POSTER SESSION 7C

NOVEL AND INDUSTRIAL CROPS: REALISING THEIR POTENTIAL

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IENICA – Interactive European Network for Industrial Crops and their Applications

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ABSTRACT

Crop-derived materials can provide novel raw materials, as well as technical, environmental and waste disposal advantages over synthetic fossil-derived materials, whilst offering alternative options for agriculture. Uptake of 'renewable raw materials' is uneven and fragmented, however. In recognition of this, the EC in 1997 commissioned the 'IENICA' project. IENICA provides an overarching, pan-European facility, involving 26 countries, linking all EU industrial crop activities. Through a series of integrated activities, including the production of a novel crop agronomy booklet, market data sheets, national reports, newsletters and the organisation of a number of conferences and seminars, IENICA has identified significant potential for renewable raw materials in Europe. The project has also identified a number of barriers and constraints to the development of the industry which must be overcome before true market exploitation of renewable raw materials can occur.

INTRODUCTION

Although plant-based materials have been used for many thousands of years, the introduction of synthetic materials, which can be produced more cheaply, efficiently and reliably, has significantly reduced their use in industry. However, a number of key factors are driving the return to the use of natural materials and the non-food crop sector is once again seeing a resurgence in interest. These drivers include:

- Stringent environmental targets and regulations (e.g. emissions targets set by the Kyoto agreement to reduce climate change and VOC reduction targets) at regional, national and international levels, and increasing consumer demand for green products and environmental awareness;
- An increasing interest in alternative farm enterprises, led by decreasing farm incomes;
- An industrial 'pull' – where renewable materials offer either a reduction in price over the synthetic alternative (unlikely at present due to economies of scale) or superior technical performance. Industrial 'pull' is generally considered to be the key factor for the future of the non-food crop sector, as true sustainability will only come through market demands.

Currently the development and uptake of industrial crops throughout Europe and the rest of the world, is uneven. Development has been strongly supported and encouraged in some countries (such as Germany, France and the Netherlands) whilst in others it has occurred in a fragmented fashion. Uptake and development to date have been slow in the UK and while steps are being taken, the industry is someway behind counterparts in other EU countries.

This fragmented European approach led, in 1997, to DG Research of the European Commission to fund a group of researchers to form an 'Interactive European Network for Industrial Crops and Applications', under the FAIR programme. Fourteen countries participated in this three-year project (EU-15 except Luxembourg), with one partner institute in each country. Continuation funding was secured in 2000 from Framework Programme 5 of the EC to support the project for a further 3 years and to include a number of the EU accessing and associated states (EU project QLK5-CT-2000-00111). IENICA now involves 26 countries: Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Lithuania, the Netherlands, Poland, Portugal, Romania, Spain, Sweden, Switzerland, Canada, the USA and the UK.

The principle aim of IENICA is to "achieve enhanced technology transfer and market orientation in order to extend sustainable and economically viable non-food products from plants, through positive interaction and collaboration at all stages in the production-supply-processing-market chain". Towards this aim, the project's principle objectives are to:

- Create synergy within the EU industrial crops industry and facilitate interaction and interchange of information by developing an integrated network linking key individuals from industry, government and science in member states;
- Disseminate data by acting as a European Gateway facility for all data on non-food crops;
- Identify the strengths of the EC accessing and associate states and link this data into existing networks and market assessments;
- Allow an enhanced efficiency of use of limited RTD funding by identifying true market potential to focus funding for maximum value for money

METHODOLOGY

IENICA is based upon a series of independent 'workpackages' which integrate to meet the primary aim and key objectives of the project.

National reports

Produced by each of the original project states (EU-14) and currently being prepared by the participating accessing and associated states, the reports detail which non-food crops are grown, current levels of production, current and potential applications and markets plus barriers, constraints and opportunities to the development of the sector. Issues are considered in each of four market sectors: fibres, oils, carbohydrates and speciality crops. This data is essential to industry, policy-makers and scientists to help assess current and future trends as well as strengths and weaknesses in the sector. This helps identify where investment should be directed. An EU summary report will be prepared compiling the data and key issues from the national reports. An EU summary for the original fourteen partners was published in 2000 (IENICA, 2000)

Agronomy booklet

This will examine the agronomy of selected industrial crops, from a generic perspective, and will be published for use by farmers and growers. Information will be provided on a crop by crop basis covering issues such as climatic and soil requirements, recommended sowing dates and rates and likely pest and disease problems. A national expert contact in each partner state will also be provided for each crop.

Market data sheets

Four specialist market data sheets will be compiled by international experts within the network. These will contain market data and industry specifications for raw and processed materials in each market sector (oils, fibres, carbohydrates and speciality). These will supply much needed information to growers and processors and will provide a framework on which industry can build firm specifications for raw materials.

Conferences/seminars

IENICA organises a number of international conferences (e.g. BioPlastics and GreenTech, held in York and Amsterdam respectively, in 2002) and international regional seminars, which focus upon regional developments and opportunities for non-food crops. Seminars focussed on Southern Europe and the Mediterranean and Central and Eastern Europe have been held in 2003.

Monitor uptake

The final phase of the project will be to assess the success of the IENICA project by scrutinising the uptake of industrial crops and their products across Europe. At present uptake is sporadic and industry slow to invest where the supply chain is unreliable. This work will assess whether the introduction of a closely industry-focused approach has increased the natural momentum of the uptake of non-food crops in the EU.

Newsletters

Dissemination of information is a key element of the project and IENICA publishes a quarterly newsletter, which includes articles on new developments in non-food crops, results of scientific research and policy developments plus reports on the network activities.

Website

The IENICA website (www.ienica.net) is a key Gateway facility for non-food crop information. The website holds all project deliverables and a range of other information, including an extensive plant database with detailed information on over 100 plants with realised/potential industrial applications. A large contacts database has contact details and areas of interest for over 3000 contacts working in, or researching, industrial crops in 30 countries.

Activities are scrutinised by an Industry Advisory Group to ensure that the project remains well-focused on industrial needs and industrial uptake of non-food crop products.

DISCUSSION

The national reports have become a central resource for non-food crop information in Europe, and in many cases represent the first instance where the information has been collated and aggregated to provide and EU overview. Significant potential for increased growth in the markets for various crop-derived materials were identified (Table 1). Current work will bring this data up to date and extend it to include current and potential production and applications in the accessing and associated states.

Table 1. Production of crop derived raw materials for industrial use (million tonnes)

	EU Output 1998	EU Output 2003*	% Growth (Estimated)
Vegetable Oils	2.6	4.1	58
Starch	2.4	3.6	50
Non-Wood Fibres	0.5	0.6	21
TOTAL	5.5	7.64	38.9

Source: IENICA UK Report (Actin, 1999) * Based on % growth

Some of the major findings and issues identified are detailed below.

Oil crops

European production of vegetable oils is dominated by oilseed rape and sunflower with some soya bean and linseed production. These oil crops have some non-food applications in the oleochemical, surfactant, soap, paint and surface coatings and lubricant sectors. EU markets are potentially significant but currently under-exploited: the potential EU market for biodegradable lubricants, for example, is estimated at 370,000 tonnes; current exploitation is just 35,000 tonnes. Market opportunities exist particularly where high environmental contamination occurs i.e. in 'total loss' oils such as chainsaw oils, hydraulic fluids and drilling oils where oil is 'lost' to the surrounding environment. European vegetable oil production is currently supplemented by considerable quantities of imported oils, particularly tropical oils such as palm and castor oil, and tallow of animal origin. These imports represent 80% of EU oil demand. There is considerable potential to expand EU-produced vegetable oil use on the basis of import substitution alone. Considerable activity is underway to develop new oil crop species and modify the oil composition of existing EU oil crops (e.g. high oleic sunflower).

Fibre crops

In 2000, flax and hemp were the only commercialised sources of European plant fibres, with investigations into *Arundo donax*, kenaf, fibre sorghum, miscanthus, nettle and reed canary grass. Applications for natural fibres include textiles, pulp and paper, fibre-reinforced composites, filters and absorbents and insulation materials. Market potential for high quality, high value textile products is limited and new uses for increased production are likely to focus upon high volume/lower value markets. Potential in the automotive industry is for up to 350,000 tonnes of raw material per year in Europe, with principal applications in door liners, boot liners and parcel shelves. Industry indicates a potential of up to around 10kg of raw material per vehicle.

Carbohydrate crops

Wheat, barley, maize, sugar beet and potatoes are the dominant carbohydrate sources in Europe. Estimates of the total EU starch market for the year 2000/2001 is 7.3 million tonnes/annum, of which 3.7 million tonnes is in the non-food sector: 1.4 million tonnes in paper and cardboard making, 1.1 million tonnes in plastics and detergents and 1.2 million tonnes in fermentation and other technical uses. Additionally, smaller markets exist in water purification, cosmetics, toiletries, pharmaceuticals, paints and agrochemicals. Several of these latter offer high potential for added value, but for limited tonnage. A significant quantity of the carbohydrate processed and used in Europe, particularly maize starch, is imported. However, European demand for carbohydrates is increasing and there is potential to replace imported products. All starch extraction processes produce by-products and whilst these are currently sold as animal feed, higher added-value applications (i.e. in cosmetics) are being developed.

Speciality crops

These generally represent high value/low volume markets and a very diverse range of species is grown in Europe. Applications are wide-ranging, for example, essential oils, pharmaceuticals, inks, dyes, perfumes and novel plant protection products. Markets are international and highly competitive and Intellectual Property Right protection and registration procedures can be confusing and prohibitively expensive. The quality and proportions of the desired plant-derived molecules vary in many species, which affects stability and quality of supply. Europe plays a major role in the international trade of medicinal and aromatic plants with typically around 120,000 tonnes imported annually from more than 120 countries. Between 1,200-1,300 species native to Europe are commercially traded and though some species are cultivated (10-15% of total volume), collection from the wild still plays a major role, causing problems for environmental sustainability and continuity of supply.

Factors affecting further development

IENICA has identified a number of barriers and constraints to the development of non-food crops. The natural-oil industry, for example, needs to improve the, currently slow, progress being made in the domestication of new oil species with useful fatty acid profiles. Likewise, in the natural fibres sector, little plant breeding of the most important crops (flax, hemp, miscanthus, reed canary grass) is taking place to meet the changing fibre-market requirements. Development of new crops (such as quinoa and sweet sorghum) is necessary within the carbohydrate sector to offer new crop options for European agriculture. Hand harvested speciality species have high production costs and crop production is generally high risk, with volatility of crop performance, quality and end product.

A number of generic issues were also identified across all sectors, including:

- Competition from cheap imports
- Price: European raw material prices are often not competitive compared with world market prices or fossil fuel and mineral oil derived synthetic materials
- Crops produced by gene transfer offer potential to meet industrial demands in all sectors, but are currently unacceptable to the general public
- The utilisation of by-products is necessary to improve the total income from all crops

- The environmental benefits of natural materials are poorly communicated to the general public. Education coupled with EU-wide labelling schemes (as already exist in some countries) would enhance consumer demand
- Communication between the main participants in the non-food industry needs improvement
- The industry is often based upon old technology and new environmentally sensitive and cost effective solutions are required. It is often difficult to introduce raw materials from new sources into production systems, where technology and practices are well established.

In terms of the UK market, the national report for the UK (ACTIN, 1999) identified a total of *circa.* 1400 organisations who are interested or involved in alternative crop development or utilisation – from academia through to industry. However, the industrial crop market in the UK was classed as "immature – industry lacks knowledge of, and links to, the supply chain and processes which can automatically utilise alternative crops cost-effectively". It was noted, however, that a strength of the UK is its diverse science base, with wide-ranging market expertise, academic support, an extensive research programme and skills ranging from basic agronomy through to economic and lifecycle assessment, which should support uptake and development.

An issue affecting all sectors is the lack of industrial specifications for raw materials. The market data sheets currently in preparation will go some way to addressing this issue and will, in association with the agronomy booklet, attempt to create linkages and communication within the supply chains.

Consumer and industry demand are, arguably, the major drivers of development in the industry and IENICA has taken significant steps towards raising greater awareness in both. The strong industrial focus has remained a key factor in all activities and industry has been keen to support IENICA. The non-food crop industry still has a long way to go to reach the potential identified by IENICA and momentum must be maintained.

ACKNOWLEDGEMENTS

I would like to thank all those who have contributed to the success of the IENICA project to date, particularly project members and collaborators.

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Identification of opportunities for under-utilised crops in Wales – A novel approach

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ABSTRACT

This study was undertaken to identify opportunities for exploitation of under-utilised plant species to add value to agriculture and the wider rural economy in Wales. From lists of plants with known or documented uses 150 plant species were selected for further study, gathering information on potential markets, climatic and soil requirements, agronomy and any potential impacts on the local environment. Species were gradually eliminated based on climatic and other requirements, commercial viability, anticipated environmental impacts and estimated social, economic and cultural value arising from production and processing. Key species were mapped using GIS technology to identify areas of potential and marginal production. The location and extent of local processing facilities was also reviewed and the viability of local processing considered. The most promising opportunities were prioritised in a matrix that comprised likely time to fruition and potential limits to uptake. Information from the study will be utilised to encourage the development of new enterprises in Wales.

INTRODUCTION

Wales covers 2.1 million hectares; of this 81% is dedicated to agricultural use and 12% to forestry and woodland. The majority of agricultural land (84%) is permanent grass or rough grazing with only a small proportion (12%) dedicated to arable cropping, and this is dominated by rotational grassland (Welsh Institute of Rural Studies, 2002). The country remains dominated by livestock production, which has impacts on the available arable land for provision of feed and bedding supplies.

In the past 5 years there has been a dramatic and devastating fall in Welsh farm incomes, exacerbated by the outbreak of Foot and Mouth Disease during 2001. Total income from farming has declined by as much as 25% in recent years (MAFF, 2001), the greatest effect has been apparent in the designated Less Favoured Areas. Many farm businesses are currently unprofitable, in 2000, 15% of agricultural producers made a loss, the average loss being £5,500 although some were as high as £20,000.

There is a need to find additional ways of exploiting plants and animal products in new sectors to help add value to Welsh agriculture. Opportunities to develop new products from the rural economy which encourage local processing or primary manufacturing would also aid rural recovery in Wales and may offer opportunities for local branding to add value, or enhance tourism etc.

In July 2002 the Central Science Laboratory, in collaboration with the School of Agriculture and Forest Sciences at the University of Wales, Bangor (UWB) and the Centre for Ecology and Hydrology (CEH), also based at UWB were commissioned by the Welsh Development Agency to assess the economic potential of plants and animals not currently fully exploited by the Welsh agricultural sector. The aim was to identify food and non-food products to supply proven market opportunities, ideally where Wales and the Welsh Rural Economy has an advantageous position in the marketplace.

METHODOLOGY

The study was separated into two Phases; Phase I involved an evaluation of the agronomy and/or husbandry of the potential species, Phase II focused on a smaller range of species identified as having potential and involved a detailed evaluation of the commercial potential and potential added value for each identified opportunity.

Phase I

An initial list of over 150 plant species, with known or suggested potential for minor food or non-food use, was compiled by searching the internet, reviews of journals and through personal communications. Of the list of plant species identified with potential for commercial use 43 were identified as already growing in Wales (in the Atlas of British and Irish Flora) and a further 11 were identified, through The Postcode Plants Database, as native species. For each of the identified species a literature review was undertaken to identify potential uses, physical requirements (i.e. soil type and climate), nature of growth (e.g. annual, biennial, herb) and canopy characteristics, agronomy/husbandry, ability to cross pollinate or become a weed species, and value to insects and mammals. From the latter, it was possible to estimate the likely impacts on the landscape and related species. A website was created (http://safs.csl.gov.uk) to enable data to be searched by a wide audience.

Using the information gathered on each species, for those assessed as having the greatest commercial potential a number of mapping parameters were derived for use with a Geographic Information System (GIS) to illustrate potential and marginal areas for production. Table 1 illustrates the mapping parameters and includes details of the scale and sources of information.

Upon completion of Phase I a number of species were eliminated on the basis of their climatic and agronomic requirements. The number of species progressing to Phase II was reduced to 28.

Phase II

A more detailed market review was undertaken to assess current, potential and developed markets for renewable raw materials. For each species, information was collated regarding product value, potential market outlet, market size and likely timescale to commercialisation. A review of processing facilities was also undertaken, providing information on both the location and the extent of processing facilities already available in Wales or in nearby localities.

Table 1. Details of GIS mapping parameters, categorisation and sources of information.

Factor	Mapping parameters	Resolution	Source
Soil Type	1. Saltmarsh 2. Shallow acid peat over rock 3. Shallow soils over limestone 4. Sand dune soils 5. Slowly permeable clay over mudstone 6. Well drained loamy soils 7. Well drained sandy soils 8. Well drained soils in floodplains 9. Well drained acid loamy soils over rock 10. Well drained very acid loam and sand 11. Loamy acid soils with a wet peaty surface 12. Seasonally wet, loamy and clayey soils 13. Wet acid soils with a peaty surface 14. Stoneless loamy and clayey soils 15. Stoneless loamy and clayey coastal soils 16. Permeable sandy and loamy soils 17. Restored soils 18. Deep acid peat soils	$5km^2$	Simplified soil map from the National Soils Resources Institute (NSRI)
Rainfall bands	1. Up to 800mm 2. 800 – 1200mm 3. 1200 – 1600mm 4. >1600mm	$5km^2$	Met Office Rainfall data from GIServices
Days between first and last frost	1. 140 days 2. 155 days 3. 168 days 4. 185 days 5. 198 days 6. 213 days	$5km^2$	From Horticultural Website
Slope and altitude (for limits on mechanisation)	Option to exclude slopes greater than 15% Option to include/exclude upland or lowland areas	$50m^2$	Digital Elevation Model (held by CEH)
National Park Boundaries	Option to include/exclude National Park land	$100m^2$	Data held by CEH
Sites of Specific Scientific Interest	Option to include/exclude	$100m^2$	Data held by CEH

Detailed assessments were undertaken to allow the remaining species to be ranked in order of potential viability and success. The nature and magnitude of any likely environmental impacts were assessed, taking into account the following factors:

- Impacts on risk of soil erosion, loss of soil structure, and impacts on organic matter content
- Impacts on risk of flooding
- Odour, CO_2 emissions
- Anticipated inputs – fertiliser, herbicides, insecticides, fungicides
- Anticipated impacts on the farmed landscape
- Potential impacts on local biodiversity – risks to genetic resource, diversity and habitats

Species were considered for their social, economic and cultural value at the farm level and to the wider rural economy (by comparison with cereal production as a baseline). Each enterprise was allocated a total score (as in the example below for hemp and woad production). This was used as the basis for the final prioritisation.

Table 2. Scoring matrix to demonstrate the social, economic and cultural value of each enterprise (1-10 score for each item, where cereal production would typically receive an 'average' score of 5 in each category).

Class	Criterion	Hemp	Woad
Producer	Return/ha	5	6
Return	Demand	7	3
	Ease of access	4	4
	Total	16	13
Regional	Overall regional return	3	2
Economy	Jobs in production	4	1
	Quality of jobs in production	5	5
	Potential for post-production processing (A)	7	6
	Number of jobs in post-production (B)	6	1
	Quality of jobs in post-production (C)	7	5
	Total	32	20
Culture	Practicality	5	5
	Enhancement of Welsh agriculture	6	4
	Enhancement of Welsh tourism	5	5
	Total	16	14
TOTAL		64	47

On completion of Phase II an interactive workshop was held in North Wales, attended by around 70 key influences and related parties, to provide feedback and comment from a regional and practical perspective.

RESULTS

Table 3 shows the list of prioritised plant opportunities, the likely time to fruition and extent of perceived and actual limits to development.

The majority of the highlighted crop opportunities can be categorised as high value, low volume or high volume, low value. There is greatest potential for retaining added value locally with high value, low volume markets such as natural dyes and essential oils (e.g. Valerian, Peppermint, Woad, Madder). For relatively low value, high volume, commodity traded produce (e.g. oilseed crops) there is often little potential to add value to the local and wider rural economy.

Fibre crops appear to offer significant potential for added value processing in Wales, in part due to the expertise established at the Biocomposites Centre, Bangor. Other 'niche' crops such as echium (for healthcare), woad (as a dye) and peppermint also offer potential for adding value through the development of small-scale local or mobile processing facilities.

Table 3. Prioritised list of plant species and enterprises for further development in Wales.

Time to fruition	Few or no limits to uptake	Moderate limits to uptake	Major limits to uptake
0-3 years	Crambe (I) High Erucic Acid Rape (I) Hemp (I)	Linola (F) Flax (I/T) St Johns Wort (H) Valerian (H) Borage (H) Evening Primrose (H) Echium (H) Peppermint (E) Foxglove (P) Poppy (P)	
3-5 years		Meadowfoam (I/T) Miscanthus (Fibre) Calendula (Oils & food dye) Woad (Dye) Gold of Pleasure (H) Oats (H) Mugwort (P)	Yarrow (Dye) Madder (Dye) Native Grasses (Fibre) Bog Myrtle (N)
5-10 years		Spurge (Oils/polymer) Nettle (Fibre)	Giant Reed (Fibre) Reed Canary Grass (Fibre) Sea Buckthorn (H) Henbane (P)

I – Industrial H – Healthcare P – Pharmaceutical N-Novel
F – Food T – Textile E – Essential Oil

There are no large scale commercial seed oil crushing or refining plants located in Wales; the nearest facility is located in Liverpool. Commodity-traded oilseeds therefore offer little opportunity for Wales in competition with the rest of the UK, despite the fact that there are few obstacles to production in low-lying areas of relatively moderate and low rainfall in Wales.

On the basis of all information gathered, 5 enterprises deemed the most promising for Wales in the short and medium term were identified (Table 4).

Table 4. Most promising opportunities for non-food crops in Wales.

Time to fruition	Plants	Application
0-3 years	Hemp and/or Flax	Fibre
	Miscanthus	Fibre
3-5 years	Nettle	Fibre
	Woad	Natural Dye
	Oats	Healthcare Products

Capitalising on existing Welsh experiences and knowledge in the area of fibres, fibre crops should receive high priority for research and development in Wales. Development of a generic fibre industry could capitalise on such markets and ensure that the added value obtained from processing remains in Wales.

Oats are widely grown in Wales and developments to commercialise novel products have been undertaken. Technical barriers have to be overcome but there is significant potential for Wales to capitalise on the industry in the mid to long term (3-5 years). In the interim, small scale markets exist for oat oils and starch.

Production of woad is not currently commercialised in the UK and therefore there is an opportunity to establish a small niche industry to counter imports. The indigo produced from woad is a valuable dye and could compliment the co-development of natural fibre industries. However, woad needs further research and development to commercialise its production.

The above represent opportunities with least barriers to adoption. Future work will focus on these to optimise returns to Welsh farmers and the wider Welsh economy. A similar methodology could easily be applied to other regions in the UK.

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[^{14}C]-Glyphosate: Uptake into *Echium plantagineum* following pre-emergent application

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ABSTRACT

Echium is a member of the borage family and like borage Echium grows rapidly and competes well with weeds. The seed oil is unusual in that it contains a unique ratio of omega-3 and omega-6 fatty acids. These lipids, previously obtained from other sources, have been used for many years in health supplements. Of particular interest when considering *Echium* as a health food supplement are the appreciable amounts of gamma-linolenic acid (GLA) as well as the unusual polyunsturated fatty acid stearidonic acid. These acids occupy similar positions in the biochemical pathway of essential fatty acids. *Echium* is currently the best agricultural source of this material. The seed oil is also valued for its moisturising and anti-inflammatory action.

Health food supplements are generally grown without the use of pesticides due to the limited range of products approved for use in this sector. In addition, there are consumer concerns over any possible contamination by agrochemical products. This paper presents information on the uptake of glyphosate, a widely used and well characterised herbicide, into *Echium* following pre-emergent application to soil.

INTRODUCTION

This work was undertaken to develop and demonstrate a novel approach to pesticide metabolism studies for horticultural crops grown for the healthfood market. A key aim was to show that *Echium* could be grown in a novel pot growing system and provide information on the uptake of glyphosate by *Echium* following application to soil prior to crop emergence. Another aim was to monitor soil characteristics over a 12 month period which included the growing season of *Echium*.

MATERIALS AND METHODS

Echium plantaginuem was obtained from an accredited supplier and sown in a 230 litre pot in May 2002 in accordance with the principles of current commercial practice (Figure 1). The pot was then buried within a larger area of 4 m^2 of crop. This gave a treated crop area of 0.5 m^2 which equated to approximately 50 plants. [^{14}C]-Glyphosate was obtained from Sigma and the area in the pot was sprayed on the day of sowing at a nominal field rate of 1.44 kg/ha using a sprayer devised for applications of this sort (Figure 2). Soil cores (10 to a depth of 10 cm

c. 1 kg) were taken from inside and outside a control pot (sprayed with non-radiolabelled glyphosate as for the radiolabelled compound) planted with *Echium* in March, May, September and November (2002). Soil cores were analysed for organic carbon (dichromate digest method), pH (soil extracted into water) and microbial biomass (fumigation/extraction method).

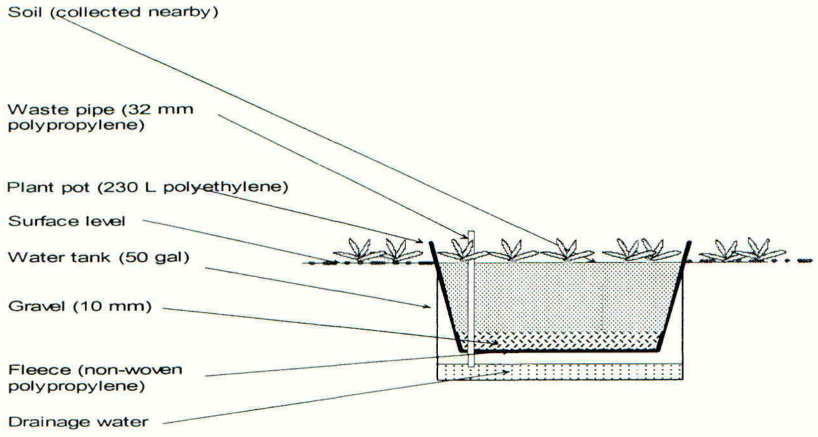

Figure 1. Novel pot used for growing *Echium*.

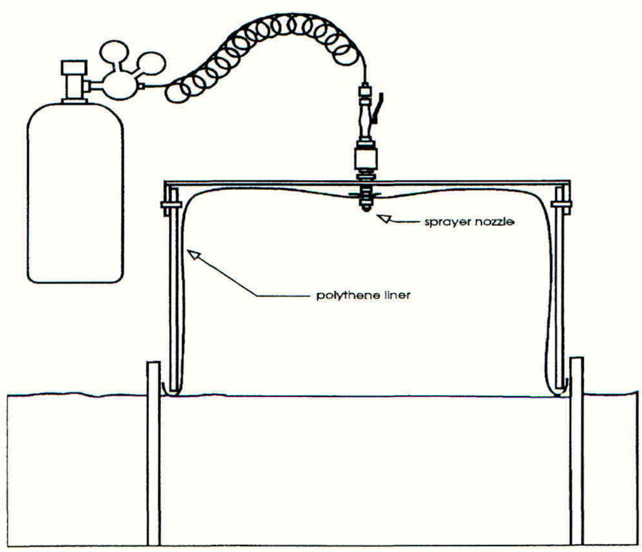

Figure 2. Spraying equipment.

Echium was harvested by cutting as close to the soil as possible approximately 110 days after sowing and was separated into seed and straw components. These were homogenised to a fine powder and aliquots (c. 0.2 g) taken for analysis. Soil was allowed to air-dry and then homogenised to a fine powder and aliquots (c. 0.2 g) taken for analysis. Radioactivity in the samples was determined after combustion in oxygen using an Automatic Sample Oxidiser (Model 307 MK2 Tri-Carb®, Packard Instruments Co. Ltd.).

RESULTS

Soil pH and microbial biomass in soil taken from inside the pot increased over the course of the growing season (May to September) whereas soil taken from outside the treated area showed no notable increase. Comparable growth of *Echium* was achieved in both the treated and non-treated areas. However, at the time of harvest (September) the microbial biomass in the treated area was approximately twice that measured in the untreated area.

Table 1. Soil parameters inside and outside the sprayed area.

Pot	Parameter	Month (2002)			
		March	May	September	November
Treated	Organic carbon (%)	1.6	1.4	1.5	1.6
(In)	pH	6.0	6.1	6.7	7.6
	Biomass (µg C/g)	173.4	194.3	303.3	298.6
Untreated	Organic carbon (%)	3.0	1.7	1.7	1.9
(Out)	pH	5.8	5.5	5.9	6.3
	Biomass (µg C/g)	28.4	185.1	142.8	212.5

The particle size distribution of the soil used in the pots was: 63µm – 2mm, 41.80%; 2µ - 63µm, 46.43% ; <2µm 11.77%.

No uptake of glyphosate was detected in *Echium* at harvest (all values were below the limit of detection) but traces of glyphosate residues were still present in soil 110 days after treatment (Table 2).

Table 2. Uptake of glyphosate at harvest.

Sample	Concentration (µg equiv./g)
Soil	1.888
Grain	BLQ
Straw	BLQ

(BLQ - Below limit of quantification (<0.02 µg equiv./g))

CONCLUSIONS

This study demonstrated the use of a new type of pot system for the conduct of pesticide metabolism studies in herbaceous crops. It also demonstrated that application of glyphosate as a pre-emergence spray to *Echium* does not result in detectable residues in seed or plant material at harvest.