Influence of Variety and Organic Cultural Practices on Yield and Essential Oil Content of Lavender and Rosemary in Interior BC

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Disclaimer: The views expressed in this report are those of the investigators and participating organic producers. Interested persons should conduct their own detailed feasibility studies to assess the technical and economic viability of lavender and rosemary production. Additional information for commercial producers may be obtained from the BC Ministry of Agriculture, Food and Fisheries.

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SUMMARY

While labor costs may preclude large-scale commercial production of essential oils of lavender and rosemary in BC, value-added markets for small acreage exist and could be expanded. A potential new value-added market for these oils is the production of botanical pest control products for use in various crop production systems and ornamental horticulture. This investigation was aimed at evaluating the suitability of five varieties of rosemary and lavender under organic propagation and production conditions in zone 4 – 6 regions of interior BC.

Propagation studies aimed at identifying potential organic rooting stimulants were conducted at a greenhouse at Soloman Herb Farms in Kamloops. Our findings suggest that rooting stimulants are not necessary for propagation of lavender and rosemary by semi-hardwood cuttings.

To compare the yields of different varieties of lavender and rosemary five plants of each variety were grown in test plots in Kamloops and Osoyoos from May to October 2004. During this period of field production the two sites experienced similar temperature and precipitation. Kamloops had an average monthly temperature of 17.9 ^{0}C and rainfall of 221mm while Osoyoos experienced an average monthly temperature of 18.8 ^{0}C and rainfall of 214.9 mm. Among the lavender varieties tested 'Grosso', 'Provence' and 'Super lavender' had a higher herbage yield than 'Hidcote' and 'Folgate' after one year of field production in Kamloops. 'Provence' also showed a greater growth index than 'Folgate' at both locations. The highest yielding variety of lavender, 'Grosso', produced 1.55 ± 0.25 t/Ha of herbage after one year of growth. This amount of herbage could produce about 15.5 kg/Ha of lavender oil. The current retail price of lavender oil in Kamloops is $492/kg.

There were no significant differences in herbage yield or growth indices between any of the rosemary varieties tested ('Rex', 'Barbecue', 'Tuscan blue', 'Spice island' and 'Gorizia'). The highest yielding variety of rosemary, 'Tuscan blue', produced 5.71 ± 0.52 t/Ha of herbage after one year of growth with a potential oil yield of 57.1 kg/Ha. The current retail price of rosemary oil is $ 418/kg.

Our findings regarding the efficacy of rosemary and lavender oils against aphids and two spotted spider mites suggest that concentrations of 2% or more are effective. Further investigations are needed to determine the effectiveness of lower concentrations because of potential injury to soft plant tissues at high oil concentration.

Rosemary is unlikely to overwinter consistently in areas cooler than zone 8. Methods of winter protection and/or optimizing production of the crop as an annual require further investigation. Overwintering survival of different varieties of lavender should also be investigated.

INTRODUCTION

English lavender, *Lavandula angustifolia* (family Labiatae, mint family) is a bushy, branching shrub, native to western Mediterranean region. The smooth-edged silver-gray leaves are opposite, lanceolate, somewhat hairy, and up to 2 inches long. The small lavender-purple flowers are in whorls of six to ten; forming terminal spikes 6 to 8 inches long. The fruit is comprised of four shiny gray-brown nutlets. Lavender is a perennial; growing to hardiness zones 4 - 8 (Jo Ann Gardner, 1997).

Lavender requires well-drained soils such as sandy, sandy loam, or gravelly soils. It goes well in low-fertility soils of *pH* between 6.5 and 7.5. For fast establishment lavender should be propagated by vegetative methods. Furthermore, seeds of lavendin are sterile. Lavender can easily be propagated from softwood cuttings. Hardwood cuttings can also be propagated, but take longer to root. Tissue culture from callus derived from leaf buds is possible. Row spacing should be 3-6 ft (ideally 4 ft) and 1-3 ft between plants (most commonly 30") giving a density of 3,000 - 5,000 plants per acre. Establishment plants should be "hardened" off before being planted in the field. In mild climates, fall planting is best. In areas with harsh winters, spring planting is the only option for planting outdoors. Flower buds should be trimmed off during the first year, and sometimes the second to speed up establishment. Drip tape irrigation is recommended, primarily in the first year but sometimes in the second. Irrigation increases production of mature plantings. Overhead irrigation may increase disease problems. Composted chicken manure or fishmeal can be used at planting. About 100 lb. N per acre should be applied for the first three years to encourage vegetative growth. Mature plants need no more than 50 lb. N per acre. Excessive applications of N can decrease oil quality, and make plants unhealthy. It may also lead to increased weed competition. Phosphorus and Potassium requirements are also very low. Periodic liming may be necessary to keep the *pH* at 6.5 or higher.

Weed control is probably the biggest production issue. It is critical for good yield, high quality, and aesthetics. Weed barriers and mulches dramatically decrease weeds. Drip irrigation also discourages weeds between rows. Mature stands shade out most weeds. Root rots, alfalfa mosaic virus (transmitted by aphids) and spittlebugs are the only significant pests of lavender.

There is much confusion, cross naming and inconsistency in descriptions of cultivators of lavender. *Lavandula angustifolia* ("True," English, French) includes the varieties Twickel Purple, Jean Davis, Royal Velvet, Hidcote and Royal Purple. Spike lavender is *Lavandula latifolia*. Grosso, Super lavender, Giant Hidcote and Abrialis are hybrid lavendins, *Lavandula x intermedia*. Spanish lavender is *Lavandula stoechas* (Curtis B., 2000)

Rosemary, *Rosmarinus officinalis* L., (Family: Lamiaceae (Labiatae)), is an evergreen, perennial shrub native to the chalky, calcareous hills along the Mediterranean Sea. Reaching a height of up to 1.8 meters, the plant is characterized by linear, narrow leaves

whose undersides are matted with thick hair. Leading areas of rosemary production are the Mediterranean countries, the United States, and England.

The reported life zone for rosemary is 9 to 28 degrees Celsius with an annual precipitation of 0.3 to 2.7 meters and a soil pH of 4.5 to 8.7. The drought tolerant plant grows in rocky to sandy soils, as long as there is adequate drainage and a minimum soil depth of about 0.2 meters. The pale-blue flowers can develop throughout the growing season, although profuse blooming occurs during late winter or early spring. Rosemary has no serious pests or diseases. The plant is not cold hardy.

Commercial production is from both cultivated and wild plants. Fields of rosemary are usually harvested once or twice each year, depending upon the geographical area and whether the harvest is for plant material or essential oil. A first cutting can be obtained in the planting year but is usually delayed until 18 months after establishement. Leaves are dried in the shade to maximize retention of color and aroma. There is some loss of color when leaves are frozen.

The volatile or essential oil of rosemary contains 1,8-cineole, pinene, camphor, bornylacetate, camphene, linalool, d-limonene, borneol, myrcene, -terpineol, and -caryophyllene. The oil is extracted from flowering tops, stems, and leaves by steam distillation or the use of organic solvents. An oleoresin is also commercially available (Simon, J.E. *et al*., 1984).

Although there is only one species, it is variable, giving rise to many named cultivators. ‘Prostatus’ is a hardy type grown outdoors year round in zone 7. ‘Miss Jessup’ an upright variety with pink flowers and ‘Tuscan Blue’, an extraordinarily vigorous upright plant growing to 10 feet with blue flowers, are both hardy to zone 7. ‘Hardy Hill’, with blue flowers is hardy to zone 6. ‘Arp’ is hardy to zone 6 and may be hardy in some areas of zone 5 with protection. Generally rosemary is supposed to be able to survive where winter temperatures do not drop below 10 degrees (Jo Ann Gardner, 1997). 'Gorizia' has upright growth, long and broad leaves (double the size of other plants), medium blue flowers, gentle aroma and is hardy to about 15°C. 'Rex', another upright variety with blue flowers has a very striking appearance (almost black-green leaves that are white beneath) is a dynamic bloomer.

Uses of Lavender and Rosemary

Lavender and rosemary are suitable for home ornamental and herb gardens, hence their propagation and marketing as bedding plants is feasible. Both provide aesthetic and culinary uses and are good companion plants.

Lavender has traditionally been produced for aromatic, cosmetic, culinary, decorative, and medicinal purposes. The dried flowers are used for scenting sachets, potpourris, and decorative pillows. The aromatic oil is used in toilet water, cologne, and perfume. Lavender is also used in bath products, and stimulating and cleansing facial steams. It is said to repel mosquitoes. It can flavor vinegars and jellies. Decorative uses include floral arrangements, wreaths, and wands. Lavender is said to have some medicinal qualities.

Traditionally, rosemary is used for scenting, stewing and for alleviating stomach disorders and headaches. Dried rosemary leaves, whole or ground, are used as seasonings for soups, stews, sausages, meat, fish, and poultry. The essential oil is used in food products, perfumes, and cosmetics, such as soaps, creams, deodorants, hair tonics, and shampoos. Rosemary is also used in non-alcoholic beverages. The plant and extracts have antibacterial and antioxidant activity, and can be used to extend the keeping quality of fats and meats.

Many varieties and forms of rosemary are grown as ornamental and hedgerow plants. Often the plant is used as a ground cover along roads and on embankments because of its beauty and deep root system, which helps stabilize the soil and allows the plant to withstand hot, dry periods. It is considered a good source of nectar for bees, having blossoms that attract bees and appear when few other plants are blooming.

As a medicinal plant, rosemary has been used as an external stimulant and as a relaxant for nervousness, muscle spasms, and headaches. At one time it was used in wines as a carminative, and it is thought to act as a stimulant to the kidneys. Rosemary has been used as an expectorant and as a folk remedy against asthma, eczema, rheumatism, and wounds. It has been used in the treatment of cancer, and is categorized today as a therapeutic emmenagogue. The plant is also used as an insect repellent (Simon, J.E. *et al*. 1984). Rosemary is generally recognized as safe for human consumption as both a natural flavoring/seasoning and as a plant extract/essential oil (21 CFR sections 182.10, 182.20). Several medicinal compounds have been isolated from rosemary; Rosmarinic acid is used for treatment of toxic shock syndrome, diosmin for reducing capillary fragility and rosmarol for its high antioxidant activity. Its leaf and flower infusions are effective against dandruff when combined with borax.

More recently, due to an increase in organic crop production and public awareness about the harmful effects of pesticides, there has been renewed interest in botanical active ingredients including essential oils. Essential oils of both lavender and rosemary have been reported to repel and control a wide range of insect pests including aphids (Hori M., 1998), mites (Rifaat M. et al., 2002), codling moth (Landolt P J. et al. 1999), onion thrips

(Koschier H E. et al., 2002) and *Varroa* mites (Ariana A. et al. 2002). Use of lavender and rosemary oils in food preservation is also an emerging new market (Bellow C.G. *et al*. 2000, Ouattara B. 1997, Madsen H.L 1998).

Feasibility of Lavender and Rosemary Production in BC.

BC is unlikely to compete with Spain, Israel and China in large-scale production and wholesale of lavender and rosemary oil due to the opportunity costs of land and labor. However opportunities exist for value-added markets for oils and plant material. For example, 128 plug trays can fetch $ 75, 2″ pots retail for $3.50 - $5 and 4″ pots for $5 – $7.5. Angustifolia varieties produce 5 to 25 lbs. of oil per acre. Lavandins yield 20 to 35 lbs. of oil per acre.

In 1998 lavandin varieties were reported to generate around Cdn $500 to $2,500 per acre for oil production. True lavender (*L. angustifolia*) generated around $150 to $450 per acre. Flower yields for 'Grosso' is approximately 4-7 bundles per plant (150 stems per bundle). About 12-15 bundles produce one pound of dried buds hence about 1/4 to 1/2 lb. of dried buds per plant. About 1,000 - 1,500 pounds of dried buds per acre can be achieved. Retail prices in 1998 were $7.50-$ 12.50 per dried bundle $8.75. Wholesale price was $2.50-3.75 per bundle. High-end retail price for clean, colorful buds was $37.50/lb. (Curtis, B., 2000).

The current retail price of lavender oil in Kamloops is $492/kg and the price of rosemary oil is $ 418/kg.

Emerging value-added markets in pest management are likely to increase the demand for lavender and rosemary.

Objectives of the Study

This study was aimed at evaluating the suitability of five cultivators of rosemary and lavender under organic propagation and production conditions in zone 4 – 6 (Kamloops and Osoyoos) regions of BC.

PROPAGATION, FIELD AND LABORATORY STUDIES

Propagation of Lavender and Rosemary

During late summer 2003 to early spring 2004, several experiments were conducted at Soloman Herb Farm to investigate potential organic rooting stimulants for vegetative propagation of rosemary and lavender. Comparisons were made in percent rooting of heel, semi-hardwood and softwood cuttings of lavender and rosemary treated with various substances to either prevent rotting and/or stimulate rooting. We also intended to compare the success of cuttings taken at different seasons.

Experiment 1

On 31 July 2003, semi-hardwood stem cuttings of both rosemary and lavender were propagated in standard propagation trays (3 X 3 cells per treatment group) containing two types of soils. The first comprised of 1:1 ratio of peat:sand, while the second was 1:1 peat:perlite mixture. Before being set in the media, cuttings were left overnight in either water or 2% honey solution. This provided the following treatment combinations for each plant species-

1. Nine semi-hardwood stem cuttings of rosemary treated with 2% honey solution in 1:1 peat:sand.
2. Nine semi-hardwood stem cuttings of rosemary treated with 2% honey solution in 1:1 peat:perlite.
3. Nine semi-hardwood stem cuttings of rosemary treated with water in 1:1 peat:sand.
4. Nine semi-hardwood stem cuttings of rosemary treated with water in 1:1 peat:perlite.
5. Nine semi-hardwood stem cuttings of lavender treated with 2% honey solution in 1:1 peat:sand.
6. Nine semi-hardwood stem cuttings of lavender treated with 2% honey solution in 1:1 peat:perlite.
7. Nine semi-hardwood stem cuttings of lavender treated with water in 1:1 peat:sand.
8. Nine semi-hardwood stem cuttings of lavender treated with water in 1:1 peat:perlite.

Once set in the media, the propagation trays were placed in a propagation table covered with clear plastic and shade cloth, and furnished with bottom heat set at 23^0 C. The propagation table was located in an unheated greenhouse. Misting of cutting was done by hand spray, 3-5 times a day.

Results

All cutting failed due to excessive heat in the greenhouse.

Experiment 2

On 15 August 2003, cuttings were taken in the same manner as in Experiment 1 but this time only 1:1 peat-perlite mixture was used and the propagation table was equipped with an automatic misting system timed to provide 4 misting cycles during the day and none at night. This setting was later reduced to 2 cycles during the day.

Results

Germination percentage [100 X (# of rooted cuttings/total # of cuttings)] was less than 5% for both water and honey solution indicating the need to improve propagation conditions before proceeding with tests of potential rooting hormones.

Experiment 3

The propagation table was moved away from direct sunlight in the greenhouse to an adjacent produce processing room. Lavender and rosemary semi-hardwood cuttings (5 – 10 cm in length) were taken and their bottom leaves removed except the top 2-cm. A total of 32 cuttings were taken for each plant species. Cuttings were placed overnight in either water or 2% honey solution. After this soaking period, cuttings were placed in 1:1 peat:perlite mixture. Bottom heat was set at 23^0 C and temperature was monitored at the growing level of the cuttings (plant-level temperature) and outside the propagation table (ambient temperature). Relative humidity was raised and maintained above 75 using a fogger (Fogmaster Tri-Jet, Model # 6208, The Fogmaster Corporation, Deerfield Beach, FL). The fogger was initially set to run for 2 minute every 2 hours during the day but after one day this setting was reduced to one minute every two hours. Each fogging cycle produced 500 ml of water. Rosemary cuttings were set on 29 August and the trial was stopped on 23 September 2003. The study with lavender cuttings started on 4 October and ended on 28 October 2003.

Results

Average ambient and plant-level temperatures during rosemary propagation were 17.7 ± 1.9^0 C and 23.3 ± 1.4^0 C respectively. Average daily maximum and minimum temperatures were 27.2 ± 1.3^0 C and 17.7 ± 1.3^0 C respectively. During lavender propagation, average ambient and plant-level temperatures were 14.3 ± 1.6^0 C and 23.1 ± 1.8^0 C respectively. Average maximum and minimum temperatures were 26.6 ± 1.5 and 17.4 ± 1.2^0 C respectively.

None of the cuttings rooted either due to high average maximum temperatures, wide fluctuations in temperature, a short duration of soil moisture deficiency or wrong season for taking cuttings.

Experiment 4.

To determine whether bottom heat is necessary, a tray of rosemary cuttings (4-6 inches long) was started outside the propagation table on 23 October 2003. These cuttings were treated with various natural substances that have the potential to either induce rooting or suppress microorganism that may cause rotting. Test materials included coconut milk, 1-% honey solution, wood ash, Aloe Vera extract, black pepper, ground ginger and a water control. To reduce rate of soil drying, the media used contained 60% peat and 30% perlite. Cuttings were watered twice from the bottom to ensure even soaking. The propagation tray was covered with a plastic dome to maintain relative humidity above 85.

Results

All cuttings remained healthy till 27 November 2003 but none rooted. Since cuttings in previous experiments deteriorated faster, this observation suggests that bottom heat must be carefully regulated to reduce deterioration cause by drying and/or rotting.

Experiment 5.

To further investigate the effect of bottom heat and to compare rooting of heel cuttings with stem cuttings, rosemary cuttings were started in a tray containing 4 X 16 cells. Thirty- two, semi-hardwood stem cuttings were placed on one half of the tray lengthwise, while the second half contained 32 heel cuttings. Part of the tray (widthwise) was placed on a heating mat ensuring that half the cuttings from each group (stem and heel) received bottom heat and half did not. Cuttings were watered from the bottom and the tray was covered with a plastic dome. Subsequently, cuttings were watered, as needed using a hand sprayer. The experiment commenced on 12 December and was terminated on 31 December 2003. Relative humidity, soil temperature and plant-level temperature on the heated and unheated sides of the tray were recorded regularly.

Results

Mean RH was 92.0 ± 1.6, soil temperature on the unheated side was 18.9 ± 0.8, plant-level temperature on the unheated side was 18.9 ± 0.7, soil temperature on the heated side was 25.9 ± 1.0 and plant-level temperature on the heated side was 22.5 ± 1.0.

Most of the cutting exhibited some rotting by the end of the experiment. However unheated heel cuttings remained healthier longer than the three other treatments. Heated stem cuttings also remained healthier slightly longer that heated heel cuttings and unheated stem cuttings.

These observations suggest that RH may have been too high.

Experiment 6.

To determine if conditions at other facilities would be more conducive, rosemary and lavender plants were send to two propagators in the Fraser Valley region of BC, Freedon Greenhouses (a commercial bedding plants propagator) and University College of the Fraser Valley (UCFV).

Results

Whereas Fredon Greenhouses was unable to propagate the plants, UCFV successfully propagated lavender heel cuttings and rosemary semi-hardwood cutting without the use of rooting hormones under the following propagation conditions-

> *Media: Peat/perlite/sand 40:40:20. Seedlings later potted up into 4" pots using peat/perlite/fine bark containing micronutrients and calcium nitrate.*
> *Propagation Bench: Mist system with automated leaf controller until rooted, then hardened off on a bench in a glass house: Temperature settings: Heating at 18 degrees Celsius, Venting at 25 degrees Celsius. Moved to a poly hoop frame with temperature set at 10 degrees Celsius, sides rolled up during the day (weather*

permitting). We do not have a control for RH, so it varies greatly, but very high in glass house with the mist system going all of the time, and dropping considerably in the polyhouse (with daily fluctuations depending on outside environment as it had it's sides rolled up).

[Source: Brent Bailey. UCFV Agriculture Technician, Agricultural Technology Program].

Determination of Yield of Five Varieties of Lavender and Rosemary in Organic Field Production

Herbage yield and growth of five varieties of rosemary and lavender was determined at two field locations. Site A was located on an organic farm 25 km South of Kamloops (latitude 50^0 26′ N, longitude 120^0 26′W, elevation 345 m, climatic zone 4a – 4b). Site B was also at an organic orchard 10 km north of Osoyoos (latitude 49^0 1′N, longitude 119^0 26′W, elevation 297m, climatic zone 5b-6a). Mean monthly temperatures and precipitation at the two sites are shown in Table 1 below.

Table 1. Mean Monthly Temperature and Precipitation at Kamloops and Osoyoos Field Sites.

	Mean Monthly Temperatures (^{0}C)		*Mean Monthly Precipitation (mm)*	
Month	*Kamloops*	*Osoyoos*	*Kamloops*	*Osoyoos*
April	12.1	12.3	11.5	14.5
May	14.8	15.4	52.1	35.8
June	20.8	21.3	23.4	47.4
July	23.4	24	39.6	38.2
August	22.2	23.5	55.5	64
September	14.3	16.4	38.9	15

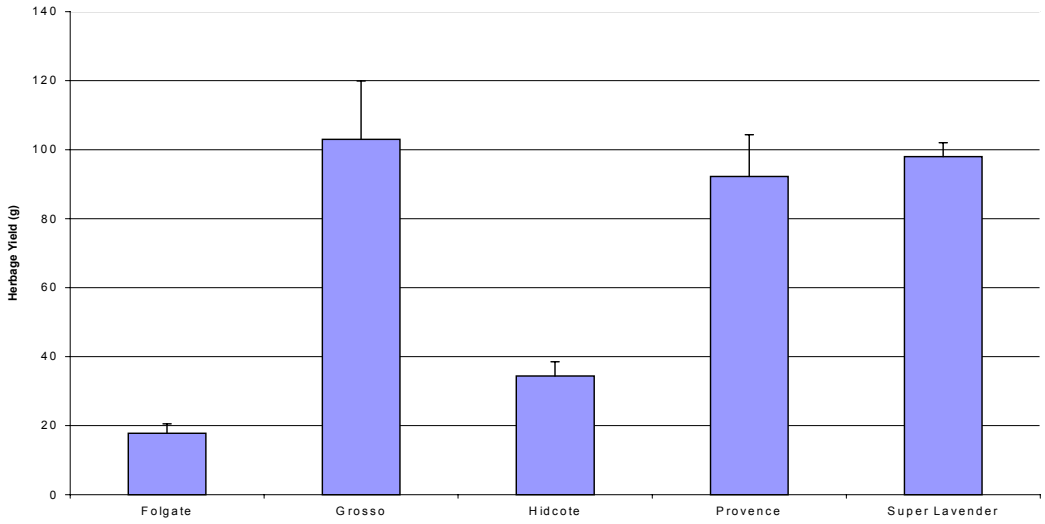
At each site the test varieties of lavender and rosemary were planted in two rows forming a completely randomized block design. The five lavender varieties were ‘Grosso’, ‘Folgate’, ‘Super lavender’, ‘Provence’, and ‘Hidcote’. Rosemary varieties were ‘Tuscan blue’, ‘Rex’, ‘Gorizia’, ‘Spice Island’ and ‘Barbecue’. Uniform seedlings, about 10 cm tall were selected and planted at a plant spacing of 60 cm and row spacing 75 cm. Prior to planting, five soil samples from the lavender and rosemary test plots in Kamloops were collected and combined to form one representative sample for each plot. Samples were submitted to Norwest Labs for nutrient analyses. Apart from addition of compost at transplanting, no other soil nutritional amendments were undertaken. Transplanting in Kamloops was done on 12 May 2004 and in Osoyoos on 20 May 2004. Growth measurements (overall height and spread, and numbers of stems) were undertaken in Osoyoos on 18 September 2004 and in Kamloops on 21 October 2004. In addition to growth measurements, total herbage yield was determined to estimate oil production potential after one year of field growth in Kamloops. All plants in Kamloops were potted up for winter protection in the greenhouse. Plants in Osoyoos were not harvested but were mulched for winter protection. Height (h) and spread (s) measurements were used

to calculate a volume-based growth index using the formula $1.05h(½\ s)^2$, which was used for statistical analyses. All data was subjected to Analyses of Variance and T-Tests.

Results

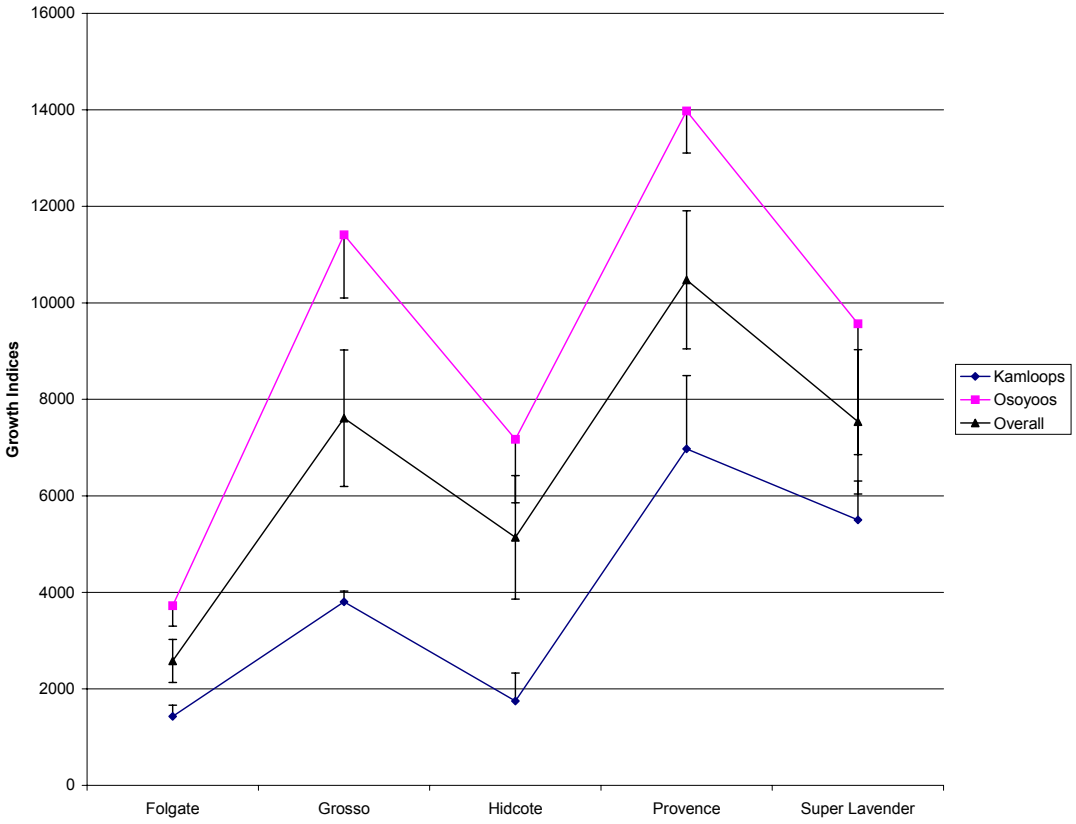
Soil analyses indicated that both the rosemary and lavender plots in Kamloops were deficient in phosphorus (Appendix 2). Figure 1 below represents the average herbage yield (g) of five plants from each of five varieties of lavender grown in Kamloops. Herbage yields of 'Grosso', 'Super lavender', and 'Provence' were significantly greater than yields of 'Hidcote' and 'Folgate'. There was no significant difference in yield between the former three varieties ('Grosso', 'Super Lavender', and 'Provence') nor between the later two varieties ('Hidcote' and 'Folgate').

Figure 1. Mean (+ SE) Herbage Yield (g) of Five Varieties of Lavender ('Folgate', 'Grosso', 'Hidcote', 'Provence' and 'Super Lavender') in Kamloops (N=5)



Growth indices of lavender at both locations are represented in Figure 2 below. From these indices, some varieties such as 'Provence' appear to have grown bigger in Osoyoos than Kamloops. Comparisons between varieties at the two locations were similar with 'Provence' showing a significantly higher growth that 'Hidcote' and 'Folgate' at both locations. However, while 'Super Lavender' had a higher growth index than 'Folgate' in Kamloops, 'Grosso' showed a higher index than 'Folgate' in Osoyoos. Combined growth index data from both locations indicated that 'Provence' grew to a bigger size than 'Folgate'.

Figure 2. Average (± SE) Growth Indices of Lavender Varieties Grown in Kamloops and Osoyoos Including an Overall Index Combining Height (h) and Spread (s) of Each of the Five Varieties ('Folgate', 'Grosso', 'Hidcote', 'Provence' and 'Super Lavender') at Both Locations



There were no significant differences in herbage yield (g) between the five varieties of rosemary grown in Kamloops (Figure 3). There was also no significant difference in growth indices between the five varieties for combined data from both locations (Figure 4). There was also no difference in growth indices between Kamloops and Osoyoos for any of the five varieties.

Figure 3. Mean (+ SE) Herbage Yield (g) of Five Varieties of Rosemary ('Barbecue', 'Gorizia', 'Rex', 'Spice Island' and 'Tuscan Blue') in Kamloops (N=5)

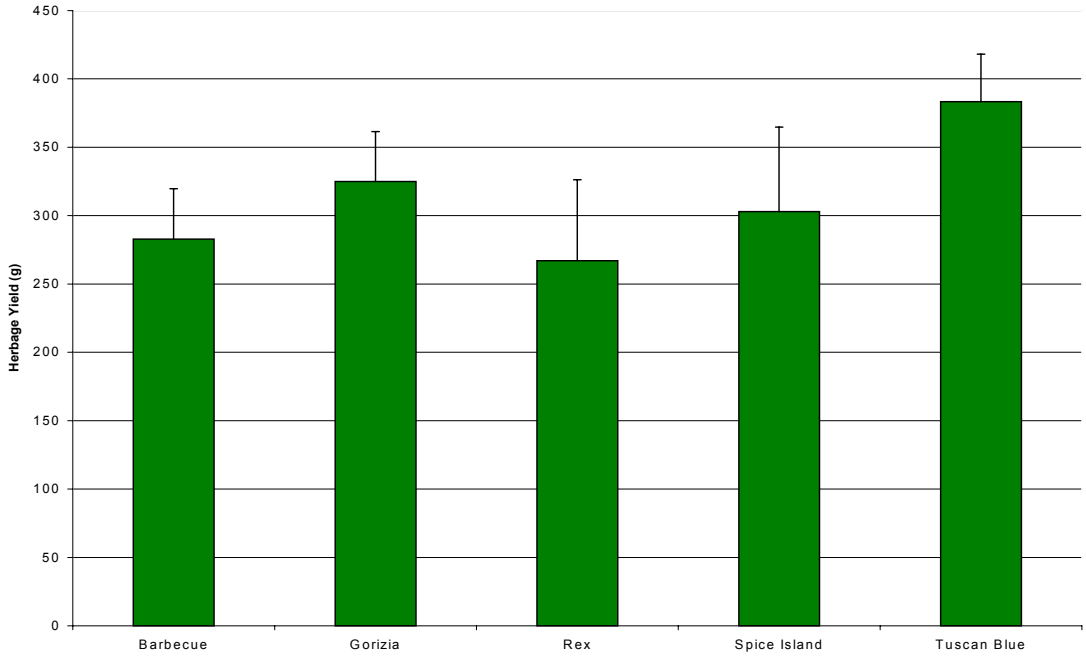
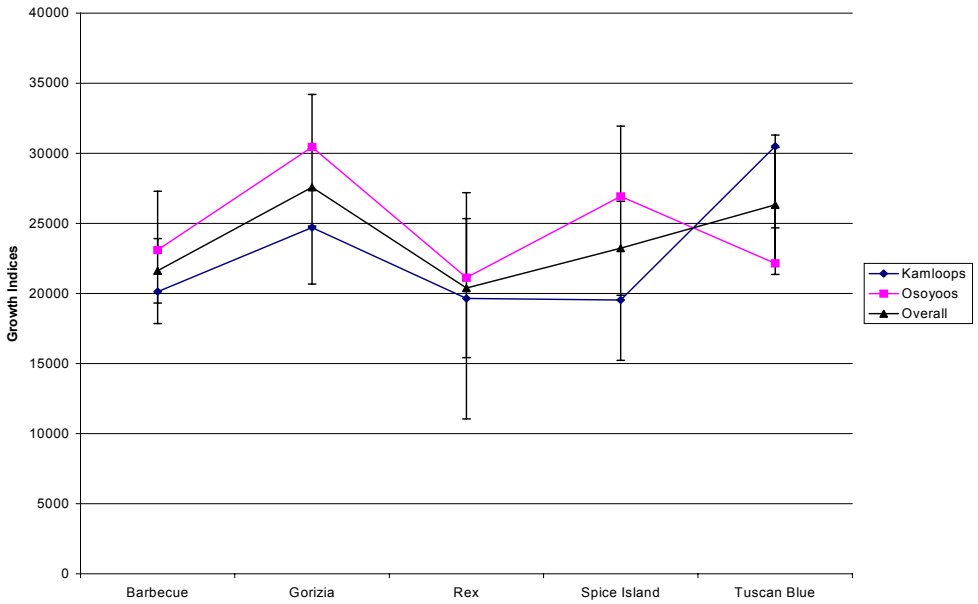


Figure 4. Average (± SE) Growth Indices of Rosemary Varieties Grown in Kamloops and Osoyoos Including an Overall Index Combining Height (h) and Spread (s) of Each of the Five Varieties ('Barbeque', 'Gorizia', 'Rex', 'Spice Island' and 'Tuscan Blue') at Both Locations



Determination of Yield/Ha and Oil Content of the Five Varieties of Lavender and Rosemary

The average herbage yield (g) and area (cm^2) covered by five plants of each variety of lavender and rosemary grown were used to estimate herbage yield/Ha and oil yield (kg/Ha) for each variety. These estimates are shown on Table 2 below.

Table 2. Estimated Herbage and Oil Yield in t/Ha and kg/Ha respectively of Five Varieties of Lavender and Rosemary.

	Herbage Yield of 5 Plants (g)	**SE of Herbage Yield of 5 Plants**	**Herbage Yield in t/Ha**	**SE of Herbage Yield in t/Ha**	**Oil Yield in kg/Ha**
Lavender					
Folgate	17.8	2.746	0.27	0.04	2.7
Grosso	103	16.917	1.55	0.25	15.5
Hidcote	34.4	4.13	0.52	0.06	5.2
Provence	92.2	12.138	1.38	0.18	13.8
Super Lavender	98	3.987	1.47	0.06	14.7
Rosemary					
Barbecue	282.8	36.98	4.24	0.55	42.4
Gorizia	325	36.421	4.88	0.55	48.8
Rex	267	59.24	4.00	0.88	40.0
Spice Isl	303	61.758	4.55	0.93	45.5
Tuscan Blue	380.4	34.731	5.71	0.52	57.1

Note. The area covered by five plants was 6750 cm^2. Oil yield was estimated as 1% of herbage weight.

Other Observations

During winter storage in 2003 some rosemary seedlings, particularly the 'Tuscan Blue' variety exhibited symptoms of leaf necrosis with brown spots followed by desiccation and dead within 2-3 weeks. Diagnostic tests at the Ministry of Agriculture indicated the presence of powdery mildew and root injury (Appendix 2).

Ecoways Environmental Services submitted this portion of the report

DISTILLATON OF ROSEMARY AND LAVANDER OIL AND THE EFFECTIVENESS OF THEIR ACTIVE INGREDIENTS AS A PESTICIDE AGAINST SPIDER MITES AND APHIDS.

Experiment 1. Distillation and recovery of Lavender oil.
This component of the experiment was conducted in Kamloops BC from early June 2003 to develop extraction procedures as well as to investigate the efficacy of extractions against selected horticulture pests. The study focused on distillation and recovery of the active ingredient linalool from various cultivators of lavender (*Lavandula officinalis*) plants with the aim of identifying cultivators with higher yield of the target active ingredient.

Methods and Materials
Six different varieties of Lavender (*Lavandula officinalis*) were harvested at various times during the summer and fall of 2003. The varieties include Hidcote, Munstead, Rosea, Lady, Provence and Grosso. Each variety was harvested separately and brought back to the laboratory for extraction.
The samples were allowed to dry at room temperature and finely ground to approx. 150 microns. They were then stored separately in labeled airtight re-seal able plastic bags.

Samples of each variety were separately extracted using the following techniques:

The Steam Distillation

- 500g of each test material was individually mixed with 2.5L of water in a 5L round bottom flask (broiler) attached to a 24/40 standard Kimax* Soxhlet extraction apparatus.
- Test powders were allowed to soak thoroughly in the water prior to heating.
- Cool water was run through the condenser, and the sample was then gently mixed under constant heat of approximately 98^0-100^0 C
- Distillation was continued until approximately 1500mL to 2000mL of distillate had been collected.
- The distillate was transferred to a screw capped 500mL centrifuge tube and 5mL of methylene chloride (dichloromethane) were added. The mixture was run in an industrial (IEC Model K centrifuge) for 2 minutes to achieve separation.
- Using a Pasteur pipette the bottom layer was collected and transferred to a clean Erlenmeyer flask.
- The distillate extraction was repeated three times and each subsequent methylene chloride extract was combined

To dry the extract

- To each methylene chloride extract was added between 4-5 small spatula scoops of anhydrous sodium sulfate and allowed to stand for 5-10 minutes.
- The dried methylene chloride solution was then transferred with a pipette (leaving behind the drying agent) in a pre-weighed beaker.

- The methylene chloride solution was then evaporated inside a fume hood over a warm hotplate.
- The % oil recovery is then calculated using weight of beaker minus the weight of remaining oil.

Results:
Variety 1. Hidcote, from each 500g of dried pulverized total plant stock was collected approximately 5-6mL of essential oil. Total oil collected was 100mL.
Variety 2. Munstead, from each 500g of dried pulverized total plant stock was collected approximately 6-7mL of essential oil. Total oil collected was 120mL.
Variety 3. Rosea, from each 500g of dried pulverized total plant stock was collected approximately 4-5mL of essential oil and a total 90mL.
Variety 4. Lady, from each 500g of dried pulverized total plant stock was collected approximately 5-6mL of essential oil and a total of 100mL
Variety 5. Provence, from each 500g of dried pulverized total plant stock was collected approximately 4-5mL of essential oil and a total of 95mL
Variety 6. Grosso, from each 500g of dried pulverized total plant stock was collected approximately 5-6mL of essential essential oil. Total oil collected was 100mL.

Discussion:
The overall oil recovery from the different varieties of lavender was in the range of 1-% essential oil to dry material. Oil recovery is typically around 1-2% maximum for lavender plants suggesting that the techniques used were sufficient for efficient recovery of essential oils.
In addition to producing needed essential oils, this technique also produced a distillate form that should be investigated for effectiveness against target pests. So far most studies have investigated essential oils and ignored solvent soluble extracts for potential insecticidal action.

Experiment 2: Distillation and recovery of Rosemary oil.

Distillation of rosemary was not undertaken because of inadequate supply of leaf samples.

Experiment 3: Bioassays on spider mites and aphids

The aim of this study was to investigate the effectiveness of various formulations of commercial rosemary oil against aphids and mites on tomatoes, peppers and roses. All experiments were conducted in a greenhouse facility at the University College of the Fraser Valley, Chilliwack, British Columbia. Daytime temperatures, inside the greenhouse, varied widely during the study, ranging from 19.5 to 44.7 ^{0}C . Plants used for insect and spider mite infection were purchased from local retailers or producers and were pest-free at the beginning of the experiments. Insects were collected from local greenhouses and colonies were established on test plants. Aphids did not establish on either roses or peppers and were continuously replenished with field or commercial greenhouse collections. Spider mites established well on roses but not on tomatoes.

Methods and Results of Essential Oils Efficacy Studies

Table 1 summarizes the procedures employed and observations made in various efficacy tests. Tests 7 and 8 on Table 1 suggest that liquid formulations of rosemary and lavender oil each at 2% concentration, is effective against both aphids and spider mites. The final formulation of the 2% rosemary-lavender mixture, caused 94.9 ± 3.650 mortality of mites on roses and 100% mortality of aphids on peppers.

Table 1. *Summary of Procedures and Results of Tests of Essential Oil Formulations against Aphids and Two-Spotted Spider Mites*

Test #	**Target Pest**	**Test Formulation**	**Procedure**	**Observations**	**Conclusion**
1	Aphids on peppers	0.5, 1.0, 1.5 and 3% rosemary & wintergreen oil in lethicin and water	Pepper leaves were sprayed to drip with test solutions then aphids were placed on the leaves. Trounce was used as a positive control.	Whereas Trounce caused 100% mortality, the test formulations produced 0% mortality at the concentrations tested.	The formulation containing rosemary, wintergreen and lethicin is not effective against aphids.
2	Aphids on peppers	Same as in Test 1 above	Aphids were individually placed on pepper leaves. Using a hypodermic syringe, 0.02 ml of test solutions were placed on each test aphid. Movement and mortality were observed.	Test solutions beaded on the aphids without spreading. No mortality was observed.	Spreading and wetting ability of the formulation is poor.
3	Aphids on peppers	The same stock formulation as in Test 1 above but with 0.3% surfactant added.	Aphids were either directly sprayed after placement on leaves or were placed on leaves after spraying. Trounce and/or water was used as a positive and negative control respectively.	Aphid Mortality was as follows; *Trounce*; 83% *0.5% Oils*; 0% *1.0% Oils*; 0% *1.5% Oils*; 6.7% *3.0% Oils*; 4.2% Whereas aphid mortality occurred in 54.0 seconds with Trounce, it took more than 4 minutes with effective test formulations.	Test formulations were less effective compared to Trounce.
4	Aphids on peppers	A new formulation of 1-% rosemary oil in 0.5% soap surfactant.	Same as Test 3 above.	Percent mortality for pooled data was as follows; Trounce; 90.8 ± 5.340 Rosemary 76.25 ± 3.612	t-Test suggests that mortality caused by Trounce was not significantly different from that caused by the rosemary oil.

5	Spider Mites on roses	Same as 4 above.	The number of mobile mites on a leaf was determined before and 30 minutes after treatment.	Observed mortality was- Water; 5% Rosemary; 25%	There is some indication of activity against spider mites. Higher concentrations may be more effective.
6	Aphids on peppers	2% rosemary oil in 0.5% surfactant, 2% lavender in 0.5% surfactant, and a mixture containing 2% lavender and 2% rosemary in 0.5% surfactant.	Same as 3 above	Percent mortality was as follows; *Rosemary alone*; 60% *Lavender alone*, 90% *Mixture*; 100%	This concentration did not cause plant injury as observed in preliminary tests with a 10% concentration.
7	Mites on Roses	Same as 6 above	Trifoliate rose leaves were placed in water vials to prevent mite escape. Numbers of mites before and 30 minutes after treatment were determined.	Mean mortality was as follows; *Lavender;* 92.4 ± 5.515 *Mixture;* 94.9 ± 3.650 *Rosemary;* 59.8 ± 14.782 Water 18.8 ± 12.242	Both oils and the mixture caused significantly higher mortality compared to the water control.
8	Aphids on peppers	Various concentrations of rosemary, wintergreen and lavender oil in 0.5% surfactant.	Aphids infecting pepper plants were counted before and immediately after treatment with various concentrations of test materials. Leaves were thoroughly sprayed using a spray bottle. Care was taken to achieve equal amounts of spray per treatment. The surfactant was used as a control.	Mortality was as follows; *1% Lavender*; 73.3 ± 6.667 *1% Rosemary* 60.7 ± 11.233 *2% Lavender* 86.2 ± 3.204 *2% Rosemary* 72.4 ± 3.359 *2% Wintergreen* 61.9 ± 11.900 *0.5% Surfactant* 50.4 ± 9.799	Mortality caused by 2% lavender was significantly higher than that caused by 2% wintergreen, 1-% rosemary and control. 2% rosemary was also more effective than the control.

Conclusion of Efficacy Studies with Commercial Oils of Rosemary and Lavender

What was discovered to give the greatest mortality against mites and aphids was a mixture of 2% rosemary and 2% lavender oil combined. There is need to conduct further studies with combinations of these active ingredients starting at 0.5% up to 2.0 %. These mixtures should be comparison with other approved commercially available products in large-scale field and greenhouse experiments.

CONCLUDING REMARKS

Optimum production of lavender and rosemary requires vegetative propagation by conventional methods (e.g. cuttings) or tissue culture. The findings of this study suggest that both plants can be propagated without the use of rooting hormones. Lavender can be propagated by semi-hardwood cuttings of the main stem in summer or by mound layering in spring, summer and fall (David H. 2002). Root divisions in the fall (Willis, A.R., 1991) can also be used. Rosemary was propagated by semi-hardwood cutting in our study but can also be propagated by layering (Willis, A.R., 1991). Organic growers considering propagating these plants for field production or for marketing as bedding or hedging plants need to ensure that they can maintain the required propagation conditions, particularly a temperature of about 18 ^{0}C and misting. A fogger such as the one used in our study was adequate in maintaining RH above 75 for a small propagation table. A well-drained rooting media is important for rosemary propagation.

In comparing the performance of the five varieties of lavender and rosemary, it should be noted that the two test plot locations experienced fairly similar temperature and precipitation during the study. Our findings suggest that among the lavender varieties tested, 'Grosso', 'Provence' and 'Super lavender' produced significantly more herbage than 'Hidcote' and 'Folgate' in Kamloops. This herbage yield data is supported by growth index data from both locations. The former three varieties will provide similar yields after one year of growth at both locations. Rosemary varieties showed no significant differences in yield and growth indices.

Growth index data also suggests that in general lavender performed better in Osoyoos than in Kamloops. Soil conditions may be responsible for these differences since climatic conditions were similar. Our herbage and oil yield estimates compare well with the 20 - 35 lb. of oil per acre of established lavender (Curtis, B., 2000). Similarly our herbage and oil yield data compared well with reported yields in other semi-arid parts of the world where herbage yield of 12.08 t/Ha were obtained with oil yield of 58.88 kg/ha (Munnu, S., 2004).

Both lavender and rosemary are susceptible to only a few diseases and insect pests. Powdery mildew as observed on our overwintering plants and root rots are the main cause of concern in rosemary. BC lavender growers should be aware of the potential devastating effect of rhizoctonia root rot. Growers trying to establish a cluster of lavender farms in 2000 in Gillespie and Blanco counties (Hill Country, Texas) lost 90% of 'Grosso' and 'Provence' plantings to rhizoctonia. These were the initial plantings intended for essential oil production (Curtis, B., 2002). Rosemary will require some form of winter protection except in Zone 8 and warmer regions. Alternatively it could be produced as an annual crop.

Our findings on the efficacy of lavender and rosemary oil against aphids and spider mites support the findings of other studies (Hori M., 1998, Rifaat M. *et al*., 2002). This new use of lavender and rosemary oils offers an opportunity for a new value-added market, hence requires further investigations.

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APPENDIX 1 SOIL TESTS RESULTS FOR REPRESENTATIVE SAMPLES FROM LAVENDER AND ROSEMARY PLOTS IN KAMLOOPS

APPENDIX 2 DISEASE DIAGNOSIS REPORT OF ROSEMARY SEEDLINGS SUBMITTED TO PLANT DIAGNOSTIC LAB, ABBOTSFORD BC