation between sites and clones. Given the proposed structure the process model will be suitable for predicting yield at new sites or relevant site-clone interactions and thus will be predictive beyond the range of the empirical model. Model outputs will be suitable for upscaling through a Geographical Information System [GIS]. Assessment of the predictive accuracy of the process-model will be achieved through a model inter-comparison exercise with the empirical model.

SUMMARY

This project is the largest field trial of poplar and willow species grown as crops for the provision of biofuels in the UK and in Europe. The main aim is developing an empirical and a process-

based model that will forecast growth and yield performance of poplar and willow short rotation coppice.

The project commenced in November 1994 and is currently in the fourth and final phase. The key outputs from this final phase will be

- An **empirical model** summarising the range of variability in growth and yield at clonal level and across the UK.
- A **process-based model** that accounts for the variation in growth responses resulting from natural and artificial genotypic, and phenotypic selection processes in poplar and willow.
- Further detail is available from the project web site: www.forestry.gov.uk/src

COST

The total cost of Phase IV is £1,762,165, with the Department of Trade and Industry (DTI) contributing £680,276, and DEFRA, Forestry Commission and DARDNI the balance.

DURATION

72 months – June 1999 to May 2005 (Phase IV).

BACKGROUND

The need for yield modelling relating the yield to site and genetic factors was apparent in the early 1990s. In 1993, an urgent need was identified for information on the potential yield of SRC, on different site types in the UK, to support policy and investment in biomass-based energy generation technologies. Emphasis was placed on the delivery of maps and equations for predicting the potential yield at any specified location in the UK prior to crop establishment. The need to be able to project the growth of established SRC plantations for production forecasting and supply planning was also identified. Finally, a requirement was stipulated for models able to predict yield for SRC stands based on newly bred varieties, for which extensive measurements of yield would not be directly available.

In response, Forest Research drew up proposals for the establishment of a two tier design of experimental trials, to support a programme of modelling that could meet DTI's need for comprehensive information on SRC growth and yield. Experiments in the first tier were referred to as 'extensive' trials. These involved three poplar and three willow varieties, selected to be representative of the form and growth of the principal varieties. It was proposed to establish a total of about 40 extensive trials across a range of sites representative of agro-climatic conditions in the UK. Experiments in the second tier were referred to as 'intensive' trials - a small number of experimental sites with a relatively large number of varieties, on which exhaustive assessments were made.

The extensive and intensive trials were designed to provide complementary data for development and calibration of a number of models for predicting yields. In general, extensive trials gave information on the generic variation in SRC yields across a wide range of site types, whilst the intensive trials provided information on the interactions between variety and site. The ambitious nature of the intensive trials meant that only a small number (about six) could be established, but their locations were selected to represent widely varying agro-climatic conditions.

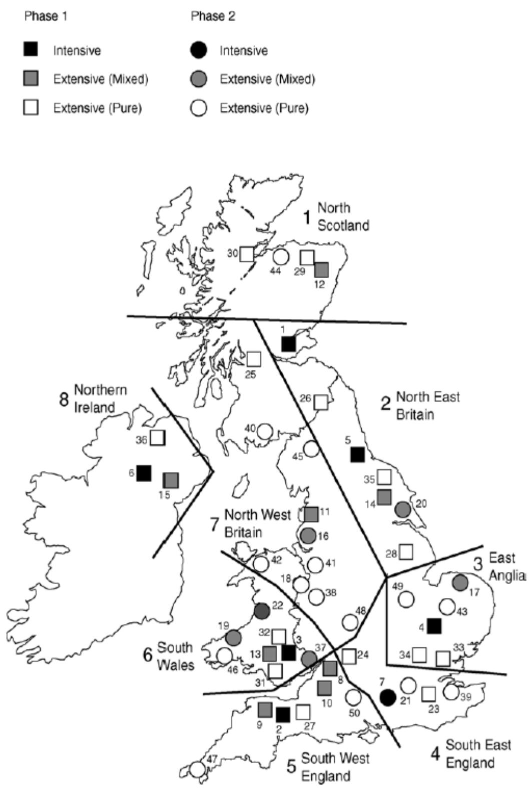

Figure 1. Distribution map of project sites

PHASES I-III

Phase I (November 1994 – March 1995)

Phase 1 commenced with the establishment of the first in a total of 42 extensive trials and six intensive trials. The funding did not cover the full duration of monitoring and measurement in the trials required to calibrate the full range of models initially proposed.

Phase II (June 1995 – March 1998)

This Phase marked the completion of intensive and extensive site establishment, bringing the exact totals to 42 extensive trials (16 with mixture plots) and seven intensive trials.

Phase III (June 1998 – May 1999)

This Phase funded the ongoing measurement and monitoring of the trials.

Note: Phases I-III explicitly did not fund modelling, beyond analysis of data for quality assurance.

PHASE IV

Phase IV (June 1999 – May 2005) explicitly covers model development and calibration, specifically a matrix integration (mechanistic biophysical) model, including a matrix projection (empirical) model based on data from two rotations (including multivariate/response surface analysis of data from two rotations as part of the development).

The project is progressing in *three phases* using the existing experimental infrastructure developed by the project, that establishes a harmonised network of field sites across the UK. Together these sites provide the experimental infrastructure used for model development and model refinement.

Phase 1 aims to characterise the relationships between clones, site conditions, growth and yield across the UK by:

- Monitoring growth and yield at clonal level at a representative range of sites in the UK.
- Monitoring of biomass at the intensive and extensive sites so as to examine and relate changes in growth to changes in allocation to tree compartments (leaf, branches, stems, stools, fine and coarse roots), as a function of crop age, cutting cycle and clone.

- Sampling individuals to relate morphological and biophysical properties to site conditions and growth.
- Selecting individuals so as to examine and relate changes in growth to changes in biomass across a range of clones.
- *Phase 2* develops **empirical models,** summarising the range of variability in growth and yield at clonal level and across the UK by:
- Developing and calibrating appropriate numerical functions for inclusion in empirical models summarising growth and yield as a function of crop age, cutting cycle and clonal groupings of poplar and willow, and accounting for site conditions.
- Examining the numerical functions which express model sensitivity to the factors being manipulated, and use the experimental results to further refine the numerical functions.

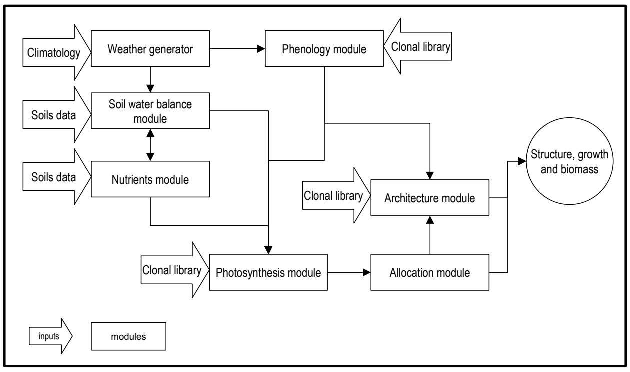

Figure 2. Overview of principal modules in the stand scale empirical model

Phase 3 is developing a **process-based model** that accounts for the variation in growth responses resulting from natural and artificial genotypic and phenotypic selection processes in poplar and willow by:

- Developing a range of modules that, by simulating relevant physical, biophysical and biological processes operating at the plot scale and the daily timestep, account for the variation in growth responses observed between clones of poplar and willow
- Assessing the predictive performance of the process-based model through a model inter-comparison exercise with the empirical model.

RESULTS TO DATE

Principal results to date include:

- Establishment and management of 51 experimental sites across England, Wales, Scotland and Northern Ireland. Following completion of the second rotation the experimental component of the project is largely complete.
- Harmonised, protocol-based data collection at the experimental sites to evaluate growth and yield performance, pest and disease, soil properties and meteorology using non-destructive and destructive techniques.

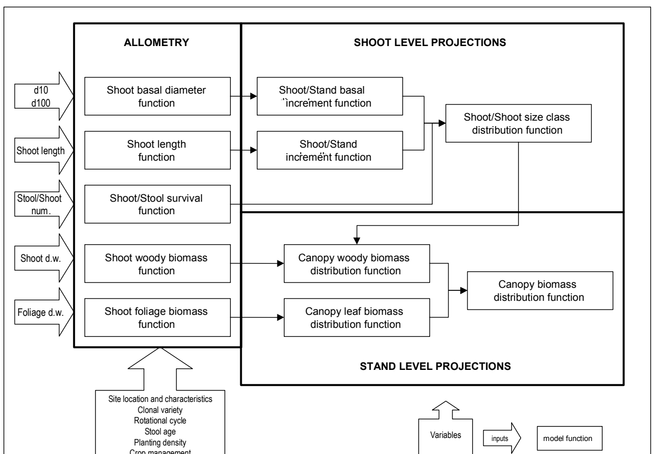

Figure 3. Overview of principal modules in the stand scale process-based model

- Harmonised, protocol-based data collection at selected sites on relevant physiological processes of growth, such as above- and below-ground allocation, plant ecophysiology, respiration, sapflow and canopy architecture dynamics.

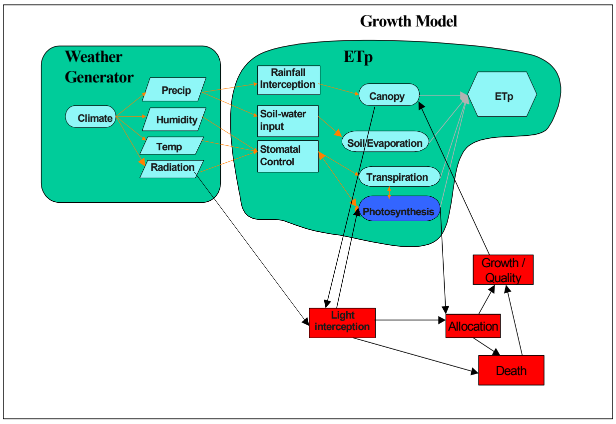

Figure 4. Revised structure of the ForestGROWTH process model for SRC

- Harmonised, protocol-based data collection at the experimental sites on the intra- and inter-annual variability of the incidence of relevant pests and diseases.

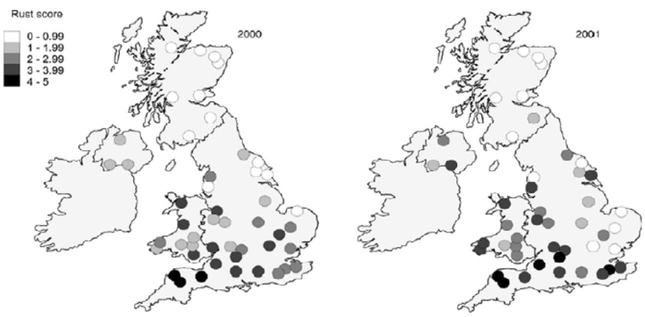

Figure 5. Geographic distribution of poplar rust in September 2000 and September 2001. Combined mean rust score (RUST-L) for 'Beaupre', 'Ghoy' and 'Tricholbel', at each site.

- Establishment of a quality-assured relational database containing inter-annual project data.
- Development of a preliminary yield model providing annualised predicted yields at UK and regional scales. Provisional yield estimations for each clone at each site are available for each year in the first rotation, and for the first year in the second rotation (for Phase 1 sites only).

Variety	Cutting cycle 1 year 1	Cutting cycle 1 year 2	Cutting cycle 1 year 3	Cutting cycle 2 year 1
Jorunn	6.22	17.36	24.83	12.63
Germany	4.6	14.18	24.02	7.73
Q83	3.84	13.25	21.08	11.14
Spaethii	4.68	15	25.9	11.46
Dasyclados	6.33	14.98	21.69	9.88
ST248155	4.68	13.57	23.42	12.28
Delamere	3.99	14.8	23.74	12.24
Bebbiana	3.69	12.2	19.64	8.01
V789	4.72	9.84	17.43	9.32
Stott10	7.77	19.06	28.89	10.7
Stott11	7.96	20.76	31.4	13
Jorr	6.38	16	27.16	11.47
Bjorn	5.76	14.96	22.54	9.25
Tora	6.94	18.12	28.39	11.03
Orm	6.4	15.99	24.86	10.49
Ulv	5.69	15.53	24.18	11.74

Figure 6. Mean standing biomass (odt ha-1) estimated for 16 willow clones planted at 7 'Intensive' sites. Note: data shown is preliminary and should not be quoted, published, or relied upon for decisions.

- Development and initial validation of modules of a process-based model, coupled with the project database. The model will describe the growth performance and yield of SRC poplar and willow species, as well as encompassing mechanistic understanding of the growth observed in field trials and any significant variation between sites and clones.

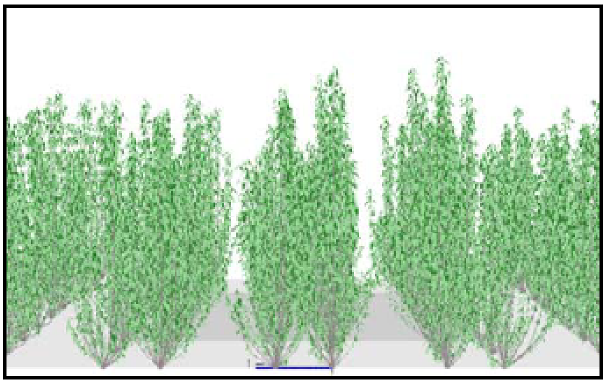

Figure 7. Simulation of 'Trichobel' architecture, May

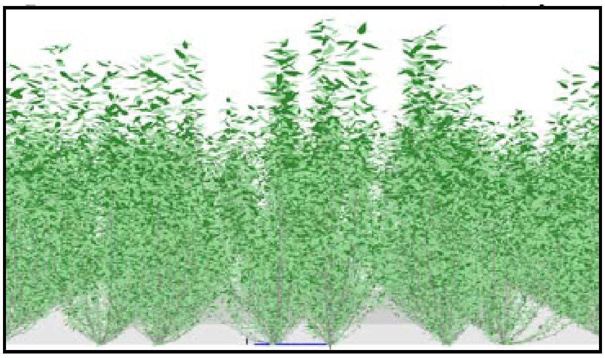

Figure 8. Simulation of 'Trichobel' architecture, September

- Technology transfer to researchers, industry and other stakeholders through site visits, a project help-desk, information notes (FC Practice Note 7 and FC Research Information Note 294), conference proceedings, presentations, scientific papers in international peer-review journals and a dedicated web site.

FUTURE DEVELOPMENT

The empirical models summarising the range of variability in growth and yield at clonal level, and across the UK, are due for completion in April 2005. Activity will include the design and development of a user interface, in liaison with UK industry.

Work to parameterise and validate the canopy architecture, carbon allocation and other modules of the process model is continuing. Work will include the design and development of a user interface, in liaison with breeding programmes, including agreement on which fundamental variables, either database or user driven, should be included.

The completion of the validation and testing of the Forest Growth process model for a range of poplar and willow varieties is scheduled for the end of May 2005.

FURTHER INFORMATION

A report describing shoot allometry and yield estimation techniques used in this project was completed and published in December 2003. ('Shoot Allometry and Biomass Productivity in Poplar and Willow Varieties Grown as Short Rotation Coppice: Summary of Results 1995-2000', Ref.: B/W2/00624/REP/01, URN 03/1437).

For further information about this project visit the web site www.forestry.gov.uk/src.

dti

Report Ref: B/W2/00652/REP Publication date: May 2003

MAINTENANCE OF FIRST-GENERATION COPPICE PLOTS

Edward Stenhouse Ltd

OBJECTIVES

The original project objectives were:

- To grub up the mature coppice at Knowle Farm and return the land to agricultural use.
- To monitor the growth of willow coppice at Brahan for three years.
- To monitor the growth of poplar coppice at Swanbourne for three years.

The second and third objectives had to be amended because the subcontractor accidentally killed the coppice at Brahan, and upon evaluation the coppice at Swanbourne was found to be of such poor quality that monitoring its growth would not have provided representative information. The amended objective of these two sites was therefore:

- To return the Brahan and Swanbourne sites to the landowners at minimum cost to DTI.

SUMMARY

Grubbing Trials at Knowle Farm

The site comprised 10ha of poplar grown in blocks on free-draining grade 1 farmland. The aim of the trials was to return the land to a condition where it would be suitable for either livestock or arable enterprises in an environmentally acceptable and cost effective manner.

Four methods were trialled. Three involved mechanical removal of trees by:

- 360-degree excavator
- forestry mulcher powered by a Valmat 8750 Sigma Power tractor
- pan buster towed by four-wheel drive 120hp tractor.

(A shaker-raker was also tested but was found to be unsuitable).

One method involved application of chemicals to the stumps to kill the tree and encourage decay of the root system.

Only the 360-degree excavator was able to remove 100% of the stools. It was an effective method of clearing the site but the work rate was slow, and specialised machinery and operator were required, so it was expensive. Much of the surrounding soil was removed with the tree roots, and the trees/stumps required disposal.

The mulcher did an excellent job of grinding off all the above ground growth. However, the roots were still alive and *in situ*, so that only surface cultivations could be undertaken. The stumps are likely to regrow and require spraying off. Ordinary

cultivations will have to wait until the stool has decayed.

The pan buster was not considered suitable because it was unable to remove more than about 60% of stools after two passes.

In the chemical method, the trees were harvested by cutting stems and the stools were sprayed with glyphosate to kill the stool and prevent regrowth. The stools were then left to rot over the winter. Half the stools had nitrogen applied to see if this would accelerate the decay of the stool. It was found that it was easier to pull up the stools in the Spring than when they were freshly cut, and that it was easier to extract the stools to which nitrogen had been applied.

The trials showed that it is possible to extract the coppice stools quickly to return the land to arable cultivation immediately. However, this is an expensive option and can lead to damage to the soil in terms of surface soil removal.

Killing the stools using glyphosate and waiting for them to rot before removal or cultivation is a cheaper operation. However, this reduces the flexibility of the land use until the stools are rotted.

<u>Reinstatement of Swanbourne</u>

The original objective at Swanbourne was to monitor the poplar coppice for a further three years. However, the quality of the coppice was found to be poor (overgrown and diseased), so that further measurements of yield would not give a meaningful long-term trend for a typical coppice plantation. It was decided to finish the trial and return the land to the landowner.

The landowner decided to keep the site as a small mixed woodland. This meant grubbing up the majority of the poplar and replanting with mixed native deciduous species. The poplar had to be killed, but the roots could be left *in situ* to decay as replanting could take place around them. Grubbing was therefore undertaken with a forestry mulcher. However, the machine was of lower power than that used at Knowle, and the result would not have been acceptable for further cultivations, although it was adequate for the replanting. The plot was subsequently replanted with deciduous woodland and returned to the landowner.

<u>Reinstatement of Brahan</u>

The original programme of work at Brahan involved replanting a small area of coppice in among the mature coppice and monitoring the growth for three years. However, the subcontractor who was managing the site accidentally sprayed the wrong area and killed the newly established coppice.

It was decided, therefore, to finish the trial and return the land to the landowner. (Costs of replanting and management were reclaimed from the contractor). The landowner agreed to keep the crop and the site was returned with the standing crop.

COST

The Department of Trade and Industry (DTI) met the total cost of the project, £21,500.

DURATION

The work started in Spring (March) 2000 and was completed in Autumn 2002.

BACKGROUND

Short Rotation Coppice (SRC) has shown potential in this country for use as a sustainable energy resource. It may be grown on farmland, providing both a source of income for the grower, and a sustainable and renewable fuel for the supply of energy. Should a plantation reach the end of its economic life as a result of disease or decreases in yield or simply the grower's wish to revert to normal agricultural crops, the SRC must be grubbed out.

An effective regime for this exercise and its cost has not yet been developed. To provide confidence to growers and developers this needs to be determined.

It is known that current industry opinion would tend to favour the cutting and chemical treatment of coppice stools followed by a process of decomposition in the ground, as the optimal removal technique. However, in circumstances where land is required immediately for an alternative use or to take advantage of aid under the CAP this may not be an option.

THE WORK PROGRAMME

Initially, the grubbing trials were arranged for April 2000, but weather conditions were extremely bad, with continual rain. It was therefore decided to postpone the work, since storm water lying on and running off the field would not only have made the trials unfair, but would have ensured that wheelings and excavation caused serious structural damage to the soil.

The trial was rescheduled for mid May. Ground conditions were extremely good on the day. The trial site was divided into four sections:

1. Mature Uncut
2. Mature Cut
3. Poor Uncut *(Poor = stunted growth as a result of rust)*
4. Poor Cut.

Although all of the plantation had been severely affected by disease, the mature section was of significantly greater bulk, both as regards stools and stems, than the poor section, where many stools were dead. To represent a harvested site for both sections, stems were felled and removed prior to the commencement to provide areas for trials 2 and 4.

Initially both the pan buster and shaker-raker were tested to choose the best implement to trial. The shaker-raker tines were found to bend round the stools and the frame attachment had so much movement that the tines failed to lift any stools. Further work with this was therefore abandoned. The pan buster comprised a fixed share and the frame was more rigidly mounted to the tractor with the consequence that it was able to lift only stools, which were squarely engaged by the share.

The 360° excavator and forestry mulcher were tested on both cut and uncut stools. The pan buster could only be tested on cut stools because the tractor was an agricultural one and, unguarded, it risked being damaged by the standing crop if driven through it.

The chosen equipment was timed completing a previously measured double row 75 cms apart and 154 metres long on a slope.

The 360° excavator grubbed all cut and uncut stems in the row and windrowed them.

The forestry mulcher cut off all growing material above ground level in the cut and uncut areas, but required at least two passes to break down the cut material into a reasonable mulch. It should be noted that the forestry mulcher only cut the material above ground. This is likely to result in regrowth of the cut material and incur an additional cost of spraying to achieve a reasonable seedbed.

The pan buster required two passes on a single row to lift approximately 60% of the stools, the remainder being left firmly in the ground. Further passes did improve the lifting percentage. This equipment is designed to create a furrow or improve soil structure. This action does not facilitate the lifting action required to remove coppice stool. It is probable that given suitable modifications, equipment of this type may achieve a more significant result, but this was beyond the remit of this trial. The time taken to remove the lifted stools by hand and load them onto a teleporter was recorded.

The results showed that while the 360° excavator removed all the stools, the grubbing cost of £544.66/ha for the cut crop was considered high. Removing the stools from the field by hand almost doubled the costs. Grubbing the uncut crop was significantly slower and therefore more expensive.

System 1 – Excavator

Crop Type	Area covered/ ha	Time taken/ mins	Ha/hour
Mature Cut	0.0512	66.9	0.0459
Mature Uncut	0.0234	94.86	0.0148
Poor Cut	na	na	na
Poor Uncut	na	na	na

System 2 – Farm System

Crop Type	Area covered/ ha	Time taken/ mins	Ha/hour
Mature Cut	0.126	29.075	0.26
Mature Uncut	na	na	na
Poor Cut	0.18	30.85	0.36
Poor Uncut	na	na	na

System 3 – Forestry Mulcher

Crop Type	Area covered/ ha	Time taken/ mins	Ha/hour
Mature Cut	0.18	38.49	0.28
Mature Uncut	0.045	13.98	0.19
Poor Cut	0.18	19.28	0.56
Poor Uncut	0.345	40.35	0.513

The forestry mulcher was capable of providing a level field which could be surface cultivated and sown with a suitable crop, eg grass very cheaply at an average of £171.71/ha. However it would be likely that the roots would take some years to rot down before the field could be used for normal agricultural operations.

Picking up and carrying off grubbed stools was a slow and expensive operation, using a teleporter and by hand, at an estimated £545.37/ha. No other method was trialled and work needs to be done to resolve a method. Because of the additional costs incurred in grubbing the uncut stools, it was concluded that growers should ensure that the crop is harvested before grubbing.

CONCLUSIONS

In summary, the forestry mulcher costs were about one tenth of the 360-degree excavator which had an average cost /ha of £1,662.29, including carrying off the stools.

The trial results established that none of the chosen ‘mechanical removal’ techniques adequately addressed the problem of returning an SRC site to a more conventional agricultural regime. This was due to either excessive cost, as was the case with the 360-degree excavator, or inability to remove the whole crop, as seen with the Pan Buster and the Mulcher.

POTENTIAL FOR FUTURE DEVELOPMENT

It is recommended that:

- Research should be undertaken to establish an effective design for stool removal equipment. Ideally, the equipment should provide for the lifting of the grubbed stools into a trailer.
- Tests should be carried out on the amount of soil and stones adhering to root plates in a range of different soils, immediately after grubbing and after weathering. This would determine whether stools can be sufficiently free of tramp to be used in a biomass energy system.
- The results of these recommendations should go towards the development of a prototype grubbing machine.
- The effect on soil characteristics of incorporation of SRC residues (ie chips and root matter) needs to be assessed.

dti

Report Ref: B/W2/00751/REP (URN 03/1619) Publication date: November 2003

IMPROVING THE WATER USE EFFICIENCY OF SHORT ROTATION COPPICE (SRC) WILLOWS – YEAR 1

Rothamsted Research (with Cranfield University, ADAS and the European Willow Breeding Partnership)

OBJECTIVES

The principal aim of this project was to determine the range of water use efficiency and drought resistance within existing willow varieties, in order to identify the potential for improving productivity through plant breeding. The project planned to examine the water use of a number of near-market varieties and evaluate simple techniques for early drought tolerance screening in the breeding programme. The work was undertaken at two levels:

1. Field observations of water use by medium scale plots of willow cultivars, to determine the patterns of water use, its role in determining crop yield, and the importance of irrigation in maximising yield.
2. Detailed observation of crop physiological responses of willow to drought in order to develop an understanding of the crop traits associated with improved water use efficiency and drought resistance.

SUMMARY

This report covers only the preliminary results obtained during the first experimental season. During this period the primary activities were related to initiating the two experimental approaches involving field-scale experiments conducted by ADAS and detailed physiological studies by Cranfield University. The project was proceeding on schedule but DTI funding ceased before much of the data collected during the first year had been analysed. The results presented in the report are therefore only indicative and should be treated with caution.

With the closure of the European Willow Breeding Partnership (EWBP) in 2002, the project funding was transferred to DEFRA and is now a component of their willow breeding project co-ordinated by Dr Angela Karp at Rothamsted.

COST

The total cost of this project (year 1) was £78,340 with the Department of Trade and Industry (DTI) contributing £39,115, and the EWBP the balance.

DURATION

12 months – November 2001 to November 2002

BACKGROUND

The UK has undertaken to reduce its emissions of greenhouse gases, and to meet this commitment has undertaken to ensure that 10% of its electricity requirements will be met by renewable energy sources by 2010. Of these, biofuels (including short rotation coppice (SRC) willow) will be an important component. However, the high water requirements of SRC mean that water stress may reduce biomass yields to below commercially viable levels in the drier eastern areas of the country. Increasing the water use efficiency and/or the drought resistance of willow would have the potential both to improve its productivity in wetter areas and to extend the agroclimatic range over which it would be feasible to grow these crops.

A better understanding of the extent and nature of varietal differences in the responses of willow SRC to water stress is required in order to identify the potential for breeding superior willow varieties, which use water more efficiently, and/or are more drought resistant.

This work should help, in the longer term, to increase the productivity of willow through the identification of drought resistant and water efficient varieties. These would be important to help increase the production and profitability of SRC grown commercially in the drier areas of the UK, and also elsewhere in Europe.

THE WORK PROGRAMME

The two strands of this project both involved growing a range of willow varieties in order to quantify responses to water stress.

In the meso-scale experiment established at Gleadthorpe, 12 varieties of released or near- release varieties bred at Long Ashton and elsewhere were planted in two blocks. In the establishment year, both blocks were irrigated to encourage growth. Plant height, establishment rate and biomass production were recorded.

Figure 1. Arrangement of pots for detailed study of 50 willow varieties prior to emergence – April 2002

In the detailed experiments established at Silsoe, 50 varieties representing a range of genetic material including parent species were planted in pots and also in a small field experiment. The pots were subject to periodic water stress episodes whilst the field experiment was irrigated to avoid water stress. A range of morphological and physiological parameters were measured to identify whether any would provide a quick indicator of drought tolerance or high water use efficiency for use in subsequent breeding programmes. Parameters measured included: leaf length, width and area; specific leaf area; stem height; biomass production and chlorophyll fluorescence.

CONCLUSIONS

Few conclusions can be drawn from the first year of a three-year project. However, initial results from the field-scale experiment at Gleadthorpe indicate that there is likely to be a wide range in stem biomass production by the different varieties. Their relative performance under water stress has not yet been tested as differential irrigation will only be applied in the year after cutback.

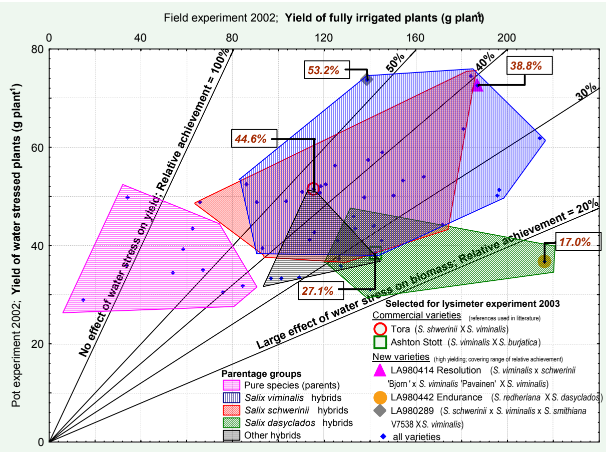

Figure 2. The relationship between biomass production of 50 varieties of willow in the field and in pots (greater water stress) during 2002. Lines show 20%, 40%, 60%, 80% and 100% relative achievement for pots vs field grown plants

As the plants developed through the season they began to extract an increasing amount of water and from a greater depth in the profile. By October, the roots appeared to be extracting water to a depth of about 1.3m, similar to that observed in experiments elsewhere, though changes in soil water content at this depth may also be attributable to drainage of water from the profile.

The next phase of the project, funded by DEFRA under the biomass breeding programme, will allow these preliminary results to be confirmed on the field-scale experiment and further detailed physiological measurements to be made on five varieties selected from the original group of 50 grown under stressed and unstressed conditions in lysimeters, to identify how a range of high-yielding willow varieties respond to water stress.

POTENTIAL FOR FUTURE DEVELOPMENT

With the closure of the EWBP in 2002, the project funding was transferred to DEFRA and is now a component of the willow breeding project co-ordinated by Rothamsted Research.

FURTHER INFORMATION

For further information about this project visit the DEFRA Web site (http://aims.defra.gov.uk//).

dti

Report Ref: B/W6/00599/REP (URN 03/1219) Publication date: December 2003
Report Ref: B/W6/00599/REP/2 (URN 03/1301)

IMPROVING WILLOW BREEDING EFFICIENCY

Rothamsted Research (with University of Southampton)

OBJECTIVES

- To improve willow breeding efficiency through the implementation of molecular marker technologies.
- To develop additional willow markers for genetic studies and use these to construct genetic maps.
- To map quantitative trait loci (QTL) for pest and disease resistance and biomass yield and identify linked molecular markers for use in marker-assisted selection.
- To identify physiological traits definitive of biomass yield.

SUMMARY

Increased energy production from renewable resources is currently a high priority in Europe as a result of dwindling fossil fuel reserves and the need to produce energy in ways that are non-polluting. The generation of energy from biomass sources can contribute towards a solution. Several willow species have been highlighted as particularly suitable for this end use when grown as Short Rotation Coppice (SRC). Although efforts to breed high-yielding varieties for this purpose have resulted in significant improvements in recent years, the scope for further progress remains great. However, current breeding efforts are hampered by inefficient selection regimes and the limited knowledge available on the genetic basis of important agronomic traits. The main objective of this project was to use molecular markers in genetic mapping strategies to address both of these issues.

Two genetic linkage maps, based on two different full-sib biomass willow mapping populations, were generated, largely based on microsatellite and Amplified Fragment Length Polymorphism (AFLP) markers. Both maps were produced according to a double pseudo-testcross strategy in which separate parental maps were constructed before integration to form a consensus map. The first map was derived from a pre-existing population (K3), comprised of only 66 progeny. A second, much larger, full-sib population, K8, was established to underpin subsequent trait analyses and QTL mapping. This population comprised 947 full-sib progeny and was planted in a field trial at Long Ashton Research Station. This trial was used for assessments of traits of agronomic importance, including total yield, several components of yield (eg height, diameter, etc), resistance to *Melampsora* rust diseases and

resistance to willow beetle herbivory. Laboratory-based assessments of disease and pest resistance were also performed. All resulting trait data were used in conjunction with genotype and linkage information to map genomic regions influencing these traits via QTL analyses. Putative QTL for all target traits were identified, with indications of robustness provided by the identification of corresponding QTL positions for correlated traits and by the detection of several QTL that were consistent over different assessment years and environments.

Salix genotypes of differing biomass yields were studied at five coppice ages over two growing seasons to identify traits definitive of high yield in willows. Maximum stem heights and stem diameters increased with biomass yield. 'Tora' produced more sylleptic branches on the leading stems than 'L78183.' Individual leaf area and cell number per leaf was greater in 'Tora', whereas cell area was greater in 'L78183,' suggesting that final leaf areas were attained in 'Tora' through the production of many, small cells, and in 'L78183' through fewer, large cells. Leaf extension rates were higher in 'Tora' than 'L78183'. Leaf area index (LAI) was higher in 'L78183' than in 'Tora' which had a very open canopy. A/C_i analysis revealed the low-yielding genotype as the most photo-synthetically efficient at the individual leaf level whereas light response curves suggest that 'Tora' utilises light more efficiently. The results suggest that leaf extension rate and cell number per leaf may be indicative of yield, and may be useful as selection criteria for potentially high-yielding hybrids for biomass use.

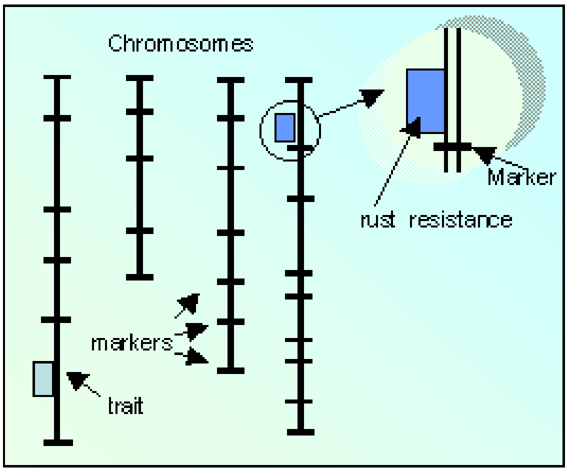

Figure 1. Genetic maps provide a framework for gene location. Markers closely linked to traits can be used to detect the presence of the trait in simple screening assays.

COST

The total cost of this project was £358,114 with the Department of Trade and Industry (DTI) contributing £312,314 and the European Willow Breeding Partnership the balance.

DURATION

56 months – November 1998 to June 2003

BACKGROUND

Increased production from renewable energy sources is currently a high priority in Europe as a potential solution to the need to replace fossil fuels in ways that are non-polluting. The European Union is now committed to reach a target for additional biomass energy of 8.5%, or 90 million tonnes of oil equivalent (mtoe) per year by 2010. This equates to planting biomass crops on 7.1% of all EU agricultural and forestry land (10 million hectares). Breeding of high yielding, pest- and disease-resistant biomass crops urgently needs to be accelerated to help meet these targets.

Willows (genus *Salix*), grown in short rotation coppice (SRC) have great potential as biomass crops. Over the past few years, significant advances have been made in the breeding of willows with high biomass yields, with cultivars such as Tora and Bjorn (bred in Sweden), and Ashton Stott (bred in the UK) in trials reaching 20-22 oven-dried tonnes/ha. However, the scope for further yield increases is still enormous. Furthermore, yield can be reduced significantly by disease caused by *Melampsora* rusts, and pest damage such as caused by the blue willow beetle (*Phratora vulgatissima*). There is a need for a continuous supply of high yielding cultivars, with new forms of pathogen and pest resistances, for use in commercial plantations. There is also a requirement for varieties that are able to sustain yields in less optimal growing conditions, such as drought or poor soils, or are optimised for different end uses.

The ability of willow breeders to select promising parents for crossing and to identify progenies with favourable combinations of characters is hampered by the limited knowledge available on the genetic basis of important traits. Molecular techniques can accelerate the efficiency of willow breeding by helping to locate genes controlling agronomic traits and providing markers for marker-assisted selection of desired traits (Figure 1). However, this is not a trivial task in willow. Willows are dioecious and highly hetero-zygous. There are 19 chromosomes in the haploid set. Many species are polyploids and numerous inter-specific hybrids occur at all ploidy levels. Homozygous lines are not available and crossing among parents gives F_1 comprised of varied genotypes from which different types of segregating families may be derived.

Given these constraints, genetic mapping in willows is best achieved through a double pseudo-testcross strategy. This approach assumes that both parents in the cross may carry a high level of heterozygosity and allows markers that are heterozygous in either parent to be detected. The double pseudo-testcross approach has been successfully used for genetic mapping in crops of similar genetic complexity to willow, such as poplar, apple, rubber and larch.

To underpin breeding efforts in willow, in this project, microsatellite and AFLP markers were developed and applied in a double pseudo-testcross approach. Two genetic linkage maps were constructed based on two different full-sib biomass willow populations. The first map was derived from a pre-existing population (K3), comprised of only 66 progeny. A second, much larger, full-sib population, K8, was established for mapping quantitative trait loci (QTL). This trial was used for assessments of total yield, several components of yield (eg height, diameter, etc), resistance to *Melampsora* rust diseases and resistance to willow beetle herbivory (Figure 2). Laboratory-based assessments of disease and pest resistance were also performed. All resulting trait data were used in conjunction with genotype and linkage information to map genomic regions influencing these traits via QTL analyses.

A number of physiological traits which correspond to yield have been established in woody plants grown as SRC but, to date, there has been a paucity of work defining yield traits in *Salix.* Biomass estimation modelling has found that stem features such as basal diameter and height are closely linked to total biomass yield and highly correlated to each other. High positive correlations have been found between mature individual terminal leaf area and biomass productivity. The total leaf area of a plant is often tightly correlated with the total accumulated biomass of that plant. Studies have suggested that leaf area index (the ratio of single-surface leaf area per unit of land area) is highly linked to, and may be estimated from, basal stem diameter measurements. Decrease in leaf area index through the season in relation to canopy closure and leaf loss has been reported. Rates of leaf maturation also affect leaf area index, suggesting that both individual leaf development and canopy development may be indicative of yield. Epidermal cell number per leaf has been found to be strongly correlated with stemwood yield values. Leaf photo-synthesis has been discussed as being positively correlated to biomass production in loblolly pine (*Pinus taeda*), *Larix* hybrids and *Populus* hybrids. However, in a study of photosynthetic characteristics in five poplar genotypes, little connection between photosynthesis and biomass yield was detected, concluding that leaf-level rates of photosynthesis may not be a yield-defining characteristic in *Populus.*

To improve our ability to identify indicators that could be used in early selection for yield by breeders, basic photosynthetic and anatomical leaf characteristics, canopy development and stemwood traits were determined in a variety of genotypes chosen over a range of yield categories. Once traits definitive of high yield are identified, genetic mapping efforts can be concentrated on identifying loci linked to these traits for use in marker-assisted selection.

Figure 2. Field assessment of the K8 mapping population in the first year of growth following cutback

GENETIC MAPPING OF COMPLEX TRAITS IN WILLOW

The double pseudo-testcross approach was successfully employed for the construction of the genetic linkage map of *S. viminalis* based on the K3 mapping population. This required significant investment in marker development, ultimately resulting in the generation of 56 polymorphic microsatellites and 477 AFLP markers for inclusion in linkage analysis. In addition, 19 micro-satellite primer sets originally developed for poplar were tested in willow. Five loci were successfully amplified in the mapping pedigree, of which two segregated and were mapped. Also, two publicly available *Populus* Expressed Sequence Tags (ESTs) were used as a basis to test the efficacy of developing ESTP markers for use in willow. Primers designed to these two sequences resulted in amplification of willow products. One locus was polymorphic in the mapping pedigree and was subsequently mapped.

The K3 paternal map comprised a total of 132 AFLP markers and 25 microsatellite markers that mapped to 21 linkage groups of three markers or more. Resulting groups spanned 777.5cM with an average marker interval of 7.9 cM. The K3 maternal map comprised 139 AFLP markers and

33 microsatellite markers located on 25 linkage groups of three markers or more. These groups spanned 910.2cM with an average interval between markers of 8 cM. The resulting 21 K3 consensus groups comprised 191 AFLP markers of types *aaxab* and *abxaa*, 81 AFLP markers of type *a0xa0*, one ESTP marker and 43 microsatellites of all possible segregation types.

A new mapping population was required, as the existing K3 progeny population did not appear to segregate as required for all traits to be targeted in the study. Furthermore, only 66 progeny were available at the start of the project. For QTL mapping much larger population sizes are required to detect robust statistical associations between markers and traits.

The progeny of two crosses were chosen initially as candidates for the second mapping population to increase the likelihood that segregation for all traits of interest would be achieved. A single population was then chosen later on the basis of trait assessments made in the first year of growth. The two candidate crosses were selected from seven potentially suitable crosses made as part of the European Willow Breeding Programme. These crosses were deemed likely to segregate for traits of interest and had all produced adequate numbers of seed to produce a sufficiently large mapping population to underpin QTL analysis. Two populations derived from crosses between different full-sib progeny of the K477 population (produced in Sweden) were elected as the mapping populations that were established for initial study. This choice was made on the basis of expected trait segregation and seed availability. These two full-sib populations, named K1 and K8, were planted in a field trial designed specifically to allow the collection of trait data suitable for use in later QTL analysis. Following establishment, field-based trait assessments were performed on both populations for yield-related traits and field-based resistance to *Melampsora* rusts during the first year of growth. Laboratory assays of rust resistance (Figure 3) and palatability to the blue willow beetle (*P. vulgatissima*) were also performed. Following these initial trait assessments the K8 full-sib population, comprising 947 progeny, was chosen for more detailed phenotypic study and to underpin later QTL analyses.

Figure 3. Laboratory leaf-disc rust assay showing susceptible (left) and resistant (right) genotypes

The double pseudo-testcross strategy was successfully employed to construct the K8 linkage map for underpinning subsequent QTL analyses, resulting in the construction of separate framework parental maps and a preliminary consensus map.

Genotyping throughput was greatly improved via microsatellite multiplexing approaches based on fluorescent detection.

Bulked Segregant Analysis was successfully employed to select AFLP primer combinations that would yield markers in the vicinity of a microsatellite marker that was found to be linked to rust resistance in early non-parametric QTL analysis.

The preliminary K8 maternal framework map comprised 27 AFLP markers and 24 microsatellites. The resulting 12 linkage groups (including duplets) spanned 528.7cM with and average interval between markers of 13.6 cM.The preliminary K8 paternal framework map comprised 28 AFLP markers and 22 microsatellites. The resulting 13 linkage groups (including duplets) spanned 490.0cM with an average interval between markers of 13.2 cM. The parental linkage maps were integrated to produce a preliminary consensus linkage map comprising 19 *abxaa* AFLP markers, 20 *aaxab* AFLP markers, 49 *a0xa0* AFLP markers and 50 microsatellites. The total map length (including duplets) of these groups was 1191.8cM with an average interval between markers of 10.1 cM. Microsatellite markers allowed the identification of several homeologous linkage groups between the K8 and K3 maps. With one exception, microsatellite marker groupings were in agreement with those identified in K3.

Although the K8 linkage maps will require additional work in future, to improve genome coverage, marker saturation and accuracy in some regions, the maps were suitable for use in the preliminary QTL analyses performed in this project. Putative QTL for all target traits were identified, with indications of robustness provided by the identification of corres-ponding QTL positions for correlated traits and by the detection of several QTL that were consistent over different assessment years and environments.

SRC *Salix* genotypes of differing biomass yields were studied at five coppice ages over two growing seasons with the long-term aim of identifying traits definitive of high yield for the breeding of elite energy crops. In the first season, basic leaf and stem traits were measured in six *Salix* genotypes, to identify morphological characteristics associated with high biomass yields. Thereafter, *S. viminalis* L. 'L78183' (low yield) and the hybrid genotype *S. schwerinii* E. Wolf x *S. viminalis* L. 'Tora' (high yield) were compared.

Maximum stem heights and stem diameters increased with biomass yield. 'Tora' produced more sylleptic branches on the leading stems than 'L78183.' Leaf traits differed significantly between the two genotypes: individual leaf area and cell number per leaf was greater in 'Tora', whereas cell area was greater in 'L78183,' suggesting that final leaf areas were attained in 'Tora' through the production of many, small cells, and in 'L78183' through fewer, large cells. Leaf extension rates were higher in 'Tora' than 'L78183'. This result was mirrored in leaf production rate. Leaf area index (LAI), examined at two coppice stages, was higher in 'L78183' (values of 2.06 and 1.67) than in 'Tora' (maximum value 1.43) which had a very open canopy. Furthermore, A/C_i analysis revealed the low-yielding genotype as the most photosynthetically efficient at the individual leaf level whereas light response curves suggest that 'Tora' utilises light more efficiently. The results presented in this study suggest that leaf extension rate and cell number per leaf may be indicative of yield, and may be useful as selection criteria for potentially high-yielding hybrids for biomass use.

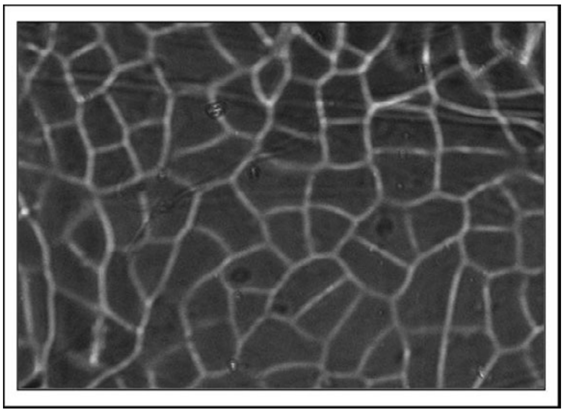

Figure 4. Leaf cell number may be indicative of yield in high-yielding biomass varieties such as Tora

CONCLUSIONS

- This project has been successful in meeting the overall aims and objectives as set out at the start of the study.
- Additional molecular markers were developed and successfully used to generate linkage maps and identify genomic regions underlying traits of agronomic importance in biomass willow.
- Two genetic maps were constructed, the first was derived from a small population obtained from a *S.viminalis* cross, the second was based on a much larger population and was used for QTL analysis.
- Microsatellite markers were used to anchor linkage groups between the two maps.
- With one exception, microsatellite groupings in K8 were in agreement with those in K3, indicating excellent co-linearity between the maps.
- Putative QTL for all traits targeted (resistance to rust, resistance to leaf-eating beetles and yield) were identified.
- Comparisons of photosynthesis between the low-yielding 'L78183' and the high yielding 'Tora' showed that 'L78183' was most efficient at the individual leaf level whereas light response curves indicated that Tora utilises light more efficiently.
- Leaf extension rate and cell number per leaf may be indicative of yield, and may be useful as selection criteria for potentially high-yielding hybrids for biomass use.

POTENTIAL FOR FUTURE DEVELOPMENT

Although still preliminary in some cases, the results presented in this report represent a significant step forward in terms of making molecular breeding of SRC willows an attainable future prospect and provide many avenues for future research, such as the testing of markers linked to QTL in marker-assisted selections. The identification of markers linked to rust resistance locus may be particularly amenable to such a role, although some work remains to be done to determine which markers are most tightly linked and may subsequently be most useful.

Although putative QTL for all traits were identified, the limited genome coverage afforded by the K8 map at present may have prevented the discovery of additional important QTL. For this reason it is important that the maps are further improved, through the development and mapping of additional highly-informative molecular markers.

This study also confirmed that stem traits can be used as good yield indicators in willow but, in addition, the data suggest that more attention could be paid to resource allocation from sylleptic branches in *Salix*, if this branching growth form were to be practical for mechanised maintenance and harvesting.

The carboxylation efficiency of Rubisco and the maximum rate of electron transport in the thylakoid may be less important and useful as a yield indicator than the harvest and utilisation of light and simple morpho-physiological measurements of leaf production, extension and longevity.

Furthermore, willow breeding for yield may benefit from crosses concentrating on leaf area characteristics involving the production of many, large epidermal cells.

Future work should concentrate on the identification of robust QTLs by trait assessments over successive years and at more than one site and finer resolution mapping of these QTLs by increasing marker coverage particularly on those linkage groups where several QTL are co-locating. Morpho-physiological assessments of yield need to be continued in a wider range of genotypes and on the parents and progeny of the K8 mapping population. Finally, markers linked to traits need to be validated for use in breeding programmes.

dti

Report Ref: B/W2/00718/REP (URN 04/1657) Publication date: December 2004

AN EVALUATION OF THE OPTIMUM TIMING FOR PLANTING SHORT ROTATION COPPICE

Biomass Energy Services Ltd (with ADAS, Scottish Agricultural College and Working Willow Consultants)

OBJECTIVES

- The principal objective is to determine the optimum period for planting Short Rotation Coppice (SRC) willow by assessing the establishment, and measuring the biomass productivity, of willows planted at different timings in the spring and the autumn, on a range of sites (arable, arable/grassland and reclaimed land).
- To assess the potential requirement for planting machinery and the potential impact on planting stock production and storage of autumn planting.
- To provide clear recommendations and guidance to UK industry on the optimum timing of planting SRC.

SUMMARY

Four trial sites in the UK were selected to represent a cross-section of climates, soil types and previous cropping and land use history. Three varieties of willow were planted: Jorr, Tora, and Ashton Stott.

Site no.	Location	Soil type	Previous land use
et01/ab	Aberdeenshire	Sandy clay loam	Arable/ set-aside
et01/ay	Ayrshire	Re-claimed coal spoil	Deep coal mining
et01/yo	North Yorkshire	Sandy clay loam	Arable/grass
et01/no	Norfolk	Sandy loam	Arable/ set-aside

Figure 1. Site location details

A total of six different planting treatments were installed – three during spring/early summer and three during the autumn of 2001. These treatments were repeated in 2002, to take account of the possibility of different climatic conditions producing variant responses to planting, establishment and productivity.

The final assessments from the four trial sites measured the establishment of the cuttings, the level of survival of the willows at harvest and compared the oven dry weights of the treatments.

The early spring planting timings (March/April, T101 and T102), give the greatest productivity. Substantial yield penalties are incurred when planting is delayed until late spring/early summer.

Early autumn planting was unsuccessful at all sites, but late autumn planting generally resulted in reasonable establishment and may be a viable option on restored/industrial sites. Here, ground conditions are often more challenging and the prime objective on these sites is for relatively quick ground cover, and enhanced environmental and habitat benefits are more important than high-yielding crops.

COST

The total cost of this project is £213,141, with the Department of Trade and Industry (DTI) contributing £105,406, and UK industry the balance of £107,735.

DURATION

40 months – March 2001 to July 2004

BACKGROUND

The primary objective of this project was to determine the optimum period for planting and measure any potential penalties for establishment and productivity through delayed planting in the spring. An evaluation of the planting date factor would allow clearer advice to be available to SRC growers similar to the agronomic advice available for other arable crops.

The accepted best practice and advice for planting SRC is to plant and establish crops as early as possible in the spring in well-prepared soils as soon as ground conditions allow. The normal planting season may be considered as mid-March to mid-June, ie 12 weeks (72 working days, six-day week). However, planting is often delayed through a combination of factors, such as adverse weather and ground conditions, as well as logistical and organisational difficulties. As an example of such problems, there was not one field of SRC planted in April 2000 due to heavy rainfall and saturated ground conditions.

There was no previous evidence evaluating any impact on the establishment in the short term, or productivity in the longer term, from different planting periods.

A second objective was to plant willows at different timings in the autumn. A single field trial was previously evaluated at IACR Long Ashton measuring the productivity of willows planted at monthly intervals from October to April. The results of this trial are included in the report. A potential difficulty was perceived with the availability of willow cuttings for autumn planting. There are two possible options viz, long-term storage of cuttings using material sourced at the same time as those used in the spring treatments or using freshly cut material prepared in the autumn prior to each treatment. A laboratory trial was undertaken to investigate the viability of cuttings in long-term storage.

A demonstration of successful establishment of willows planted in the autumn would greatly extend the normal planting season. Under the Defra Energy Crops Scheme it is estimated that the scheme will result in the establishment of 22,000ha of SRC during 2001-2006. This would result in an average of 3600ha planted each year, or 300ha for each week of the standard planting season, or 50ha/day. Given that the average operational output of a Step Planter is 0.7ha/hr, one planter is capable of planting only 7ha in a 10-hour day.

The planting capability assumes no machinery breakdowns or other logistical problems and no day losses due to adverse weather. Successful establishment of autumn planted willows would double the span of the planting season and machine capability.

The technical benefits are that SRC crops could be planted into soils that may be relatively dry (and suitable for planting), but are more likely to become wetter as autumn/early winter weather conditions prevail. While the shoot and root establishment may not be substantial through the winter, if the cuttings survive any severe winter weather, then the onset of spring growth will usually occur earlier than it would be possible to plant conventionally in the spring, and thus total biomass production in the first full year of establishment may exceed the conventionally planted spring crop.

The commercial benefits of an extended planting season are that increased areas of SRC could be planted every year to meet the anticipated demand for woodchip fuel supply and the relatively high planting costs could be reduced through greater utilisation of planting machinery.

THE WORK PROGRAMME

Four trial sites across the UK were selected to represent a cross-section of climates, soil types and previous cropping and land use history. Three varieties of willow were planted: Jorr, Tora, and Ashton Stott. These varieties are representative of the current list (Forestry Commission, FCIN17) and likely future usage, in terms of productivity, form and disease diversification.

A total of six different planting treatments were installed – three during spring/early summer and three during the autumn of 2001. The treatments were scheduled to be a maximum of six weeks apart, with an optimum of five weeks apart, and allowing for adverse weather, no closer than four weeks apart (ie a target planting window of two weeks). These treatments were repeated in 2002, to take account of the possibility of different climatic conditions producing variant responses to planting, establishment and productivity.

Site no.	Treatment 101	Treatment 102	Treatment 103
et01/ab	11.04.01	08.05.01	06.06.01
et01/ay	23.03.01	03.05.01	07.06.01
et01/yo	30.03.01	08.05.01	11.06.01
et01/no	20.03.01	26.04.01	12.06.01
Site no.	Treatment 104	Treatment 105	Treatment 106
et01/ab	08.09.01	06.10.01	10.11.01
et01/ay	11.09.01	08.10.01	13.11.01
et01/yo	07.09.01	16.10.01	14.11.01
et01/no	05.09.01	16.10.01	19.11.01
Site no.	Treatment 201	Treatment 202	Treatment 203
et02/ab	14.03.02	25.04.02	06.06.02
et02/ay	20.03.02	29.04.02	07.06.02
et02/yo	05.03.02	19.04.02	29.05.02
et02/no	07.03.02	10.04.02	29.05.02
Site no.	Treatment 204	Treatment 205	Treatment 206
et02/ab	10.09.02	30.10.02	28.11.02
et02/ay	03.09.02	31.10.02	29.11.02
et02/yo	04.09.02	22.10.02	03.12.02
et02/no	06.09.02	24.10.02	04.12.02

Figure 2. Dates of planting

The willow cuttings planted in the spring (treatments T101-3, T201-3) had been prepared during the previous winter and cold stored, as is the normal practice. Cuttings required for the autumn treatments (T104-6, T204-6) were cut fresh from green stems prior to each treatment. The cuttings were hand-planted in twin-row beds with 75cm between rows and 150cm between the beds. The spacing along the rows was 59cm. This provided a notional field-planting rate of 15,000 cuttings per hectare, and provided 28 cuttings per sub-plot.

The final assessments from the four trial sites measured the establishment of the cuttings, the level of survival of the willows at harvest and a comparison between the treatments of the oven dry weights.

CONCLUSIONS

The initial conclusion quite clearly shows that the early spring planting timings (March/April, T101 and T102, give the greatest productivity. Substantial yield penalties are incurred when planting is delayed until late spring/early summer. Late autumn planting can be more productive than spring planting the following season, but this difference may be less conclusive over the normal harvest cycle and may be affected by soil type and seasonal weather conditions.

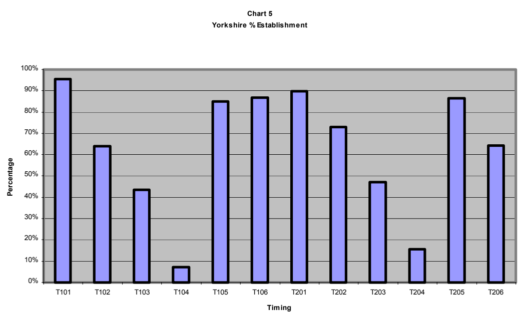

Figure 3. % establishment at the Yorkshire site

Early autumn planting was unsuccessful at all sites, but late autumn planting generally resulted in reasonable establishment, which may be productive over the normal first production cycle of four years from planting to harvest.

The levels of productivity were affected in several ways:

- Early spring planting produced more biomass by having a longer growing season.
- Early planting resulted in better establishment, vigour and more harvestable plants.

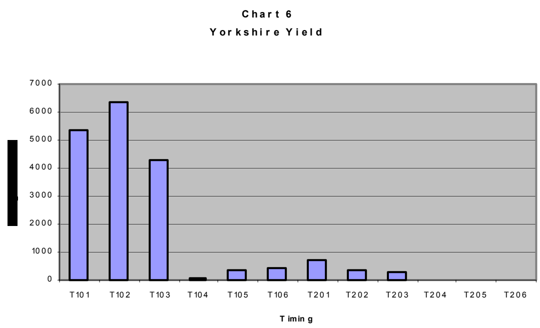

Figure 4. Yield (dry gram offtake) at the Yorkshire site

There would appear to be various factors contributing to these differences:

- Early planting of cuttings into soils with adequate moisture levels.
- Late planting into soils which are much drier.
- Late planting has a shorter growing season.
- Inherent soil fertility benefiting early planting.
- Soil type – good fertile soils will produce better yields.
- The impact of weed infestations with competition for moisture and nutrients.

- The impact of vermin grazing, especially on late planted and slower growing plants.

The conclusions that can be drawn from the long-term storage experiment are:

- Cutting material cannot be harvested in winter and kept in long-term cold storage for planting in the following autumn.
- Cutting material harvested in winter and kept in cold storage for planting in spring may be used until early June, but its quality may deteriorate, subsequently putting late June plantings at risk.

While the results from these trials provide a clear indication as to the likely levels of establishment from different planting timings, the overall productivity from different timings and different varieties should be treated with caution because, after several full harvest cycles, such differences may be evened out. However, if willows do not establish, even with some compensation by surviving plants, there will be a yield deficit compared with that from a satisfactory plant population.

Late autumn planting may be a viable option on restored/industrial sites where ground conditions are often more challenging. Autumn planting would allow for more intensive ground preparation works during the drier summer months, and possibly the application and incorporation of sludge cake as a conditioner and nutrient. While autumn planting will not provide as good establishment as the early spring planting timings, full establishment and high yielding crops are not always the prime objectives on these sites. Often a degree of relatively quick ground cover and enhanced environmental and habitat benefits are more important, as is provision of a bio-filter for industrial waste disposal in some circumstances.

The main conclusion from this project is that the best productivity is obtained from early planting in the spring (Feb-April) and that delayed plantings in late spring/early summer can result in yield penalties of more than 30%, although these effects may not be so severe over several harvest cycles.

Late autumn/early winter planting is possible, but should probably be restricted to more southerly locations in the UK, where low soil temperatures are less likely.