An economic study of essential oil production in the UK:

A case study comparing non-UK lavender/lavandin production and peppermint/spearmint production with UK production techniques and costs.

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For the Government Industry Forum for Non- Food Crops.

ADAS R & D Contract Report Details Page

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R & D Contract Report Authentication Page

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Authentication

I declare that this work was done under my supervision according to the procedures described herein and that this report represents a true and accurate record of the results obtained.

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Remit: This study was commissioned by the DEFRA Government Industry Forum on Non- Food Uses of Crops to examine the potential for large-scale production of essential oil crops in the UK to compete on the world market and to identify requirements for future research funding to enable the fulfillment of projected returns.

Summary: There are several areas highlighted in this review that reduce the viability and sustainability of the UK essential oils industry. Most fundamentally, the aim should be to raise the yields of mint oils to at least 100 kg/ha, that of lavender oil to at least 65 kg/ha and lavandin oil to at least 150 kg/ha. The areas that require attention and support are identified:

- producers need to increase planting areas significantly: the formation of **co-operatives** is highly recommended
- **financial assistance** for co-operatives is required for establishing plantations of high quality material, for land and for distillation units
- an improved infrastructure is required by means of the development of a **British Essential Oils Producers Association** and research and development **Center(s) of Excellence**
- **research** is required to produce and/or select optimised varieties and for improved **agronomic practices**
- additional **tourist** visitor centres with an educational aspect would benefit the industry and the rural community generally
- there is an opportunity for a **UK brand** to be developed, with associated traceability and quality standards (possibly organic).

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1. Objectives

Objective 1. To compare production practices and economics for essential oils in major producing countries with practices and economics in the UK. Two oil types have been chosen because of their potential for relatively large markets and history of production in the UK: lavender and lavandin oil produced in France and mint oil (peppermint and spearmint) produced in the USA.

Objective 2. To identify production techniques and costs that limit the potential expansion of the UK industry by reducing the competitiveness of UK oils on the world market and to advise on areas where future research funding could be directed to assist this development.

1. Essential oils

2.i Definition: Essential oils are by definition the liquid products of steam distillation of plant parts. An essential oil may contain tens or hundreds of volatile and non-volatile compounds, the cause of their characteristic fragrance or flavour. Other products may be sold alongside essential oils for example concretes and absolutes (so-called oleoresins) which are the products of solvent extraction (organic solvents, supercritical CO_2), and terpeneless oils that have been fractionated from raw essential oils.

2.ii Uses: Essential oils are routinely used in fragrances, cosmetics, soaps and other household products, in foods, confectionary, pharmaceutical products and cigarettes. Although essential oils contain many different chemicals, the key flavour or fragrance may be attributable to between one and five distinguishing compounds. For this reason synthetic analogues or nature-identical compounds may threaten the continued viability of production of some essential oils. Essential oils are added to foods as flavours or flavour enhancers. Their overall contribution to the bulk (and cost) of a product is very low. For this reason, most companies that produce a food product in which the key flavour is contributed by a specific quality essential oil will seek out a consistent supply of product with a uniform profile, the price is in some cases secondary to the quality. Where an inferior essential oil blend (or even a synthetic) can be substituted without flavour impairment, price becomes more of an issue.

Many plant extracts and oils also have medicinal attributes either by ingestion, by topical application or by inhalation of the vapours. It is beyond the remit of this report to summarise their medicinal uses or efficacy. Suffice to say that a recent market report highlighted the strong growth position such products hold and are predicted to continue to hold due to the increasing consumer interest in ‘alternative’ therapies (Mintel, 2001).

2.iii Function: Essential oils and related products are so-called ‘secondary metabolites’, which means that their production does not directly correspond to the activity of primary plant processes such as respiration and photosynthesis. However they may play equally important roles in enabling plant pollination or seed dispersal, competition between plants, or protection from the environment, for example against pathogens, herbivores or excess solar radiation. As such, the maximum content of an essential oil may occur at specific developmental stages depending on where in the plant the oil is produced or for what biological purpose. There may also be variable changes in yield and composition in response to environmental stresses such as dehydration or mineral deficiencies. Our understanding of the role(s) of secondary metabolites in plants has evolved significantly in recent years.

2.iv Production: Because essential oils cannot be quantified or their composition estimated by visual assessment, their yield and composition (quality) needs to be assessed after extraction (distillation), usually by gas chromatography (GC). GC analysis separates the individual volatile compounds in the complex mixture and enables their quantitation. Many perfumers and advanced producers of quality essential oils are skilled at organoleptic assessment (the so-called ‘sniff’ test), which enables rapid screening of the similarities and differences between a number of oils or blends compared with a standard benchmark of acceptability. The human nose is far more adept than most (perhaps all) scientific instrumentation at detecting off-taints or an overall acceptable blend, the latter is what the consumer perceives, after all.

Producers of plants for essential oils encounter variability in yield and quality at all stages of production. It would not be an overstatement to say that every step throughout production will inherently have an effect on the variability of the final product. It is for this reason that continual screening of the yield and quality is paramount to ensure that excessive detrimental losses or changes do not occur. The main influences on yield and quality are: genetic composition (species, cultivar), developmental stage (harvest timing), environment (photoperiod, light intensity, nutrition, water availability, pathogen and insect stresses) management (plant density, herbicide and pesticide applications, harvest timing, post-harvest handling, extraction and oil storage). As these aspects affect the case study plants they will be mentioned where known.

2.v Research: Hand in hand with the development of essential oil industries in almost all countries has been the expansion of related research facilities, many of which have been government funded due to the initially ‘new’ or ‘niche’ nature of the crops. Later, co-operatives have developed that impose a levy on the sale of oils to fund such work. Much research has been directed towards the understanding of the biochemical processes limiting oil yield and quality, with great attention being placed on selection or manipulation of genetic material, agronomic practices, disease and pest control and extraction methods.

The scale-up from laboratory scale practices and field trials to pilot- and commercial-scale production and extraction is a requirement for industry expansion, yet is the point at which many problems arise. Optimum harvest timing of a 10 ha or 100 ha plot that blooms simultaneously and should be harvested immediately after blooming is a challenge. If one considers the handling, transport and speedy extraction that are required after harvest for a crop that deteriorates rapidly when wet or shatters if left too long whilst dry, the logistical nightmare can only be imagined. It is imperative that expansion of the industry is supported by adequate funds to permit the understanding of the impacts of different treatments so that growers can make sound judgments on when to harvest, when to re-plant, when to expand etc.

2.vi Producing Countries: Commercial production of most crops first began where the plant species was endemic, with rapid spread as new crops were introduced to traditional essential oil producing areas, Grasse in France for example, or as countries deliberately invested in diversification programmes. There is substantial oil production in developing countries as a result of diverse flora, a history of use of oils and cheap labour for systems that are not easily mechanised. Four countries dominate the international scene: Brazil, Indonesia, China and India, due to their large population and internal consumption of essential oils, their investment in scientific and technical training, their strong economic position for a limited range of products and well developed export businesses.

In industrialised countries, the pattern of establishment of essential oil industries has followed similar trends, with an increase in yield obtained through selection of improved varieties, establishment of intensive methods and simplification of production systems. In this way France has maintained a dominant position for lavandin production, as has the USA for peppermint, although developing countries increasingly pose more of a threat, for example Eastern block countries for lavender production. India and China are major producers of many essential oils. New producer countries have arisen with mechanised production systems for a variety of products supported by a sound research infrastructure (Australia for example). However, world impact has not on the whole been significant. The international situation is complex, with success depending on optimal climate, research, investment and innovation, low production costs, established relationships with the industry and state politics (Hay and Waterman, 1993).

2.vii Markets: For the large scale essential oil producer, there are several methods of entering the essential oils industry: the most profitable is generally by sale of a proven quality oil directly to end users (generally food or pharmaceutical companies), less profitable is by sale at the market price to traders who may analyse, purify, blend and stock pile oils for sale to the end users. Brokers may also facilitate sale of oils. Some companies set rigid specifications for oil blends that the broker may meet – a complex and highly challenging job that is beyond the scope of most producers. The challenge lies in meeting the requirements of the end users in terms of volume, composition, price and availability. Small-scale producers may sell to wholesalers or retailers, involving some degree of tourism in their enterprise; this may yield higher returns but usually with a more limited market. The small-scale producer will find the structure of the essential oils industry difficult to penetrate, relying as it does on the need for consistent products, a good reputation of long standing and proof of quality. The hesitancy with which the industry greets new products, or traditional products from new producers or producer countries is renowned. A new product must satisfy a manufacturers desire for a high and reliable quality oil and a reasonable cost, producers must have a capability to expand. The larger producer or co-operative will be challenged to reproduce several layers of the industry (extraction, blending, analysis, marketing) in order to make serious returns from it. In either case, a serious level of investment in marketing is advised.

Of the total world production of essential oils, 15 products constitute 90% of the total, including lavandin, *Mentha arvensis* and *Mentha piperita* (peppermint) (Hay and Waterman, 1993). 65% of total world production comes from perennial woody plants (trees and bushes), the remainder from cultivated herbaceous species, relatively little production is from wild harvested plants (1.4%). In 1993 it was predicted that demand for peppermint and other mints (food usage) would show a steady increase and that demand for lavender (perfumery) would be relatively stable (Hay and Waterman, 1993). In the main, this is what has occurred, with growth for mint products around 5%. Although trade figures show the volumes and values imported and exported, some practices in this industry confuse this issue. Many countries, among them the UK, import oils and blend or reprocess them prior to re-export.

3. Mint oil production

3.i Species, world production and uses: Peppermint (*Mentha piperita* L.) is the world's third most important flavour. World production is 4,000 tonnes/year, 90% of this is produced in the US and 50-60% of US production is exported. World production of spearmint (*Mentha spicata* L., native spearmint and *Mentha cardiaca* L. Scotch spearmint) is 1,500 tonnes/year. Peppermint is grown for its menthol content, an alcohol that contributes the 'cooling' sensation; spearmint is grown for carvone, a ketone (see Table 1). Both are used in the food industry for confectionary (chewing gum), toothpastes and for flavouring menthol cigarettes. Mint oils are filtered after distillation and either further processed to extract menthol or re-distilled and rectified to the requirements of the user. There are a variety of mint products on the market, the purchasers set the requirements largely on the basis of menthol content; prices vary depending on the level of production/year and the quantity in stock. Significant levels of mint production occurs in the US, Argentina, Australia, Brazil, Bulgaria, China, Egypt, France, Hungary, Japan, Korea, Morocco, New Zealand, Paraguay, Romania, Taiwan, Yugoslavia, the UK and the USSR.

3.ii Composition: There are 200 components in mint oil, 20 are critical for chewing gum flavours. The main components and characteristics are highlighted in Table 1. In spearmint there are 100 components, with 10 being characteristic for taste and smell.

3.iii Menthol: *Mentha arvensis* (so-called Japanese mint) is grown in tropical climates such as India and China for extraction of menthol by freezing and centrifugation. De-mentholised oil is sold for extending peppermint oil. Menthol by itself is marketed on the basis of crystal size and source. India produces *Mentha arvensis* on 2-300,000 ha, the 2000 crop yielding 16-17,000 tonnes of oil. Although this has a relatively low menthol content (65-68% L-menthol), it still yields 11,500 tonnes of natural menthol, representing 60% of the world production. The abundant natural crop leads to prices of less than £7/kg, with which manufacturers of synthetic menthol cannot compete. China has gradually been reducing production of menthol and mint oils. 60% of Chinese menthol used in the tobacco industry is actually Indian; the Chinese buy in crude mint oil and crude menthol powder from India, recrystallise it with Chinese peppermint oil and sell menthol and mint oil at a premium.

Table 1. The composition and characteristics of spearmint and peppermint oils.

Constituent	**Peppermint (*Mentha piperita*)**	**Spearmint (*Mentha spicata*).**
(-)-menthol	38.7% or more	<2.0%
α-pinene	1.4%	*
β-pinene	1.6%	*
Limonene	2.6%	2-25%

1,8-cineole (and β-phellandrene)	7.9%	<2.5%
ethyl amylcarbinol	*	
Menthone	24.1%	<2.5%
Isomenthone	3.3%	<1.0%
Menthofuran	2.4%	
menthyl acetate	*	<1.0%
Piperitone	*	
Neomenthol	3.1%	
Caryophyllene	2.5%	
Carvone		57-68%
Linalool		*
dihydro carvone		*
dihydrocarveol acetate		*
Pulegone		<0.5%
Optical rotation	-18° to -33°	US: -45° to -60° Chinese: -50° to -62°
Refractive index	1.460 - 1.466	1.484 - 1.491
Density	0.892 - 0.910	US: 0.917-0.934 Chinese: 0.935-0.952
oil yield (% fresh weight)	**0.3-0.7%**	**0.3%**

* means present but not quantified.

3.iv Synthetic menthol is sold on the world market in relatively large quantities, generated from thymol, citronellal, menthone and β-pinene by Haarmen and Reimer in Germany (2,200 tonnes) and by Takasago in Japan (1,500 tonnes). Synthetic menthol could represent a real threat to some parts of the industry since it is a more consistent supply compared with menthol from natural sources, however in recent times the price has been greater than that of natural menthol. German synthetic menthol is less affected by price swings due to long-term contracts and demand for new products (Mazzaro, 2000).

3.v Agronomy of mint production: Peppermint is a perennial plant with square stems, bearing oil glands on the under sides of leaves. Mint blooms profusely but is sterile. Peppermint is grown for 3-4 years in a rotation with other field crops on many soil types (pH 6-7.5). Peppermint is initially grown in rows (year 1), and subsequently as a meadow crop. In some areas there is potential for two harvests/year, however this may yield excess oil that then reduces the price/kg. By contrast, *Mentha arvensis* is harvested three to four times per year. Irrigation is required for optimum yields of oil, with applications of fertilisers, herbicides and pesticides required for good crop development. There are significant disease problems in mint, especially Verticillium wilt (*Verticillium alboatrum*), a fungal disease which causes apical twisting and stunting, chlorosis, wilting and premature death, and rust (*Puccinia menthae* Pers). Verticillium wilt is spread by infected stock, debris, wind and water borne soil, contaminated equipment, machinery and field workers.

Mint is a day-length sensitive plant, requiring long days (> 16 hr) for optimum oil production. In addition, increased light intensity increases biomass yield. Increased production temperatures affect flowering time and increase the number of oil glands (small structures on the underside of leaves that bear the essential oil), but do not affect oil yield (%). The essential oil from mint is extracted from the leaves. Because leaves photosynthesise there is a daily and almost hourly fluctuation in the content and composition of oil, especially in young leaves. In mint, there may be a rapid interchange between the levels of menthol and menthone, high levels of the latter being undesirable. Thus the yield of oil may be higher, and the quality different, in the morning compared with if harvested later in the day. Also, the oil may alter after harvesting during wilting.

Mint is harvested much like a hay crop: it is cut, allowed to partially dry in the field (35% moisture), raked into a windrow and gathered for distillation, often in truck mounted stills within the field. In the US, mint is harvested in mid-June until late September. The hay is windrowed into 2 m windrows and left to dry in the field for 24-36 h (this can be significantly longer in other countries). Wilting is required to reduce the moisture content, since high moisture reduces the extractable oil yield. The hay is picked up by a mechanical mint chopper and placed into mint tubs that hold 0.4 ha or 9.9 m^3 of hay. Determining the optimum harvest time is difficult since a visual observation (for example at a certain stage in flowering) may not truly reflect the internal oil composition (45% menthol content being critical). Due to the nature of the harvesting process, and the material itself, mint is particularly susceptible to loss of oil yield due to unfavourable weather

3.vi Distillation: The important feature of mint production is distillation, which requires specialised equipment. This requires a large investment by the producer, and is a disincentive for those considering mint as a short-term operation, unless access to nearby stills is possible. The distillation unit for mint requires a high pressure boiler for generation of sufficient steam, a tub, a condensor and a receiver for the oil. The unit needs to be as inexpensive as possible and to have a low labour requirement. Second-hand stills are sometimes available. In most cases, two tubs are linked to one condensor to increase the speed of operations. An ample supply of steam is the limiting element in extraction, since the process itself once begun can be quite rapid. When stills are erected, it is important to consider the potential for expansion of the enterprise. Energy savings can be generated by re-using the water from the condensor which will be hot, to recharge the boiler. Distillation is done for 20-25 min until ‘breakthrough’ and for a further 40-50 min. of ‘cooking time’. The distillate temperature is 105-110°F, and this is critical. The time required to exhaust a ‘charge’ (a load of peppermint hay) depends on the quantity of steam admitted and the condition of the herb - dry herb distils most rapidly. The costs of growing, harvesting and distilling a crop fluctuates with the price of planting stock, the wage scale and other local conditions.

3.vii Oil yield: The yield of oil from mint varies greatly with the season, the cultural conditions and the geographical location. Australian research suggests that the maximum yield of oil occurs when terminal flowering is complete and the lateral branches are in full bloom, however in the UK the harvest commences before flowering to minimise the content of menthofuran. The oil yield is around 1.4% of dry matter. If the plant density is too great, the yield of oil is reduced due to the limitation for full leaf expansion, or if many of the lower leaves have fallen off due to continual dampness as a result of thick stands. Clear sunny weather during the few weeks immediately preceding harvest causes the herb to develop more oil than it will in cloudy wet weather. Heavy rains at harvest time wash off considerable amounts of oil, and rough and excessive handling when the herb has been permitted to get too dry also causes losses due to shattering of leaves. This latter case has been identified as one of the main problems reducing oil yield in Australia (Clark and Read, 2000). Mint oil when used as a flavour is generally tri-rectified (re-distilled); the rectified or fractionated oil is almost colourless and much less harsh than the raw oil.

4. US peppermint production: Peppermint (Black Mitcham) and spearmint were introduced to the US from the UK in the early 1800s and a significant industry rapidly developed. Annual production of peppermint is from 62,500 ha, with £140M in annual sales (Mint Industry Research Council). In the US, mint oil is identified by the growing region it comes from: Willamette Valley Peppermint comes from Western Oregon, Madras Peppermint comes from central Oregon and Yakima Valley Peppermint comes from Washington. Spearmint is grown in the mid-West and Far-West.

The mint industry in the US is well supported: the **Mint Industry Research Council** (MIRC) exists as a non-profit association. The Council's mission is to fund, direct and co-ordinate the scientific research and programmes needed to sustain and enhance the productivity of high quality mint. The MIRC's membership, which generates its support, includes over 600 mint farmers and their respective state organizations, mint oil buyers, and major manufacturers who make consumer products that utilize mint oil for flavoring. The grower levy paid to MIRC is £0.13/kg of oil, 75% of which goes to MIRC and the remainder funds local initiatives. A large proportion (50%) of the budget (£275,000 per annum) in recent times has been directed towards developing new varieties and propagation studies, yet the variety 'Black Mitcham' still predominates and there have been no releases of new breeding material in the US in recent times. A further 25% of MIRC income is spent on pest management and 25% on integrated pest management. Despite this research and recent bumper crops due to seasonal conditions, oil yields have been dropping in recent years for unknown reasons.

4.i Cultural Practices: US producers plant state-certified, disease free, vegetatively propagated mint plants or root-stock in rows 50-75 cm apart with starts 10-18 cm apart. The MIRC produces *in vitro* plantlets that are heat treated at 34-36°C for 6 days, surface sterilized, followed by removal of the apical meristem for multiplication. From this a node cutting develops that is used to produce open rooted plants that are sold to the producer at £0.35/plant and planted at a rate of 16,800-24,000/ha. This method of production is called 'meristem mint'. Another product, 'nodal mint' is also used. Despite this, gross margins for mint production from the US do not cost plant material at an appropriate rate, suggesting that stolons multiplied by the producer are used in most cases.

In Oregon, a number of insecticides are applied to mint, predominantly acephate (Orphene), chlorpyrifos (Lorsban), fonofos (Dyfonate) and propargite (Comite). Pesticide residues are of increasing interest to the essential oils industry as detection techniques become more sensitive, thus the MIRC's funding of IPM research. Some biological control mechanisms are used in the US including predator mites to control spider mites – however total areas protected in this way are minimal. Rust is controlled by propiconazole (Tilt) and myclobutanil (Rally); sulphur is used to control mildew. Oxamyl (Vydate) is used to control nematodes. A suite of herbicides may be applied, with bromoxynil (Buctril), diuron (Karmex), oxyfluorfen (Goal), paraquat (Gramoxone Extra) and terbacil (Sinbar) predominating. Irrigation in the US is generally accomplished by rolling aluminium lines 400 m long (110 m long x 10 cm diameter pipes); one unit can irrigate 4 ha in 6 shifts at 3 hours/shift. The cost of these units is £5,000 each. The costs of distillation are £4.60/kg, not including swathing. The cost of new stills is variable, in the region of £28,000 each for a Lewis McKellup/Hacher model. Most mint producers distil oil on their own farms using equipment owned singly or by co-operatives.

4ii Marketing: Mint producers market via intermediary buyers who buy on the basis of pre-harvest contracts and post-harvest purchases. Todd, Callison, Leman and Brown are the four main dealers. Dealers provide services such as containers, transportation, crop advice, free storage facilities, maintenance of laboratories for analysis, grading, bulking and blending oils for users. The production and marketing of mint oils is a complex process, requiring close supervision at all stages. Each drum of oil is analysed for colour, taste, odour, composition, contaminants to USDA standards. Mint oils from different regions of the US may command different prices, for example oil from the mid-West (Indiana, Michigan and Wisconsin) was higher priced than that from the Far-West (Washington and Oregon). Some manufacturers now pay premiums for oil with the desired characteristics regardless of source.

4.iii Price: There is a fairly continual inelastic demand for flavours, related to the demand for the final product, because manufacturers are reluctant to make changes to product formulations. Price may vary enormously (Table 2). For lower quality oils, price may be more important since there are alternatives such as menthol or synthetics. Generally natural oils command a higher price; increasingly synthetics are being generated with improved quality, and these are finding increased use in new product lines.

The price of peppermint oil reflects the size of the current crop, the size of current stocks and the demand for oils. All major users of oils generally hold stocks which enables them to buy when prices are reduced. Demand variables include demand for mint-flavoured products, the price of substitute flavours and synthetics, and the development of new uses for mint oils. The price of flavours is almost insignificant in terms of the total product since the flavour compounds may only represent 1/300th of the total product by weight.

The US consumes 40-50% of the world's peppermint oil, and 50% of the spearmint oil. The UK is the single largest market for US peppermint and spearmint oils, however the UK re-exports 15-20% of its imports. Although demand for mint oils remains strong, with 4% global growth, the mint industry in the US has been oversupplied in recent years due to bumper crops both in the US and Canada. This has reduced prices considerably and led to brokers stockpiling oils. It has been recommended that US farmers reduce production of mint to enable the industry to recover from oversupply, a large crop can disrupt the market for several years (Mazzaro, 2000). The peppermint crop in 1999 produced 7.4M tonnes, yet was the smallest crop in area since 1993.

Table 2. Trade prices for mint products (Sources: Fuerst Day Lawson and John Kellys, December 2001):

Product	Source	£/kg
Mentha arvensis	Indian	4.80
	Chinese	5.50
Mentha piperita	USA Yakima	17.40
	Indian Blend	10.40
Menthol	Indian	6.30
	Chinese	7
Dementholised peppermint oil		2.80-3.50
Synthetic menthol	Haarmen and Reimer	9-14
Scotch spearmint	USA	17.40
- 60% carvone	Chinese	9.70
- 80% carvone	Chinese	13.20
Native spearmint	USA	13.20-17.40

US mint oil dealers have shown a willingness to enter into long-term contracts with growers, a fact that greatly affects the economics and planting decisions. In the past, mint growers were paid £23/kg within 3 year contracts, now there are few contracts. For peppermint, a weak market has led to reduced cropping areas. Returns have been as low as £12.25/kg, with £16.70-18.0/kg being required to break even at 65 kg/ha.

4.iv Spearmint production: US Scotch spearmint undergoes severe competition from foreign imports from Canada, which supplies one third of the US demand, and China which exports 180 tonnes pa at prices half that of US grown spearmint. Native spearmint does not face the same competition from imports. In 1998, Scotch spearmint sold for £18.40/kg, with a yield of 100 kg/ha over two harvests; Native spearmint sold for £15.30/kg with a yield of 83 kg/ha. Poor weather in India in 2000 caused losses of 15-20% in the spearmint crop, and production in China has been reducing in recent years to 200-300 tonnes pa.

4.v Production economics: Mint production costs are variable and have risen in recent times in some areas, making mint only marginally profitable. Willamette Valley production costs in 1999 were

£1623/ha; in Eastern Oregon they were £1360/ha and in South Central Oregon they were £1400/ha. A gross margin based on figures from several sources is presented in Table 3. The data for this table comes from several sources and is an 'average' gross margin based on production figures for several states. It should be noted that planting material has been costed as per other gross margins obtained from the USA, using stolons perhaps multiplied up by each producer. Other information obtained during the preparation of this report suggests that planting material costs £0.35/plant, i.e. almost £7,000/ha. This would alter the gross margin to reflect a loss of over £3000/500 ha over 4 years.

Table 3. Gross margin for mint production in the USA. Assumptions: 500 ha under production, planting density (stolons) 20,000/ha, remove and replace 125 ha/year, average yield 75 kg/ha, average sale price £17.40/kg oil.

Mint production in the USA		
Income		
Average 75kg/ha x £17.40/kg	**£652,500.00** £/500 ha	**£1,305.00** £/ha
Fixed Costs (interest at 8%)	**£/ha Year 1**	**£/ha Years 2-4**
Land (£/ha) (£348K @US$5000/ha)	£233.00	£233.00
Site preparation (cultivation in prep for planting)	£6.26	£1.57
Taxes	£9.74	£9.74
Tractor (x 2, total £80K, 10 years)	£23.84	£23.84
General machinery (plough, spreader etc.£92K, 15 years)	£21.57	£21.57
Distillation equipment (8 units, £286K, 25 years)	£53.78	£53.78
Specialised equipment (tubs, digger, planter; £195K,all 25 years)	£36.66	£36.66
Irrigation equipment (£68K, 20 years)	£13.78	£13.78
Management	£55.65	£90.44
Total fixed costs	**£454.28/ha**	**£484.37/ha**
Cumulative costs (after 4 years)	£1,907.39/ha	
Variable costs	**£/ha Year 1**	**£/ha Years 2-4**
Planting material (stolons)	£69.57	£0.00
Planting (labour, fuel, wear and tear)	£10.50	£3.00
Fertiliser (280 kg/ha N, 100 kg/ha P, 125 kg/ha K)	£140.90	£140.90
Pesticides (Gramoxone, Tilt, Vydate, S, Dyfonate)	£80.00	£80.00
Labour - production (sprays, spreading etc.)	£24.00	£24.00
Crop insurance	£25.04	£25.04
Electricity (general and irrigation pumps)	£13.91	£13.91
Fuel, production, harvest @£0.20/L)	£23.65	£23.65
Harvest labour	£17.39	£17.39
Distillation fuel	£70.96	£70.96
Distillation labour	£28.00	£28.00
MIRC levy (£0.13/kg)	£9.75	£9.75
Residue disposal (spreading)	£4.00	£4.00
Repairs/maintenance (5% of $720K)	£80.00	£80.00
Interest	£17.61	£15.32
Total variable costs	**£615.29/ha**	**£535.93/ha**
Total costs (fixed and variable)	**£1,069.57**	**£1,020.30**
Cumulative total costs (after 4 years)	£4,130.46/ha	
Gross margin (incl fixed and variable costs) (£/ha/year)	**£235.43/ha**	**£284.70/ha**
Cumulative gross profit (after 4 years)		£1,089.54/ha
Total gross profit after 4 years (/500 ha)		**£544,772.35 /500ha** (=US$0.78M /500ha)

The yield of oil and the price per kg will vary due to the reasons highlighted in sections 2 and 3. With the level of total costs calculated in Table 3, a break-even yield of oil that sells at £17.40/kg is 58 kg/ha; a break even price at 75 kg/ha is £13.60. To enable a true comparison of the returns from other crops, costs other than transplanting, fertilizer, pesticides, harvesting and distillation costs would not be included. If these are removed from the table and distillation expenses of £4.80/kg of oil are included (which have been quoted by US sources) the gross margin £/ha is £530.41 in the first year and £614.46 thereafter (£2,373.79/ha after 4 years).

4.vi Mint production in Australia: In Australia there is a relatively substantial mint industry in southern regions: Victoria (100 tonnes of oil) and Tasmania (15 tonnes) (Clark and Read, 2000). There has been much recent research to identify the reasons for comparatively poor oil yields. In Victoria, yields were less than 40 kg/ha on average and in Tasmania ranged from 32-60 kg/ha, with some producers obtaining 80-90 kg/ha. The figures quoted for the US (110 kg/ha) are greater than those cited by other sources (60-86 kg/ha), so perhaps the Australians are unduly concerned.

In Australia, mint fields are established from dormant runners or stolons (also described as rhizomes in the literature) that are dug from existing fields. Stolons are planted at the rate of 10 viable stolons/m^2 (viable = at least 1 node on each piece). Stolons can be treated by radiation to reduce infection, however in the UK and Australia many growers re-plant stolons rapidly after lifting to reduce dessication. Obtaining certified disease free stock could be a better alternative. Many of the problems in Australia are caused by producers being unclear of crop requirements, and transposing US practices to Australian conditions without modification. Disease, nutritional and irrigation problems have been identified. It has been recommended that nutritional analysis of soil nutrients be carried out before and throughout the season, and nitrogen fertiliser added as appropriate to maintain a N level of 280 kg/ha, which yields maximum biomass (Mitchell and Farris, 1996). Producers either distil their own oil using owned or rented mobile distillation units or transport wilted hay to an existing essential oil distillation within 30 km. In general, a minimum area of 5 ha of production is recommended.

Almost 30% of peppermint oil produced by the crop is lost due to

- inefficient herb collection (losses of leaf upon collection after drying)
- damage to the mown herb during subsequent processes
- problems mowing and collecting herb from unevenly growing crops
- matching the mowing and collection rate and regulating crop moisture
- management of harvest timing
- mechanical problems with old vats
- inadequate control and monitoring of condensor temperatures
- no detection of distillate concentration in the separator bypass or vat yields
- possibly incomplete exhaustion of vats

Clark and Read (2000) highlighted that irrigation effectiveness was critical for oil yield (32 mm water/week at full canopy), and that poor weather during harvest was particularly damaging. An increase in leaf area led to an increase in the rate of oil flow during distillation (vat yield/distillation time) which increased oil yield/ha. Thus factors that increase leaf area and increase leaf:stem ratio are critical for improving oil yield/ha.

Oil quality is determined by the average night temperature, the maximum day-time temperature and the composition of the canopy in terms of mature and immature leaves. Three analyses are recommended at two weekly intervals up to harvest to determine optimum harvest timing. It is rare for a crop to be harvested too early.

During distillation, savings of up to 20-25% in energy costs can be obtained by using high steam flows up to ‘breakthrough’ and gradually reducing the rate of flow thereafter. It is recommended that the cutoff for extraction be at a predetermined rate of minimum oil delivery per 5 minutes and not be based on duration of extraction. UK producers indicated that this method is used here also.

5. Mint production in the UK

5.i Production and producers: Peppermint and spearmint have been grown for essential oil production in the UK for longer than in the USA. ‘Black Mitcham’, the variety historically and largely still grown for peppermint in the UK and USA was developed near Tunbridge Wells. Total peppermint production in the UK in 2001 is approximately 170 ha; spearmint is 95 ha. Of the total production area, 65% of peppermint oil and 100% of spearmint oil is held by a co-operative supported by **Botanix Ltd**., previously known as English Hop Products. The mint crop Botanix monitors in the UK is relatively young, coming up to 5 years, with biomass and yield/ha still increasing. Yields are between 60-80 kg/ha. Botanix acts as the marketing agent for the producers. In addition, Botanix selects suitable plant genotypes, sources plant material at reduced rates (17% of market rate), advises on agronomy, distils and analyses oil throughout the season to determine optimum harvest time, dries and filters the distilled oil, stores the oil under inert gas, and when a buyer has been identified and the required specifications are identified, Botanix blends and sells the oil. Producers expect to be paid in return within a time frame of 15-18 months for a particular crop, less the price of the services rendered by Botanix. There are no guarantees given to producers regarding sale or price. Botanix is a relatively large producer and trader (10 tonnes of peppermint oil), thus they are able to negotiate directly with end users to obtain better than average trade prices for their producers.

Botanix have in recent times taken on board many related research requirements themselves, sourcing, developing and selecting optimum planting material, and developing optimum harvesting and distillation equipment. At their central extraction facility in Paddock Wood, Kent, Botanix have equipment to rectify and fractionate oils, and to use new methods of extraction such as supercritical CO_2 for example, to produce ‘new’ products. The research by Botanix has led to the release of new varieties of mint (still related to ‘Mitcham’) that have 30% more oil, more resistance to rust (a big problem in the UK) and a crop that matures 2 weeks earlier. In the UK, there is little problem with Verticillium wilt (*Verticillium dahliae* Kleb), unlike in the US. It would seem that Botanix Ltd., incorporating as it does a co-operative of producers in several growing regions, a centralized research and development activity, a range of products and qualities and a world-wide reputation for quality has achieved what other groups have endeavoured to emulate. This type of system is also in operation in Australia and the US for successful essential oil production.

5.ii Cultural practices: Mint is generally planted as transplants, obtained from several propagators. They are planted after application of a pre-plant herbicide (Treflan), followed by Gramoxone if required. Folicur is sprayed to control rust (*Puccinia menthae* Pers), however the aim is to nip such outbreaks in the bud and reduce fungicide use. The carry over of such pesticides into mint oil has been determined to be negligible, even non-existent at the rates and timings used. Mint rust can reduce oil yield by up to 50% and if left untreated will wipe out a mint crop within four years. Although the climate in the UK could be limiting to maximum mint oil production, the hours of sunlight per day are recorded, and have been shown to correlate well with the inversion of menthone to menthol (desirable). Further research by Botanix Ltd. will produce predictive models for producers on harvest timing to maximise menthol content based on the sunshine periods. Other producer groups are producing smaller quantities of peppermint, for example Norfolk Essential Oils in Wisbech (approx 3 ha) and PhytoBotanica (5 ha) near Liverpool, the latter being produced organically. Most of the producers here in the UK sell directly to end users, producing as they do a high quality product backed up by gas chromatographic analysis.

5.iii Market trends: There are some interesting market trends with regard to final product formulation, with preferred taste varying between countries. In the UK, a harsher, stronger mint confection is preferred in the North, supplied by dementholised *M. arvensis* oil, and a sweeter, smoother taste is preferred in the south, which is sourced from *M. piperita* oil. There is a small market for organic produce, which is considered to be an area of growth as existing producers are converting land to certified organic.

5.iv Production economics: The gross margin presented herein is an average estimate of the costs of production based on past and present cultural practices. This includes contracting out planting and land preparation, and buying a still. Some producers share stills or contract out distillation at rates close to £3.20-3.80/kg. A double harvest is generally done from year 2 onwards, with production for 4 years. Gross margins supplied by Botanix estimate total oil yield/ha over 4 years to be 322.4 kg/ha which is high; the 4th year especially had very high predicted biomass which has not been observed in Australia in the 4th year, instead a decline after year 3 was noted.

Table 4. Gross margin for mint production in the UK. Assumptions: 40 ha under mint production in a total mixed farming enterprise of 350 ha, planting density 20,000/ha, planting material: purchased transplants for 4 ha of production grown for 1 year and multiplied up to 40 ha and contract planted as stolons; remove and replace 10 ha/year, average yield 75 kg/ha, average sale price £17.40/kg oil. Distillation is contracted out nearby.

Mint production in the UK (40 ha on 350 ha property).		
Income		
Average 75kg/ha x £17.40/kg	**£52,200.00 /40 ha**	**£1,305.00 /ha**
Fixed Costs (interest at 6%)	**£/ha Year 1**	**£/ha Years 2-4**
Land (£/ha) (rent equivalent at £250/ha)	£250.00	£250.00
Site preparation (cultivation in prep for planting)	£25.00	£6.25
Tractor (x 2, total £50K, 5 years)	£33.80	£33.80
General machinery (trailers, spreader etc.£25K, 7 years)	£12.79	£12.79
Specialised equipment (planter, custom made digger/chopper; £25K,all 10 years)	£85.00	£85.00
Irrigation equipment (rain gun, hoses, pump, ring mains £70K, 20 years)	£152.25	£152.25
Management (£25K pro rata for area)	£71.43	£71.43
Total fixed costs	**£630.27/ha**	**£611.52/ha**
Cumulative costs (after 4 years)	£2,464.83/ha	
Variable costs	**£/ha Year 1**	**£/ha Years 2-4**
Planting material (4 ha of transplants purchased and multiplied up to 40 ha)	£552.00	£0.00
Planting (labour, fuel, wear and tear)	£42.00	£10.50
Fertiliser (280 kg/ha N, 100 kg/ha P, 125 kg/ha K)	£140.90	£140.90
Pesticides (Gramoxone, Tilt, Vydate, S, Dyfonate)	£80.00	£80.00
Labour - production (sprays, spreading etc.)	£42.00	£42.00
Crop insurance	£25.04	£25.04
Electricity (general and irrigation pumps)	£13.91	£13.91
Fuel, production, contract harvest, transport of hay @£0.20/L)	£45.00	£45.00
Harvest labour	£42.00	£42.00
Distillation costs @ £3.50/kg oil	£262.50	£262.50
Residue disposal (spreading)	£4.00	£4.00
Repairs/maintenance	£10.00	£10.00
Interest	£66.17	£15.58
Total variable costs	**£1,325.52/ha**	**£691.43/ha**
Total costs (fixed and variable)	**£1,955.79/ha**	**£1,302.95/ha**
Cumulative total costs (after 4 years)	£5864.66/ha	
Gross margin (incl fixed and variable costs) £/ha/year	**-£650.79/ha**	**£2.05/ha**
Cumulative gross profits (after 4 years) £/ha		-£644.66/ha
Total gross profits after 4 years (/40 ha)		-£25,786.21 /40ha

The yield of oil and the price per kg will vary due to the reasons highlighted in sections 2 and 3. With the level of total costs calculated in Table 4, it is apparent that the break-even yield and price of oil in years 2-4 are those used in the calculations already. Thus to improve returns, substantially more oil yield is required /ha (through growth of improved varieties, irrigation and perhaps double harvests), and/or improved prices are required via keen marketing practices enabling sale into niche, quality markets. To enable a true comparison with the returns from other crops, items other than transplanting, fertiliser, pesticide, harvesting and distillation costs would not be included. If these are removed from the table, the gross margin (£/ha) is £192.60 in the first year and £794.85 thereafter, producing cumulative profits of £2,577.15/ha, or £103, 086.00/40 ha after 4 years. This is compared with £2,373.79/ha after 4 years production in the US.

5.v Comparison of US and UK production costs: When only costs associated with transplanting, fertiliser, pesticide, harvesting and distillation are included, cumulative **profits** for mint production in the UK after 4 years (£2,577.15/ha) are around £200/ha greater than those in the US in the same time (£2,373.79/ha) for similar costs. This is despite the relatively higher cost of transplants in the UK. Producers accessing planting material through co-operatives such as Botanix are able to obtain substantial discounts due to the buying power of the group. There are other ways costs for planting material could be reduced, by purchasing lesser quantities and by multiplying them up over more than 1 year, for example. It is also to be hoped that if more producers enter the mint industry, levy-assisted breeding programs and pressure on propagators will reduce the costs further, at the same time as improving plant quality. The major ways of improving returns in the UK despite costs displayed in Table 4 are to improve yields via good agronomic practices and to improve prices via wise marketing.

Production economics in the USA appear to be very different from the UK. Data from the USA suggests that an average unit would be 500ha, whereas in the UK it would be more likely to be 40ha as part of a rotation on, for example, a 350ha farm. The profits (or rather losses) for mint production in the UK when considering all costs in Table 4 were, frankly, dismal. This is due largely to the fact that in the UK, land is the limiting resource and thus relatively more expensive, and also UK producers tend to keep equipment for significantly shorter periods of time (10 years compared with 25 in some cases). In the USA, machinery costs are traditionally less than the UK. Here, the high cost of land means that maximum output is demanded, so machinery tends to be of a higher specification and is kept for a shorter period of time. In addition, the machinery and irrigation equipment is costed over a larger area in the USA, enabling the unit costs to be lower. Irrigation costs/ha in the USA thus appeared very low compared with the UK. Labour costs in the USA appeared to be lower than the UK, perhaps due to work rates and machine size, but it was not clear from the information gathered.

UK producers could reduce expenditure by using non-specialised equipment in other enterprises on the farm and by sharing distillation units with other producers. Costs for pesticide chemicals may decrease proportionally in the future, with costs for IPM increasing concomitantly as the reduction in acceptable pesticide residue limits progresses.

5.vi UK Trade in peppermint: UK trade in peppermint oil and 'other mint oils' is presented in Appendix 1, showing imports and exports (tones, £/tonne and £/kg) from the main EC and non-EC countries between 1997 and 2001 (the latter representing incomplete data). Imports of peppermint have generally been 1,200-1,500 tonnes pa, mostly from the USA, India and China. In 1999 bumper crops flooded the market, depressed the price (Fig. 2A) and boosted import figures (Fig. 1A). Approximately 25-33% of all imports are subsequently re-exported (depending on exports of UK- produced oils which are not identified in trade figures), with the large import in 1999 continuing to enhance exports to EC countries (France and Germany predominantly, Appendix 1) in 2000 (Fig. 1A). The imported oil may be rectified and blended with other oils prior to re-export, thus maintaining price/kg which fluctuates between $8-14/kg for both imports and exports (Fig. 2). In 2000 and 2001, export to the EC (France, Germany and Italy) has been greater and at higher average prices compared with export to non-EC countries. In 1997, exports to Switzerland predominated amongst non-EC countries, Brazil bought significant quantities in 1999 but not subsequently and in 2000 India predominated. Italy has also purchased increasing amounts of peppermint oil from the UK in recent years (Appendix 1).

Fig 1A. Imports of peppermint to the UK (tonnes) from EC and non-EC countries in the last 5 years (raw data in Appendix 1).

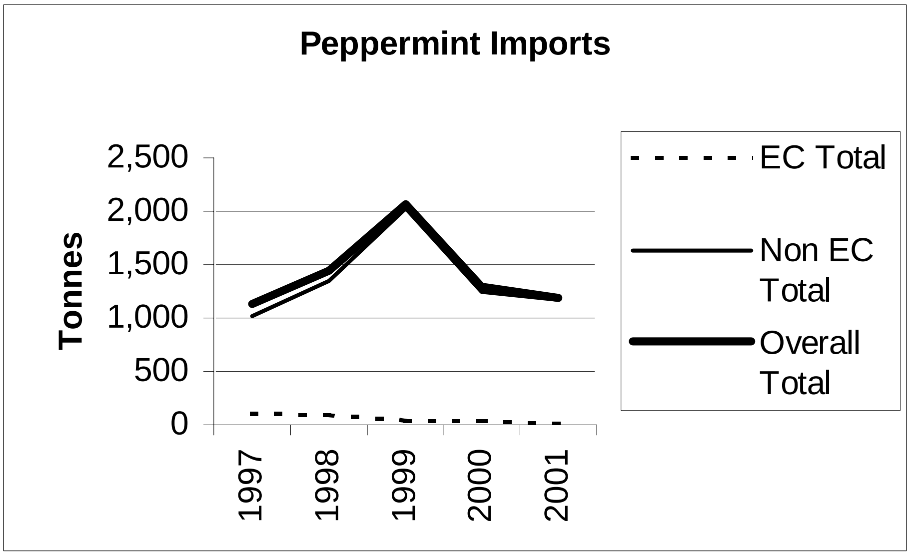


Fig 1B. Exports of peppermint from the UK (tonnes) to EC and non-EC countries in the last 5 years (raw data in Appendix 1).

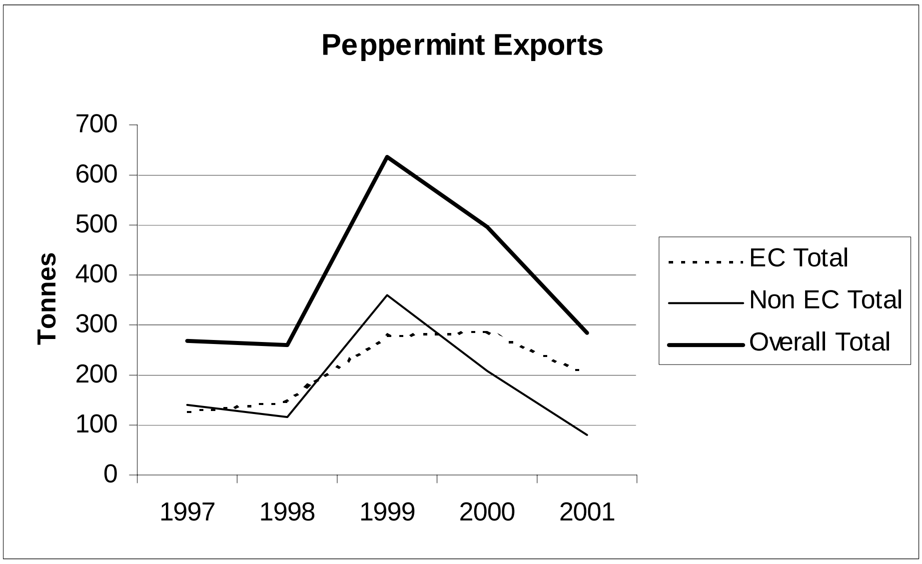


Fig 2A. Prices for peppermint oil imported by the UK (£/kg) from EC and non-EC countries in the last 5 years (raw data in Appendix 1).

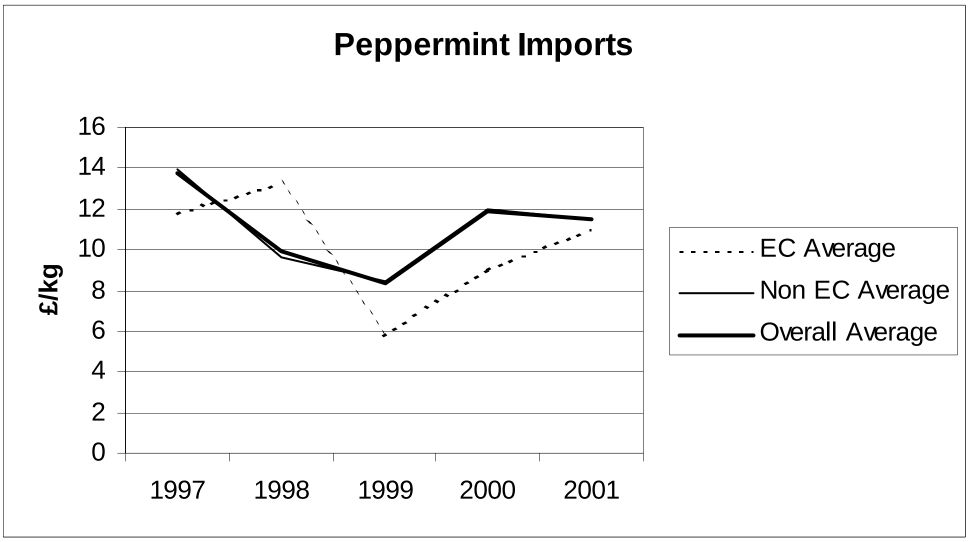
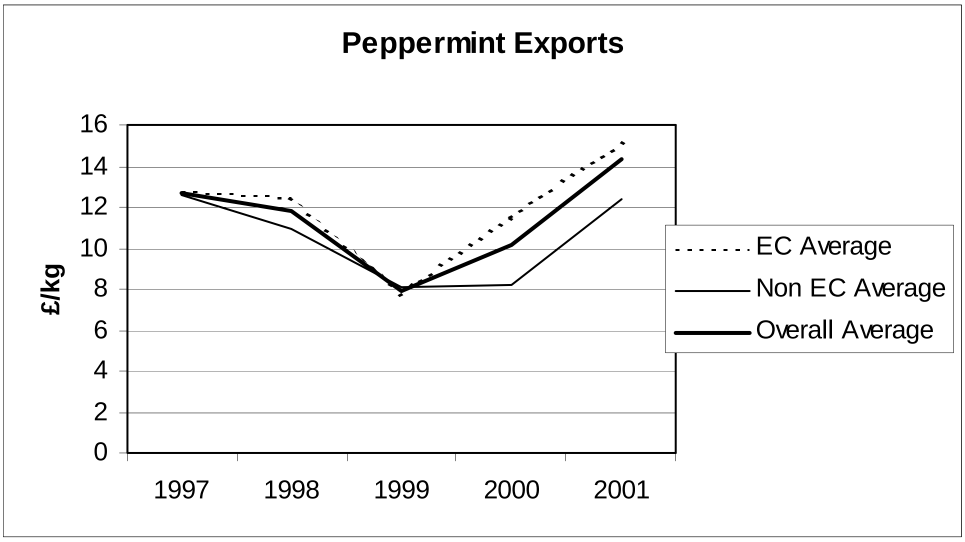


Fig 2B. Prices for peppermint oil exported from the UK (£/kg) to EC and non-EC countries in the last 5 years (raw data in Appendix 1).



In trade figures, spearmint is grouped with 'other mint oils', possibly also including menthol. *Mentha arvensis* oil and dementholised oils (Figs. 3 and 4). Imports of other mint oils are generally 33-50% of the total import tonnage of peppermint oil, and come predominantly from non-EC countries (USA, China and Canada). Imports from the US have been stable at around 200 tonnes over the last 5 years, with increasing quantities from China and decreasing quantities from India and Canada (approx 100 tonnes) (Appendix 1, Fig. 3A). The average import price has been £8-12/kg; EC-produced oils (France) commanded £20/kg in 2000 (Fig. 4A), probably due to premium product status. Approximately half of total imports (less UK production) are re-exported. Export prices to non-EC countries (The USA and Switzerland) are generally greater (£11-12/kg) than to EC countries (£8-10/kg; France, Spain and Italy) (Fig. 4B), although 4-5 times more oil is sold to EC countries (Fig. 3B). Higher prices are probably obtained via a) sale of UK-produced oils at premium prices or b) rectification and value-adding of imported oils prior to re-export.

Fig 3A. Imports of other mint oils to the UK (tonnes) from EC and non-EC countries in the last 5 years(raw data in Appendix 1).

Fig 3B. Exports of other mint oils from the UK (tonnes) to EC and non-EC countries in the last 5 years (raw data in Appendix 1).

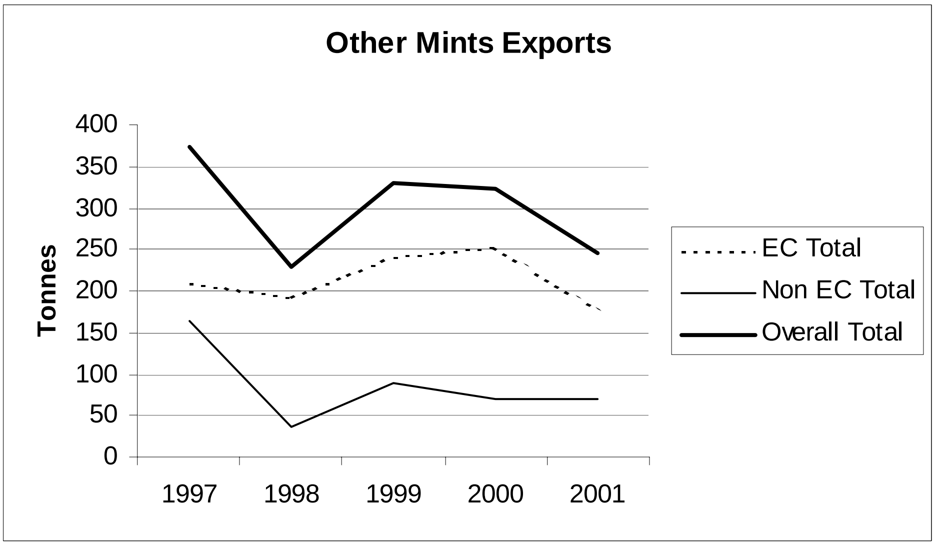


Fig 4A. Prices for other mint oils imported by the UK (£/kg) from EC and non-EC countries in the last 5 years (raw data in Appendix 1).

Fig 4B. Prices for other mint oils exported from the UK (£/kg) to EC and non-EC countries in the last 5 years (raw data in Appendix 1).

6. More competitive UK mint production

For production in the UK to become more attractive, the crop would have to compete with, for example, irrigated potatoes in terms of gross margin. This would mean improved output at higher prices; i.e.: producing a quality oil that sells for premium prices and finding ways of reducing the high costs of growing the crop arising from planting, harvesting and distilling. This might involve research into breeding improved varieties with increased yield of quality oil and better disease resistance, and by providing revenue and capital cost assistance to set up growers' co-operatives for planting, harvesting and distillation.

6.i Product volume: To enter the market place and compete it is imperative that UK production per farm or production per co-operative is increased to several tonnes at least. This could be achieved by:

- scaling up production area to a minimum of 25 ha/producer or /co-operative
- maximizing the planting density (24,000 plants/ha)
- achieving a bare minimum yield of oil of 75 kg/ha; aiming for at least 25% improvement in yield
- irrigating the crop
- undertaking a double harvest per season
- selecting UK-specific varieties with high oil yield and desirable quality
- optimizing harvest timing and post-harvest handling to prevent oil loss
- improving distillation efficiencies; ensure all oil is extracted

Scale-up probably also goes hand in hand with increasing the range of essential oils produced, preferably of species not requiring harvest or distillation in July-August. If product volume can be increased concurrently with premium prices, so much the better. Premium prices are already received by some UK producers; with due diligence and good marketing this should continue and the differential could even increase.

6.ii Infrastructure: The formation of co-operatives is highly recommended, with the support of a UK-wide infrastructure comprising:

- the development of a relevant association such as a British Essential Oil Producers Association (BEOPA) for communication and a unified voice to government
- the development of research and development center(s) of excellence, described in more detail below.

6.iii Plant varieties: The US spends considerable funds breeding new varieties of mint, probably from a limited gene pool. Despite this, few new commercial introductions have been made and oil yields are progressively declining. 'New' stock thus describes material that has either been produced in a new way (such as 'meristem' mint) or bears even more certifications of cleanliness with regard to disease. This suggests that mint breeding is especially difficult, yet in the UK, Botanix Ltd. have had some success increasing oil yields and widening the harvest window. The development of UK-specific varieties that suit the climate and soils, are resistant to strains of disease found here and produce an oil that is acceptable to existing markets for UK peppermint oils would be a valuable addition to the industry. It would be expected that producers would pay a levy per plant to the company or institute that developed such varieties. Producers should be encouraged to invest in new varieties as they are developed, perhaps every four years, in order to improve yields and produce consistent quality oil. Obviously it will be paramount that such planting material is obtainable at more competitive rates than it is presently. Timely information regarding the development and availability of such varieties is thus important, and the involvement of the previously mentioned (and as yet non existent) BEOPA would be invaluable. It would be almost impossible for a research institute not involved heavily in essential oil research, production and marketing to develop such varieties, and once developed, further products should fund themselves. However the initial costs of establishing trials and examining plants individually would require financial support.

6.iv Agronomic practices: Whilst the development of new varieties is significant, there is much that can be achieved by optimising agronomic practices, as evidenced by the Australian findings. The lack of communication between producers and the lack of an appropriate vehicle for disseminating such information, even if it were available, limits the uptake of new developments on this front. The dirth of new or relevant information, however, is an even more limiting problem. Trialling new agronomic practices for improved yields and sustainable production is something that various research and consultancy institutes such as ADAS have done well in the past, providing this information in an independent forum. Producing a crop with good biomass and oil yield and quality and a minimum of pesticide residues is a challenge that as yet we are still feeling our way forward on, and is especially important for the essential oils industry.

Continued and new funding for the advancement of

- novel, improved production methods
- integrated pest management
- MRL's for accepted pesticides for essential oil crops
- improved harvesting, handling and distillation equipment

would greatly enhance the sustainability of the industry on many fronts.

6.v Research and development: If UK production is to grow sufficiently to the point where levies fund R & D, as occurs to a limited extent in other countries notably the US and Australia, it is imperative that there exist centres of excellence that specialize in the breeding, agronomy, distillation, analysis and marketing of essential oil crops. To these centres, producers could supply material for analysis of oil yield and quality, plant development work could be done, oils could be organoleptically analysed and blended, and intelligent, timely and strategic marketing could be carried out. At present, the only place where this occurs on a large scale is at Botanix's Paddock Wood facility. For growers not in this co-operative, the pool of resources for such activity is limited, non-specialised and distributed the length and breadth of the country. Yet it may be important that similarly successful co-operatives linked with research and marketing centers arise if only to avoid a monopoly situation. Already the National Herb Centre, the Central Science Laboratory and ADAS are undertaking various aspects of relevant research.

There are a number of research avenues that could be pursued that may increase yield and quality of oil apart from those already mentioned, including

- timely application of approved, non-persistent water soluble pesticides (preliminary evidence suggests that secondary metabolism can in some cases be selectively stimulated)
- production of varieties with abnormally large or increased numbers of oil glands or vastly increased leaf areas (perhaps by genetic modification or marker assisted selection)
- production (or marker assisted selection) of varieties with upregulated enzymes responsible for biosynthesis of specific volatiles such as menthol or downregulated enzymes that catabolise such compounds
- breeding programs using primitive species and varieties to insert 'new' disease resistance genes into highly bred stock
- biological control mechanisms for Verticillium wilt, rust and other disease problems

to name but a few.

6.vi Reducing fixed costs: The equipment required for mint production in the UK, especially irrigation and specialized digging, planting and distillation equipment (even if the latter represents tubs only), are the main items that take the overall profits into losses per ha over at least the first 4 years of production (Table 4). It is not easy to see how such costs can be reduced, except if production areas are increased, thus reducing the overall costs/ha. For serious mint oil producers, this is perhaps the only way forward: to produce 100-150 ha of mint, or more. Not irrigating a crop is also an option, however this would depend on the distribution of rainfall within the growing region, and is not going to optimise oil yield overall.

6.vii Reducing variable costs: The greatest variable costs are transplants. In theory, this cost could be reduced by such material being purchased once for planting up 1 ha and subsequently digging stolons to plant new fields. In the long term, this method is likely to reduce oil yields/ha due to increased disease problems and comparatively sub-optimal planting material as research and breeding programs progress. It is not recommended.

Fertiliser and pesticide applications can be reduced by monitoring the crop carefully for pest and disease problems and nipping outbreaks in the bud. Soil and tissue analyses should be done regularly to minimize fertilizer application, however this will have its own costs. Distillation rates in the US are approximately £4.60/kg, whereas Botanix quote £3.50 for this, despite a heavier fuel charge here in the UK.

6.viii Tourism and promotion: Value-adding large-scale production of novel and specialist crops such as peppermint and spearmint oils (and other essential oils) by building a tourism enterprise around them is another way to improve returns. There is increasing consumer interest in essential oils and in both the UK and overseas, significant tourism facilities have succeeded including Norfolk Lavender, Bridestowe Estate in Tasmania, Australia, and the general understanding that perfumes come from the South of France, where perfumed lavender fields can be seen (or postcards bought, at least). There is potential for more such enterprises in the UK, strategically placed to co-incide with other tourist attractions, with appropriate educational value and with adequate access and parking. Adding value to related existing attractions, for example the Eden Project in Cornwall, could also be of merit. The opportunity for people to see where and how such crops are grown and extracted, to taste and smell the oils and the resultant products and to purchase them and related merchandise, along with the obligatory tea rooms, post cards and perhaps some new age massage or aromatherapy courses or treatments, would be of interest to the consumer, and therefore should be of interest to the producer.

7. Lavender and lavandin production

7.i Species grown and production figures: Lavender is in the *Lamiaceae* (syn. Labiatae) family, as is mint. Lavender was originally endemic to Mediterranean countries and is now grown world-wide. The species of lavender grown is generally *Lavandula angustifolia* L. syn. *officinalis*. This grows best at 700-1200m altitude. Other species include *L. latifolia* (Spike Lavender), grown in France and Spain, and a hybrid between these two species known as *L. intermedia*, or **lavandin** developed in the early 1920s and grown predominantly in France at 400-700 m. Lavandin yields oil at up to four fold higher levels than that of *L. angustifolia*, however the oil is of lower value, being higher in camphor.

Figures for world production of lavender products are variable, depending on the source. World production of quality lavender oil is approximately 200 tonnes pa, lavandin is 1200 tonnes pa (plus) and Spike Lavender is 150-200 tonnes pa. According to ONIPPAM (2001), French production of quality lavender is 65 tonnes and of lavandin: 1000 tonnes. Other producers of lavender oil include Tasmania (Australia), Bulgaria, Moldavia, Russia and China, however production in the latter 4 countries has declined significantly in recent years.

7.ii Uses: Lavender oil is used in the food, perfumery and the pharmaceutical industries. In the latter case, increased consumer interest in alternative therapies has increased the demand for lavender oil. Many semi-scientific studies have advocated or attempted to prove the efficacy of lavender oil as an analgesic and an antiseptic, however efficacy of various constituents of the lavender oil in terms of these properties has not been proved and active compound(s) have largely not been identified.

7.iii Cultural practices: Lavender oil is the steam distilled product of freshly cut flowering tops and stalks, the yield of oil may be variable, with yields varying from 11 -70 kg/ha. Lower yields are generally obtained in the Southern French mountains where seed-grown crops are harvested from poor land. Higher yields (for example 50-70 kg/ha in Tasmania, Australia) are obtained through varietal selection, vegetative propagation and highly mechanised harvesters. Generally, oil yield and quality of lavender oil is optimised by production in warmer climates and at increased altitude, however this can be cultivar dependent. Traditionally, lavender oil was from genetically variable plants grown in the mountains in SE France; a certified high quality product produced in this way is still marketed (25 kg/year).

Ideally, lavender plants are propagated by young shoots in Spring, with bushes being grown commercially for not more than 5 years, although some plantings are 10-15 years old or more. In Australia, plants are grown in rows 1-1.2 m apart, with an intra-row spacing of 0.4 m (20,000 plants/ha); plant densities are generally 12,000 plants/ha in the UK, and lower still (7-10,000/ha in France). The first commercial harvest may be done in year 2 or 3. Lavender plants require free drainage, with less irrigation compared with most essential oil crops, and a pH of 7, although crops have been grown in areas with a pH of 5.8-8.3. Lavender is deep rooting, tolerant of moderate frosts and drought, however severe frosts affect the plant. Nitrogen at the rate of 80-100 kg/ha and phosphorous at 33 kg/ha is recommended.

7.iv Plant varieties: Lavender is amenable to plant selection for varieties that yield optimal oil in terms of both yield and quality, particularly since the plant is easily propagated vegetatively. Where lavender plantations are established from seed, significant variation in oil yield and quality between plants is to be expected due to natural cross-pollination and hybridization. It is recommended that the primary aim of any new producer be to either source optimum material or to select material that is most suitable for a particular region. It cannot be stressed enough that whilst nutritional and climatic differences will affect oil yield and quality, the predominant factor governing both attributes is genetic make-up. Whereas breeding for improved oil yield or quality in mint has had relatively little success in the US, oil yield and quality is highly heritable in lavender species, as indicated by the success of the hybrid lavandin (Rabotyagov and Akimov, 1987).

Polyploidy has been induced to increase lavender yields in Bulgaria (Raev *et al.*, 1996), increasing flower size, inflorescence size and the number of leaves. This has also produced varieties more resistant to disease and extreme conditions. The new varieties produce 30% more flower material/ha, 15-20% more oil (%) and 40-250% more oil (kg/ha); flower yield is 5.7-9.9 tonne/ha, with a yield of 2.2-3.1% oil and a suitable composition. Thus there is large scope for improvement.

7.v Oil composition: Lavender oil is very stable under appropriate storage, indeed some producers recommend storage for a year to mellow the oil. Distilled lavender and lavandin oils are distinctively different and characterised by their volatile profile, obtained by gas chromatographic and olfactory analysis of the oil and the density and refractive index (Table 5). English lavender oil (*L. angustifolia*) is distinctive as it comes from varieties grown only here, at latitudes higher than the south of France or Tasmania. English lavender oil has a less overpowering top note compared with French oil, but with a distinctive depth, vigour and persistence. In France, where hot summers prevail, some of the volatile top notes of the oil may be lost. French lavandin oil is also special, but the oil of trade will almost always have been modified by the addition or removal of specific compounds to extend the product. Lavandin oil is primarily used by industry for detergents.

Table 5. The composition of various lavender and lavandin oils (mostly from International Standards).

Constituent/ characteristic	***L. angustifolia* True lavender**	***L. intermedia* (lavandin var Grosso)**	***L. intermedia* (lavandin var Abrial)**	***L. latifolia* Spike Lavender**
Linalol	25-38%	24-35%	26-38%	34-50%
linalyl acetate	25-45%	28-38%	20-29%	<1.6%
1,8-cineole	1-2%	4-7%	6-11%	16-39%
β-caryophyllene	3-12%			
Limonene	<1.0%	0.5-1.5%	0.5-1.5%	0.5-3%
terpinen-4-ol	2-6%	1.5-5%	0.3-1%	
β-ocimene	2.5-6%	0.5-1.5%	1.5-7%	
Lavandulyl acetate	3.4-6.2%	1.5-3%	1-2%	
Lavandulol	>0.1%	0.2-0.8%	0.4-1.2%	
α-terpineol	<2%			0.2-2%
Camphor	0.5-1%	6-8%	7-11%	10-20%
trans-α-bisabolene				0.4-2.5
Borneol		1.5-3%	1.5-3.5%	
Pinene				1-3%
Refractive index (20°C)	1.455-1.466	1.458-1.462	1.460-1.466	1.461-1.468
Optical rotation	-12.5° to -7°	-7° to –3.5°	-5° to -2°	-7° to +2°
Relative density	0.878-0.892	0.891-0.899	0.887-0.897	0.894-0.907
Oil yield (% of fresh weight)	**1.4-1.6%**	**1-2.5%**	**1-2.5%**	**1-1.5%**

* means present but not quantified.

8. French production: **Lavender** is produced on poorer grade soils in France, principally on the Albion plateau, which sits between the east of Vaucluse, the South of the Drome, and the northern Alps of High Provence. In 1960, there was record production of lavender oil (150 tonnes), however this progressively reduced until 1992 when production was 25 tonnes, as a consequence of various factors which will be discussed herein. This reduction in production threatened depopulation in rural mountains due to a lack of alternative crops to produce. The French regional and state governments and the EU injected substantial funds (£3.6M) in 1994 to re-invigorate the industry under guidance of the Interprofessional National Office of the Plants with Perfume, Aromatic and Medicinal (**ONIPPAM)**. Lavender varieties have been selected for improved vigour, essential oil yield and intensity of blue colour in the flowers (for dried flowers). Selected varieties are vegetatively propagated and referred to as 'clones'* (for example, 'Maillette' and 'Matheronne'); 'fine'* lavender is still grown, from seed (* terms to be defined subsequently).

Production in 1999 of lavender oil was 60 tonnes from 3,500 ha (1,200 ha 'clonal' yielding 35 tonnes @ 29 kg/ha, and 2,300 ha 'fine' lavender yielding 25 tonnes @ 11 kg/ha); the value of this production was £1.3M (ONIPPAM, 2001). French lavender oil is used mainly in aftershaves and perfumes for men (40 tonnes). Use in aromatherapy has increased by 15% per year, and is currently around 5-6 tonnes. AOC* fine lavender is used in products recently launched by Occitane, a partner of Champ de Lavande of Paris (* terms to be defined subsequently).

The SE of France produces 85-95% of the worlds' **lavandin** oil. In 2000, cropping of lavandin by almost 2000 producers reached 13,200 ha, yielding 1,000 tonnes of oil (71 kg/ha). Most lavandin oil is used for industrial applications (detergents and washing powders). Some is used in perfumery. Of all lavandin production, 75% is of the variety 'Grosso', 10% is 'Abrial', 8% is 'Super' and 7% is 'Sumian'. In 1997, 'Super' can at times yield a slightly higher price (£11.40/kg) compared with other varieties (£9.50-£10.40/kg).

8.i Cultural practices: Lavender is generally grown between 700 and 1,200 m above sea level, lavandin between 400 and 700 m above sea level. Lavender prefers chalky, light, free-draining soils, as in the dry mountain areas of the south of France. The production increases the value of poor, stony dry mountain areas where other crops are very difficult to develop. Each lavender plant is cultivated for about 10 years. Flowering occurs in July and the harvest is around the 14th of July, depending on the altitude and the year.

Lavandin has been cultivated since the early 1920's and is now cultivated in similar regions to lavender, but at lower altitudes and on a much more commercial scale. Lavandin matures in a more homogeneous way than fine lavender, and harvest begins at full flowering. The outputs are variable, depending on the season, the production region, the climate, the age of the crop and the variety. The planting density is 7-10,000 plants/ha with 60-80 cm between plants and 1.70-2.0 m between the lines. Fertilisation is done from year 3 (400 kg of manure) in March. The first harvest is done in the 3rd year.

Harvesters remove the flowering heads from three rows at one time, from mid-July till the end of August. Traditionally, the cut sheaves are left in the field for 2-3 days to dry, followed by distillation. The residue from distillation is used to fuel the boiler for subsequent distillations. Distillation takes approximately 1 hour. A new technique of distillation involves chopping the plant immediately after harvest into tubs as per mint distillation in the US. The residue from such distillation is used as manure; distillation of each tub then takes 1.5 h (due to the relatively greater moisture content).

There are around 400 producers of lavender in France, 80% of which belong to producer organizations. These collectives play an important role in the organizing and management of production, and provide distillation and storage services, marketing and technical support. There are around 150 distilleries in the south of France and many merchants of essential oils. Currently, the 30,000 ha of land under production with essential oils in France is worth £37.8M, of which lavandin and lavender comprise more than 50% by area (ONIPPAM, 2000).

8.ii Recent history: There is a wealth of information on the involvement of the government via ONIPPAM in almost all aspects of French lavender production. The reduction in lavender production between 1960 and 1992 was a result of a combination of events including competition from lesser quality products such as lavandin, synthetics and imported oils, and a decline in production as a result of a 'wilting' or 'withering' of lavender plants due to an unspecified cause, probably Shab, *Phomopsis lavandulae*. The social ramifications of reduced cropping in the mountains were significant enough to prompt the injection of substantial funds to reinvigorate the industry.

Planting areas of lavender, and thus production of oil, increased between 1992 and 1996, when a reemergence of 'withering' occurred and freezing conditions depleted many of the plants. In 1997, scarcity of imports combined with a very low French production led to high prices by the end of the season (£37.8/kg for fine lavender and £28 for clonal lavender) prices that were maintained in 1998. The production volume of fine lavender oil began increasing again in 1998. The high prices of lavender oils somewhat slowed the demand for such oils during the second half of 1998; imported prices were similarly high. As a result of the high prices, perfumers increased their consumption of lower quality, adulterated oils, and there was little demand from the pharmaceutical industry. Since that time, it appears that demands of the perfumery industries have changed, with increasing requirements for higher quality products, and those with different compositional qualities. This initiated selection strategies for new clonal varieties; in 1998, production of clonal lavender oil was mainly from 'Maillette' (84%), 'Barthée' (4%) and 'Matherone' (5%).

ONIPPAM has also enabled the organization of lavender production by: 1) encouraging growers to form into groups (such groups obtaining contracts for oil production), 2) by controlling supply and demand, and 3) by initiating discussions with partners to keep the market at a high level. The overall aim (and result) has been to stabilize the market. Production of lavender under contract represents approximately 25% of total production; 50% of lavender production occurs in co-operatives. Contracts for lavandin oil represent only a small proportion of between 0 and 10% total production between 1988 and 1998; co-operatives produce 50-60% of all lavandin (ONIPPAM, 2000).

Cropping conditions have, in particular, allowed the retention of a very competitive position in the international lavandin market due to the good climatic conditions, good technical knowledge base which is constantly being improved and little competition from other alternative crops in the growing area. The local, experienced traders play a major role in the buying, storage, distribution and export.

8.iii Research and promotion: Funds from the French government (ONIPPAM) supported research, development and demonstration trials, subsidies for new plantings and promotion of commercial and tourism potential. The research has been directed towards selection and creation of new varieties and control against a decline in oil yield by agronomic, harvesting and distillation experiments. Selection was undertaken by the Iteipmai and other partners as requested by the industry body 'Un Comité Interprofessionel (CIHEF). The focus has been on the development of new varieties more of interest to the perfumery industry in terms of composition, with good oil yield and improved disease resistance. 'Withering' or 'wilting' in lavender has been extensively researched in various laboratories of INRA and development agencies such as CRIEPPAM in Provence-Alps/Cote d'Azure and the Chamber of Agriculture of the Drome. A network by which healthy plants are made available has been established. There has subsequently been a 50% increase in production of clonal lavender oil, due mostly to the planting grant and the incentive and confidence it has given producers in the industry.

The lavender of Haute Provence has benefited from an official quality mark, Appellation d'Origine Controlee (AOC) since 1981. The AOC is only awarded to fine lavender that grows above 800 m altitude in certain council districts of the regions specified in 8; there is a maximum annual output of 25 kg for such oil.

8.iv Price: Fine French lavender (premium quality which meets the AOC requirements) commands £47-52/kg, whilst lavender oil from clonal populations commands £28-33/kg; French lavandin commands between £14-17/kg for standard grade with-30/kg for a better quality product (ONIPPAM figures, 2000).

8.v French trade:

8.v.a) Imports: In 1998, 81.5 tonnes of lavender oils (including lavandin) were imported, worth a total £1.8M; 1,246 tonnes were exported, worth £12.9M (ONIPPAM, 2000).

After a period of development of the Chinese lavender industry in 1992-3, French imports of such oils regularly declined to virtually nil in 1996; imports were re-established in 1997 at 3.8 tonnes @ £16/kg. The lack of availability (and high price) of French products in 1998 enabled a return of Ukrainian, Moldavian and Bulgarian oils onto the market, as evidenced by the increased imports from these countries in 1998 (10, 2 and 23 tonnes in 1998 respectively) compared with 8, 0 and 16 tonnes respectively in 1997 (ONIPPAM, 2000). Moldovia produced 78 tonnes of lavender in 1986 however production later declined due to the fall of the USSR and the loss of markets; production area in 2000 was approximately 1000 ha. French imports of clonal lavender from Bulgaria, China, Russia, the Ukraine and Moldavia increased in price between 1996 and 1998 from £8.50 to £34/kg, perhaps a reflection of the lack of available French product.

Lavandin is imported by France from Croatia, the price of this also increased between 1996 and 1998 (£7.60-11.80) whilst import tonnage was variable (6, 15 and 3 tonnes respectively). World trade of lavandin has increased in recent years, except for 1996. In 1996 the French released 80 tonnes of product from the 1989 crop back onto the market to stabilize the market. In early 1997, lavandin stocks dwindled and the price jumped up, CIHEF warned producers and industry of the risks of high prices as a result of under consumption of natural products and increased use of synthetics. In discussions, all parties agreed it was necessary to have a guaranteed base price to maintain use of the natural products, however this had not eventuated by 2000, and a price of £9.40 was maintained independently. The overall message is that the French government plays a role in stabilizing the market for French lavender oils and related products.

8.v.b) Exports: Lavender and lavandin oils are exported to various countries, as outlined in Table 6. The bulk of exports are to EU countries including Germany, the UK and Switzerland. Export prices to EU countries are generally greater than to Latin American or Asian countries, except to Japan and to countries that import only small quantities, probably reflecting export of higher quality products. Imports to the UK were stable in quantity, but steadily increasing in price between 1996 and 1998.

Table 6. French export figures, including both lavender and lavandin oils: tonnes and average £/kg.

	Tonnes			£/kg		
Country	**1996**	**1997**	**1998**	**1996**	**1997**	**1998**
EUAN	351	317	252	£6.15	£7.57	£8.99
Germany	246	293	256	£8.52	£8.99	£10.88
UK	154	155	153	£9.46	£11.35	£11.83
Switzerland	121	176	121	£8.52	£8.52	£11.83
Spain	49	43	55	£8.04	£8.52	£10.88
Total EU	**695**	**801**	**706**			
Brazil	92	126	83	£7.10	£7.10	£8.52
Mexico	0.5	1.5	4	£15.14	£11.83	£8.52
Argentina	6	3	2	£6.62	£8.52	£8.52
Uruguay	0	0	0.2	£0.00	£0.00	£14.19
Total Latin America	**98.5**	**130.5**	**89.2**			
Indonesia	23	11	14	£5.68	£8.52	£8.04
Hong Kong	11	15	9	£6.15	£7.10	£6.62
Singapore	30	24	15	£6.62	£8.04	£8.52
Japan	26	16	22	£13.25	£13.25	£13.25
Korea	4	0.2	1	£3.78	£7.57	£10.41
Taiwan	2	0.1	1	£5.68	£17.98	£10.41
Thailand	9	0.3	0	£3.78	£15.61	£0.00
Total Asia	**105**	**66.6**	**62**			
Total Overall	**1249.5**	**1315.1**	**1109.1**			

Source: ONIPPAM, 1998.

8.vi The French perfumery industry: France has a historic and significant place in the international perfume industry. There is a domestic market for French perfumes of £2.8 billion, to which is added £0.5 billion in imports and £2.8 billion in exports (1995). In 1995, 100 new perfumes were launched, the advertising for which cost between £9.5M and £30M and the design cost, bottle manufacture and packaging a further £50,000. The annual sales turnover of the second biggest perfume company (Oréal, French) after Estee Lauder (US) was £0.6 billion in 1994. Other French companies include Lancôme, Ralph Lauren, Cacharel, Guy Laroche, Giorgio Armani, Paloma Picasso, Lanvin, Louis-Vuitton-Moët-Hennessy (owner of Christian Dior), Guerlain, Givenchy and Kenzo. In recent times, such companies are under increasing threat from US companies such as Procter and Gamble, Unilever and Johnson & Johnson, who produce beauty and hygiene products and whom supplement their range with the luxury market, many buying out (several) existing perfume houses. The emergence of new groups in this sector intensifies competition and increases the costs of advertising and product launches. In addition, it increases the world-wide distribution of products through existing distribution chains, making perfume more available and thus increasing the demand for less expensive products. The French government predicts no increase in the demand for lavandin oil by 2010 for this reason.

8.vii Production economics: Figures enabling production costs for French lavender or lavandin to be estimated have been virtually impossible to collect, despite intensive efforts. The economics of production are skewed by government subsidies for planting. Fertilisation costs appear minimal for lavender, but are probably more substantial for broad scale lavandin production, similarly for pesticide application. Distillation costs are kept low by the use of co-operatively held distillation units that also service other crops grown in the region such as rose, tarragon and sage. The yields of oil/ha appear to be relatively low compared with Australian and UK figures (section 8), especially for lavender, however the relatively large scale of production will reduce the effect of this on the economic viability. The history of production and the proximity and communication with end users makes lavender and lavandin production in France a more sure bet than a similar enterprise in a ‘new’ producer country. The degree of government involvement both in research, promotion and price/supply fixing also lends confidence to the industry.

In Table 7, the gross margin for French lavender production there have been many assumptions and simplifications made, due to the paucity of data available on various costs associated with their production. Largely, costs are based on Table 9, UK lavender production, with differences due to the land prices, which are assumed to be negligible in France due to the long standing nature of production in this region in family oriented businesses, the planting material which is subsidised by the French government and the oil yields, which are generally lower than in the UK.

Given the total costs assumed in Table 7, the break-even yield for lavender oil in France is 18 kg/ha when sold at £35/kg; and the break-even price is £21/kg when 30 kg/ha of oil is produced. If we assume lavandin production costs are similar, with an average yield of oil of 71 kg/ha and an average price of £10.40/kg, the break-even yield is 61 kg/ha at £10.40/kg and the break even price at 71 kg/ha is £9.

Table 7 Gross margin for French clonal lavender production (not AOC grade).

Lavender production in France (40 ha on 350 ha property).		
Income		
Average 30kg/ha x £35/kg (Yield of oil based on information in section 8.)	**£42,000.00 /40 ha**	**£1,050.00 /ha**
Fixed Costs (interest at 6%)	**£/ha Year 1**	**£/ha Years 2-15**
Land (£/ha) family owned	£0.00	£0.00
Site preparation (cultivation in prep for planting)	£25.00	£6.25
Tractor (x 2, total £50K, 5 years)	£33.80	£33.80
General machinery (cultivator, sprayer, spreader etc.£25K, 7 years)	£12.79	£12.79
Specialised equipment (tractor driven harvester – custom made £15K 20 years)	£32.60	£32.60
Management (£25K pro rata for area)	£71.43	£71.43
Total fixed costs	**£175.62/ha**	**£156.87/ha**
Variable costs	**£/ha Year 1**	**£/ha Years 2-15**
Planting material (clonal, ONIPPAM grant)	£500.00	£25.00
Planting - contract	£175.00	£8.75
Fertiliser (100 kg/ha N, 40 kg/ha P, 40 kg/ha K, Mg)	£57.00	£57.00
Pesticides (Gramoxone, Tilt, Vydate, S, Dyfonate)	£133.00	£133.00
Labour - production (sprays, spreading etc.)	£21.00	£21.00
Crop insurance	£25.04	£25.04
Electricity (general farm use)	£13.91	£13.91
Fuel, production, contract harvest, transport @£0.20/L)	£25.00	£25.00
Harvest labour		£21.00
Distillation costs @ £2.80/kg oil		£140.00
Repairs/maintenance	£10.00	£10.00
Total variable costs	**£959.95**	**£479.70**
Total costs (fixed and variable)	**£1,135.57/ha**	**£636.57/ha**
Gross margin /ha	**-£85.57/ha**	**£413.43/ha**
Cumulative gross profits (after 15 years)		£5,702.39/ha
Total gross profits after 15 years (/40 ha)		**£228,095.70/40 ha**

9. Lavender production in the UK: Lavender has been under production in the UK for many hundreds of years, with a rapid decline in Southern regions (Mitcham, near London) after the First World War. England has a long reputation for producing quality lavender oil, due in part to its tradition of cultivating large stands of uniform material. UK lavender production currently comprises 125 ha, of which Botanix (Hertfordshire and Kent) grows 73 ha, Norfolk Lavender (Heacham) 41 ha, PhytoBotanica (Liverpool) 4.5 ha (organic), Norfolk Essential Oils (Wisbech) 0.4 ha and RJ Stark (Eye) 1 ha. Lavandin production is 68 ha, of which Norfolk Lavender has 4 ha and Botanix has 64 ha.

9.i Tourism and marketing: Several producers have established significant tourism industries, including Norfolk Lavender, as has also been the case in Tasmania, Australia. This provides the opportunity for maximised returns due to the niche market that can be captured and the opportunities for removing the middle layers of the industry. It does however, also mean that expansion of the industry by new producers is made more difficult due to the scale of production required to penetrate difficult markets overseas and the need for an infrastructure in terms of research, distillation, quality control and marketing. Botanix, previously known as English Hop Products, in Paddock Wood, Kent have established a co-operative of essential oil producers, many of whom were hop growers in the past. Lavender features high on the list of products. Unsurprisingly, detailed figures on economic aspects of production are sensitive and not readily disclosed by all in the industry. Due to the disparate nature of the marketing structure for the different industries, the economics of production may also differ widely.

To prepare this review, attempts were made to discuss production techniques, yield and economics with each lavender producer in the UK. Due to the disparate nature of the answers, each company will be discussed separately. The lack of knowledge of what each other are doing was striking, as was the lack of interest in a co-operative approach either now or in the future amongst most of those questioned; others agreed this was one of the few options for successful large scale market penetration.

9ii Cultural practices: Although the climate in the UK is hardly comparable with the south of France, it has long been recommended that production of lavender could occur South and East of a line drawn between the Wash and the Solent. Most producers are well within this area, except for the group near Liverpool. UK production of a French variety will yield oil/ha at levels similar to French production if the weather is good. A wet year may lead to an indifferent oil yield and quality.

Lavender harvesters are often specialised pieces of equipment that lift and chop the flowering stems only, at a rate of 2 tonnes/hr. Lavender is harvested when 70-85% of flowers have finished blossoming. In the UK, lavandin is harvested on or around the 26th of July (+/-3 d), with *L. angustifolia* 12-14 days later. The crop is generally distilled immediately, but may be allowed to dry in windrows if the conditions are not damp. The amount of stem retained on the flowering head does not affect oil yield *per se*, but may affect the efficiency of distillation, with a coarser cut increasing efficiency from 40-45 to 90% due to better steam penetration throughout the charge. Lavender is distilled at the rate of 6 tonnes/90 minute in large stills. Stills may cost £3,500 for a half tonne plant, to £100,000 for an 8 tonne unit. The yield of lavender oil obtained in the UK can be as high as 70 kg/ha (Botanix).

9.ii.a) Botanix Ltd. comprises a group of producers mostly in Herefordshire and Kent and a centralized distillation, solvent extraction (supercritical CO_2), analysis, blending and marketing department in Paddock Wood, Kent. Research on plant varieties in terms of oil yield and quality and disease resistance, agronomic practices (especially mineral nutrition) to improve oil yield and quality, distillation processes to maximize efficiency and extensive marketing are done by this company for their co-operative of producers. The gross margin for their production of lavender and lavandin oils show that plants are being sourced at costs of 60% less (lavandin) and 25% less (lavender) than market rates for quality stock as a benefit of the group buying in bulk. However, the greatest expense in both cases remains planting material. Botanix projects increased oil yields from year 2 onwards; 90-225 kg/ha over 4 years for lavandin and 10-80 kg/ha for lavender. Given the claims made by others, this should be possible but could be reduced by poor establishment, unfavourable seasons or disease problems. It is likely that this group obtain some of the best oil yields simply due to an optimised distillation process. The benefit of costing out contract distillation (£2.8/kg) illustrates the reduced savings such processes incur, negating the hefty costs associated with distillation plants. The cumulative returns within 5 years are around £4,500/ha for lavandin and £350/ha for lavender.

One of the major benefits for growers associated with Botanix is the good reputation the company has in the industry, and its success in market penetration. Products are sold mainly to specific end users, made possible largely by the scale of production under the Botanix umbrella. New producers, even of superior quality oil, will be hard pressed to compete in an industry that demands bulk at minimum prices.

9.ii.b) Norfolk Lavender near Heacham, grows 100 ha of lavender of both *L. angustiflia* and *L. intermedia*, the former from selected varieties and the latter from publicly available stock. The lavender oil produced at Norfolk Lavender is distinctive and unique, the result of many years of selection. Five varieties are grown for distillation with two additional varieties (one third of the total crop) for drying. Plants are kept in production for many years (10-15 years). The harvesting equipment and distillation apparatus/process have been evolved in-house as a result of experimentation and consultation with industry; some of the copper stills from the initial establishment are still in use (*circa* 1874) with more recent modifications. There are no marked disease problems, although once ‘Shab’, *Phomopsis lavandulae*, was a problem; present day varieties are resistant to this. Organoleptic analysis of oil quality is done to produce distinct but uniform products. The nature of the marketing operation involves formulation of a very wide range of perfumery products for sale in a (largely) niche market combined with a significant tourism focus.

Mr Henry Head of Norfolk Lavender reflects that the UK industry would be much benefited by the development of co-operatives linked with Centres of Excellence, a view also reflected by others in the industry. Costs of production he thought to be relatively high, however the mechanisation that reduces costs in France for lavandin production (harvesting 3 rows simultaneously with a wide harvester head) are not feasible in the UK unless production areas are increased significantly. Returns may be as high as £77/kg for lavender oil, however a return of £121/kg is considered the minimum ‘decent’ return. Obviously this level will never be attained through the world trade of essential oils by the tonne, however sale into a niche market or improvement of the product range and quality such that new markets can be penetrated may produce this. Norfolk Lavender would like to expand on suitable, light soils in the region, however the cost of renting land (£250/ha) makes this uneconomic.

The history of production of lavender oil at Heacham is long and esteemed (By Royal Appointment), and it is possible that significant increases in production could be made by increased plantings without threatening the stability of their established markets or the relatively high the price they receive. It would seem sensible that other enterprises in the region link with Norfolk Lavender to maximise the use of the distillation apparatus and increase market share. For lavender, this may require freezing of flower material for later distillation; for other crops an off-seasonal distillation time would be pertinent.

9.ii.c) Mr Ken Goodyer of **Norfolk Essential Oils** has 0.4 ha of *L. angustifolia* near Wisbech in Norfolk, planted with EU funding through objective 5B. The yield of oil was only 1.5 kg in 2001, however it fetched a premium price (£200/kg) through trade via the internet into the aromatherapy market. Other oils are also produced at this site and by other producers in this co-operative, including chamomile. This reduces the costs of the distillation plant that are specific to lavender production. The main limitation to increased plantings is the cost of establishment, notably the costs of planting material. Norfolk Essential Oils use seeds propagated into modules for establishment of a crop, at a penny/plant; to use vegetatively propagated material would cost 25-37p per plant. If significant new plantings are to be made, vegetatively propagated material of the highest quality in terms of oil yield and composition would be recommended. Plants were established at 12,000/ha for a cost of £120/ha; use of commercially available transplants would be £3,600-£4,800/ha. The lavender crop is only 2 years old, so maximum yields have not yet been achieved (expected in years 4-5). There have been no disease problems, and little weed control is done, mainly due to the small area grown. Phosphorous, potassium and nitrogen are applied to sporadic soil analysis. There is a 1.5 tonne distillation unit that was built in-house for a cost of £70-£80K, with a capacity of 2-4 ha/day. Oil analysis is contracted out at a cost of £35/sample. The oil is sold to aromatherapists in the US (wholesale and retail).

Both Norfolk Essential Oils and Norfolk Lavender grow their lavender on light, alkali soils rather than the characteristic heavier soils of the Fens. Mr Goodyer believes that to help the industry, plant establishment loans would be useful, such as those in France. Neither lavender nor sage may be grown on set-aside land in the UK. The returns for set-aside land mean that land rental has increased from £100/ha to £250/ha which has limited the expansion of some essential oil industries.

9.ii.d) PhytoBotanica, the group growing essential oils near Liverpool initially funded by DEFRA and EU believe that the costs of establishment are the most difficult to bear, however few figures were forthcoming. The age of their plantation suggests that maximum lavender yields are not yet being experienced. They also produce a range of essential oils, although their marketing strategy was not disclosed.

9.ii.e) RJ Stark, Eye (Suffolk) produces lavender oil for one or two particular buyers who add the product to larger volumes of lesser quality oil or other products to obtain a marketing advantage. Mr Stark does not believe there is room for expansion of his business based on the demands of this user.

9.iii Price: The price of lavender and lavandin oils largely reflects the quality and the level of supply (Table 6). These are trade prices and may not represent the prices being obtained by some producers for unique products for sale into different markets.

Table 8. UK trade prices for various lavender and lavandin oils (Sources: Fuerst Day Lawson and John Kellys, December 2001).

Product	Source	£/kg
'True' lavender oil	France	38.30
L. angustifolia		
	Chinese	31.30
Lavandin	French Grosso	10.40
L. intermedia		
Spike Lavender	Spain	21

9.iv Production economics: The main costs for production are the specialised harvest and distillation units and the planting material itself. The main areas that significant changes to these figures can be achieved are in the sharing of distillation equipment between producers or the contracting out of distillation activities, and in the choice of high yielding varieties and agronomic practices to improve oil yield and quality. Ensuring the maximum oil yield is obtained via optimized harvest timing, post-harvest handling and distillation procedures is crucial.

In table 8, the gross margin for UK lavender production there were several assumptions made: 40 ha of production on mixed farming enterprise of 350 ha; no irrigation, a planting density of 12,000/ha of top quality transplants selected for oil yield and composition @ £0.35 each, average yield of oil 50 kg/ha, average price £35/kg (to compare figures based on average trade prices rather than the relatively higher prices UK producers are currently receiving). We assumed 5% was replanted per year, with continuous cropping for 15 years. Distillation is contracted out at £2.80/kg of oil. Very little real information was available from the UK producers, and due to the variability in their production and marketing methods, the gross margin required considerable thought; some costs such as distillation costs /kg of oil used from Botanix's figures. We have made what we believe to be reasonable assumptions for capital and contract costs based on similar crops and machinery.

Table 9. Gross margin for lavender production in the UK.

Lavender production in the UK (40 ha on 350 ha property).		
Income		
Average yield 50kg/ha x £35/kg	**£70,000.00 /40 ha**	**£1,750.00/ha**
Fixed Costs (interest at 6%)	**£/ha Year 1**	**£/ha Years 2-15**
Land (£/ha) (rent equivalent at £250/ha)	£250.00	£250.00
Site preparation (cultivation in prep for planting)	£25.00	£6.25
Tractor (x 2, total £50K, 5 years)	£33.80	£33.80
General machinery (cultivator, sprayer, spreader Etc.£25K, 7 years)	£12.79	£12.79
Specialised equipment (tractor driven harvester – custom made £15K 20 years)	£32.60	£32.60
Management (£25K pro rata for area)	£71.43	£71.43
Total fixed costs	**£425.62/ha**	**£406.87/ha**
Variable costs	**£/ha Year 1**	**£/ha Years 2-15**
Planting material (transplants at £0.35 each)	£4,200.00	£210.00
Planting - contract	£175.00	£8.75
Fertiliser (100 kg/ha N, 40 kg/ha P, 40 kg/ha K, Mg)	£57.00	£57.00
Pesticides (Gramoxone, Tilt, Vydate, S, Dyfonate)	£133.00	£133.00
Labour - production (sprays, spreading etc.)	£21.00	£21.00
Crop insurance	£25.04	£25.04
Electricity (general farm use)	£13.91	£13.91
Fuel, production, contract harvest, transport @£0.20/L)	£25.00	£25.00
Harvest labour		£21.00
Distillation costs @ £2.80/kg oil		£140.00
Repairs/maintenance	£10.00	£10.00
Interest	£279.60	£19.94
Total variable costs	**£4,939.55**	**£684.64**
Total costs (fixed and variable)	**£5,365.17/ha**	**£1,091.51/ha**
Gross margin /ha	**-£3,615.17/ha**	**£658.49/ha**
Cumulative gross profits/ha (after 15 years)		£5,603.63/ha
Total profits after 15 years (/40 ha)		**£224,145.30/40 ha**

Yields of oil and prices will vary from year to year for the reasons outlined in sections 2 and 7. Substantial differences will be observed within these gross margins if better prices are obtained, if oil yields fall short of expectation and if distillation facilities are established. Given the total costs assumed in Table 9, the break-even yield for lavender oil produced in the UK is 31.2 kg/ha when sold at £35/kg; and the break-even price is £21.80/kg when 50 kg/ha of oil is produced. Efforts have been made to reduce the distillation expenditure on this enterprise and the contract distillation would only be feasible if this enterprise was situated nearby to existing distillation facilities. Although some producers have made a decision to reduce planting costs by using seed generated material, this is not advisable due to the benefits reaped by growing high oil yielding, vegetatively propagated selections throughout the 15 year crop cycle.

If we assume lavandin production costs are similar and that an average oil yield is approximately 150 kg/ha, the break-even yield is 105 kg/ha at £10.40/kg and the break-even price at 150 kg/ha is £7.27/kg.

9.v Comparison of UK and French production costs: Detailed comparisons are difficult due to the amount of assumptions that have been made, particularly relating to French production. On the basis of tables 7 and 8, UK lavender producers could expect a profit of over £5,600/ha after 15 years, very similar to the returns postulated for French producers (£5,700/ha). There will be a number of years (3-4) until full oil production is realised, as there will be variable years throughout the 15 due to climatic and plant age related factors. Once again, it is the great cost of transplant material that draws the eye in table 8. These costs could be reduced as described in 5.v.

9.vi UK trade figures: Trade figures do not differentiate between lavender and lavandin, thus the term lavender includes both types of oil in this section. Imports of lavender have been stable at 200 tonnes pa since 1997 (2001 expected to reach this figure when data for the final quarter is included) (Fig 5A). Almost all lavender imports are from France, with some from Switzerland and Poland in 2000, although this oil may not have been produced there. A small quantity of lavender oil at very high prices was imported from the US, fluctuations in this product leading to the price fluctuations on non-EC imports (Fig. 6A). Generally the EC-imported price is £12-18/kg, indicating that most of this product is lavandin. Lavender exports are generally around 50-60 tonnes pa, mostly to non-EC countries (USA, Argentina) (Fig. 5B). The price/kg is £10-12/kg upon export to non-EC countries (therefore representing lavandin), whereas the price to EC countries is £25-35/kg (Fig. 6B), although the quantity exported this way represents only 5% of that exported to non-EC countries. This 5%, mostly representing true lavender (probably UK-produced lavender) is exported to the Irish republic and France predominantly (Appendix 1), probably for value-adding and extending other lavender or lavandin products.

Fig 5A. Imports of lavender to the UK (tonnes) from EC and non-EC countries in the last 5 years (raw data in Appendix 1).

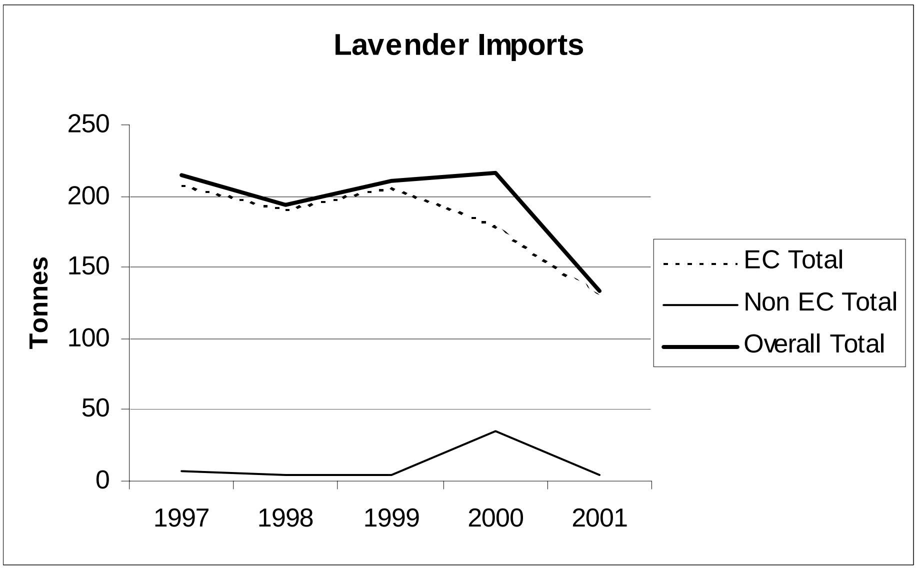


Fig 5B. Exports of lavender from the UK (tonnes) to EC and non-EC countries in the last 5 years (raw data in Appendix 1).

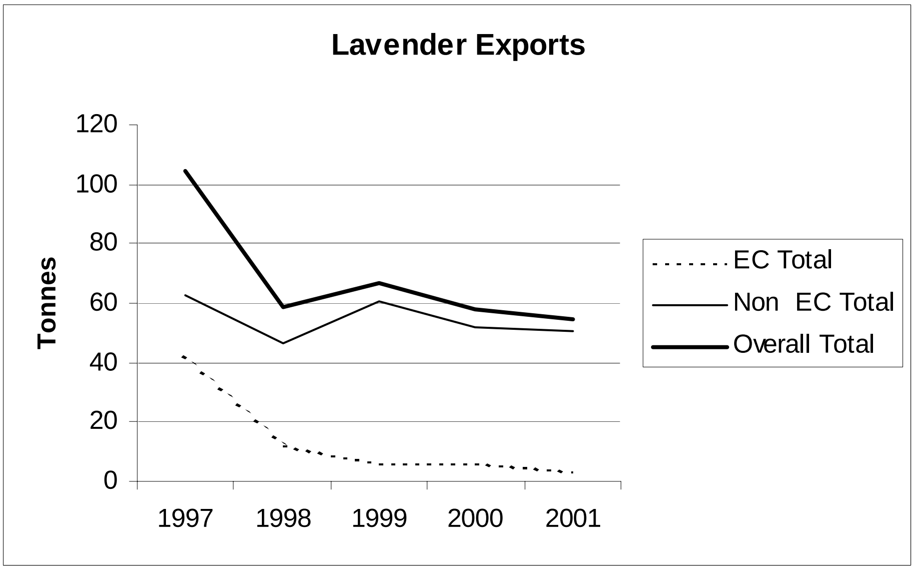


Fig 6A. Prices of lavender imported into the UK (£/kg) from EC and non-EC countries in the last 5 years (raw data in Appendix 1).

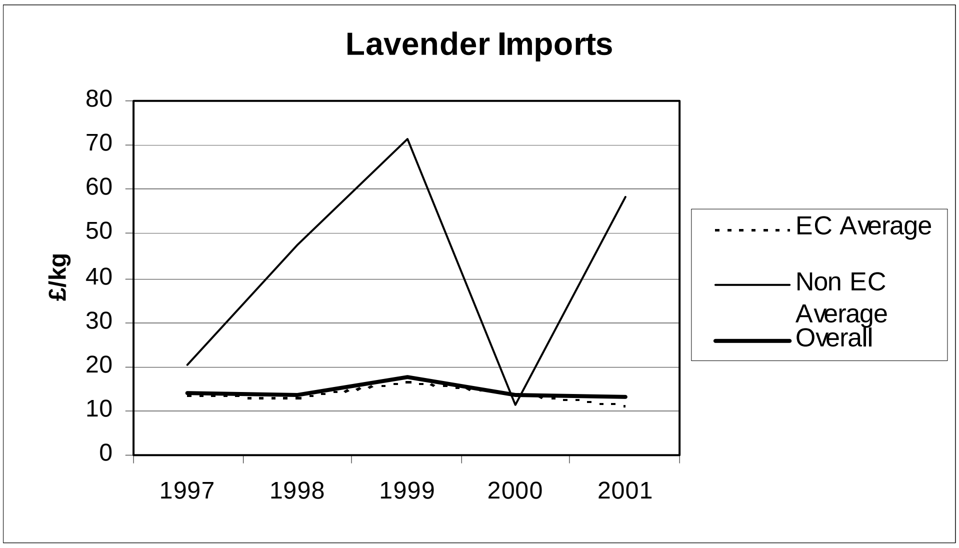
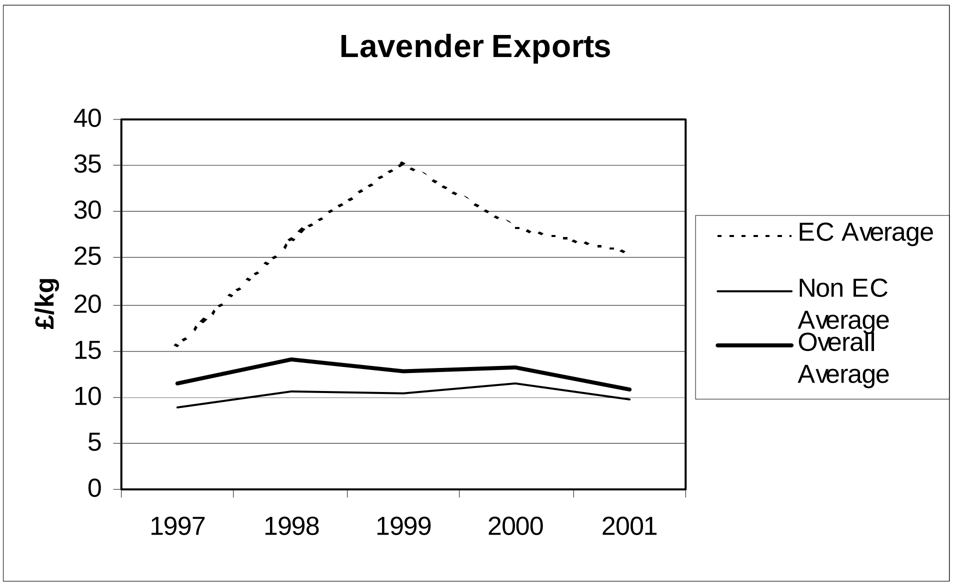


Fig 6B. Prices of lavender exported from the UK (£/kg) to EC and non-EC countries in the last 5 years (raw data in Appendix 1).



10. More competitive UK lavender/lavandin production:

10.i Communication: It became apparent from talking to lavender producers that there is no standard approach to production, extraction or distillation. There is also a distinct lack of communication between producers, which does not seem to be the case in France where co-operatives and standard production, distillation and marketing systems operate. Communication could be improved by means of an annual conference for UK producers of essential oils and interim field days and newsletters under the auspices of a British Essential Oil Producers Association (BEOPA); currently there is no such organisation. Producers are placing themselves at a disadvantage by not being aware of developments in varieties or agronomic practices.

Communication with end users is also a bigger part of French production, since the perfume industry is so local and vocal there. As production increases it will be important to have strategic communication with the end users, particularly their technical departments, so that UK products with their even more distinctive characteristics will be used in some products, preferably major perfumes that then increases the demand for the UK products.

10.ii Product range: There is a wide variety of oil qualities being produced, each at relatively low levels and with no standardisation. For the UK to become a relatively large producer of lavender oil, it would be advisable to have a UK-wide branding image and associated traceable quality level that could potentially be met by all (big) producers and for which there could be a quota attached to further boost price. This could be similar to the French AOC brand. This could involve organic production, or production of varieties specifically developed for (and in) the UK.

10.iii Product volume: To enter the trade and compete it is imperative that production/farm or production/co-operative is increased to several tonnes at least, in order that individual producers, if not in co-operatives, can compete at any level. Co-operatives would be a further improvement. This could be achieved by:

- scaling up production area to a minimum of 25 ha/producer or /co-operative
- increasing planting density to 20,000/ha
- achieving a bare minimum yield of oil of 32 kg/ha for lavender; aiming for at least twice this (achieving at least 105 kg/ha for lavandin and aiming for at least a 50% improvement)
- selecting UK-specific varieties with high oil yield and desirable quality – these could be grown under licence with a royalty attached that funded further selections
- improving harvesting equipment or buy in equipment from overseas
- improving distillation efficiencies; ensure all oil is extracted

Scale-up probably also goes hand in hand with increasing the range of essential oils produced, preferably of species not requiring harvest or distillation in July-August.

10.iv Plant varieties: There is a need for varieties that

- suit the climate and yield well
- have characteristics that are increasingly desirable to end users and
- have good disease resistance.

This has been the main focus of government involvement in the French lavender industry. End users have already demonstrated an interest in 'new' lavenders, which the UK may be in a position to supply perhaps more rapidly than France. In addition, we do not appear to have the disease problems France has, and generally our crops yield better. This is no small task and requires the focus of a group with analytical facilities and good communication with end-users. It also requires some funding, and some speed, since there exists at this point in time a good opportunity for the UK to become a more important figure in the lavender oil industry. Botanix Ltd. are leading the way in this field at present, with a successful breeding programme.

At the present time in the UK, this role would almost certainly have to fall to an industry body such as Botanix Ltd. However in Australia there has been considerable success by linking a University Centre of Excellence with industry and producers to develop improved varieties of several essential oil species. Where one company alone is directly involved there can arise a conflict of interest with other producers.

Since plant material is sufficiently expensive to cause several producers to fall back on seed-produced crops or on varieties not deemed to be optimum for oil yield or quality, as has occurred in the UK in recent times, perhaps some planting incentives could be examined, much as those developed in France.

10.v Research and Development: If UK production is to grow sufficiently to the point where levies fund R & D, as occurs to a limited extent in other countries notably France and Australia, it is imperative that there exist Centres of Excellence. To these Centres, producers could supply material for analysis of oil yield and quality, plant development work could be done, oils could be organoleptically analysed and blended, and intelligent, timely and strategic marketing could be carried out. At present, the only place where this occurs on a large scale is at Botanix's Paddock Wood facility. For growers not in this co-operative, the pool of resources for such activity is limited, non-specialised and distributed the length and breadth of the country. Yet it may be important that similarly successful co-operatives arise if only to avoid a monopoly situation. There are a number of research avenues that could be pursued that may increase yield and quality of oil apart from those already mentioned, including post-harvest handling and pre-distillation treatment to increase oil yield and freezing of flowers prior to distillation to extend the distillation window.

10.vi Reducing fixed costs: Obviously the biggest fixed costs unique to essential oil production are distillation apparatus. Lavender, by its very nature is not as prone to decrease in oil yield and quality after harvest compared with mint. Thus there is more opportunity for stockpiling the crop prior to extraction (2 days max), or for transporting it to distilleries nearby (if they have available time slots). For this reason, small-scale lavender production is well suited to a co-operative venture, as occurs in France. It is hard to present suggestions without simply describing the venture Botanix Ltd. has already established: a suite of producers spread throughout several regions producing different crops, all accessing shared distillation facilities. It would be our recommendation that new small producers link their production with one of several distillation units already in production (Heacham, Eye, Wisbech, Liverpool, Paddock Wood), or that centralized (or mobile) distillation facilities are made available. The possibility of freezing plant material prior to distillation could be investigated: this is used in Australia to enable extraction of flower material from a short harvest window without limiting production area or requiring duplicated extraction facilities. For the large scale producer, attempts to source second hand stills may be successful, and for custom-built equipment which may in some cases be less expensive than commercial units.

The costs of land, either as purchase or rent, are also excessive compared with French production which is on poor quality mountainous land, much of which has probably been in production by local families for generations.

10.vii Reducing variable costs: Shifting the distillation costs from fixed to variable costs by means of contract distillation, and reducing the specialized equipment required by contracting out other processes such as planting may increase variable costs but would improve the gross margins overall. The use of fertilisers on lavender by some producers in the UK seems excessive, and the costs of pesticides may reduce as more products become limited in application due to maximum residue limit information and traceable production.

10.viii Tourism and promotion: Since Norfolk Lavender particularly has done such a successful job at self-promotion, obtaining the ‘By Royal Appointment’ symbol and establishing a significant tourism industry, it seems unlikely that further tourism enterprises could be established. However larger scale production of an increased range of crops with viewer-friendly distillation and organoleptic analysis facilities, with the obligatory tea rooms and craft shops (and perhaps aromatherapy massage suites) could be developed elsewhere. After all, there is more than one whiskey distillery in Scotland that has successful tours! The history of production and use of lavender oil in the UK is long, the term ‘English lavender’ is well known, and the acknowledgement of the efficacy of lavender and other oils in self healing is growing.

11.Summary and Conclusions

For production of mint and lavender oils in the UK to become more viable and sustainable, there needs to be improved output at higher prices concomitant with reduced costs for growing the crop arising from planting, harvesting and distilling. This might involve research into breeding improved varieties with increased yield of quality oil and better disease resistance and providing revenue and capital cost assistance to producers. Producers should be supported to develop co-operatives on a large scale to increase output and improve market penetration and buying power. There is also the need for the development of an infrastructure to support and develop the industry including the development of a producers association and research centers of excellence. The opportunity to diversify through tourism outlets, and to attract premium prices via a unique branding image should also be addressed.

Co-operatives: It is advised that producers increase their production and reduce costs by grouping together into **co-operatives**. This will enable them to

- better penetrate the market
- reduce the financial impact of large pieces of equipment and marketing
- obtain improved marketing resources, buying power and pressure for high quality planting material.

Production of more than one essential oil is recommended for each co-operative.

Infrastructure: There is a requirement for an improved infrastructure for the essential oils industry in the UK, by means of

- a **British Essential Oils Producers Association (BEOPA)** as a communicative tool between producers and with outside bodies
- the development of research and development **center(s) of excellence**. These should be involved in improving oil output, oil quality and sustainability of the industry through breeding, agronomy, extraction, analysis and marketing of oils on behalf of producers. They could be financed by means of a levy system with set-up and ongoing support from government.

Research: There is support required for research to raise the yields of mint oil to at least 100 kg/ha, yields of lavender oil to at least 65 kg/ha and yields of lavandin oil to at least 150 kg/ha. This could be achieved by addressing issues relating to breeding, agronomy, post-harvest handling and distillation processes. The research aims may be best achieved through funding centers of excellence that are focused on the problems associated with the essential oils industry at all levels. Specific issues that require addressing include:

- **Breeding** to develop UK-specific varieties that suit the climate and soils, are resistant to strains of disease found here and produce oils that are acceptable to existing markets. Such varieties could be licensed for production under a royalty system. The initial costs of establishing trials and examining plants individually would require financial support.

- **Agronomic practices:** There is much that can be achieved from optimising sustainable agronomic practices to produce a crop with good biomass and oil yield and quality and a minimum of pesticide residues. There is a need for research into many aspects of essential oil production including genetic control, opportunities for marker assisted selection, and biological control mechanisms for various disease problems, to name but a few.

Financial assistance: The greatest costs are incurred in purchasing or renting land and in establishing plots of good quality plant material. In France, subsidies and low interest loans have been put in place successfully to increase production area of high quality stock. In addition, access to good quality distillation apparatus is critical, and purchasing such equipment is very expensive. Support for co-operatives to access funding relief for some of these expenses would be useful.

Tourism and promotion: Value-adding large-scale production of novel and specialist crops such as essential oils by building a tourism enterprise around them is another way to improve returns and boost the rural economy generally. There is increasing consumer interest in essential oils and in the UK and overseas, significant, multiple tourism facilities have succeeded. There is potential for more such enterprises in the UK, strategically integrated with other tourist attractions, with appropriate educational value. These will require support until they are commercially viable in themselves.

Branding: France has seen fit to produce a branding image that denotes quality and limited supply. The UK, perhaps through the (as yet non existent) BEOPA, should aim to produce a UK branding image with an associated traceability and quality that could potentially be met by all producers and for which there could be a quota attached to further boost price. This could involve organic production, or production of varieties specifically developed for (and in) the UK.

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Appendices.

13.Appendix 1. Raw data for UK import and export figures for peppermint, other mint oils and lavender.

Insert Appendix 1 here (separate file).