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Increasing Growing Points and Oil Yields in Lavender by Growth Regulator Sprays

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Abstract. Immature plants of *Lavandula angustifolia* × *L. latifolia* (cv. Twickle Purple) were sprayed with Atrinal and P293 when the growing shoots bore four to six expanded leaves. Atrinal increased the number of inflorescences per plant by stimulating otherwise dormant axillary buds on the shoots of the current season. The number of nonflowering shoots arising on older wood was also increased. The number of florets and the fresh weight per inflorescence were reduced, but the number of florets per plant was increased overall. Oil content per plant was doubled without altering oil composition or floret structure. Flower stalks were shortened below and between the floral nodes. Atrinal sprays achieved a machine-harvestable canopy in 3-year-old plants. Untreated plants required a full year longer to develop similar canopies. P293 and manual disbudding were not as effective as Atrinal. It is suggested that such spray treatments have a useful potential in reducing the time required for the development of the mature canopy form, and so obtaining earlier financial returns on establishment costs.

The *Lavandula* species used for essential oil production are normally slow-growing woody plants that may take 4 to 5 years to reach maturity and full oil production (Guenther 1949). During these years, the yield of oil is determined by both the characteristics of the inflorescence and the number of harvestable inflorescences per unit area. Inflorescence characteristics and their influence on oil yields have been examined in some detail in order to select better quality lines (Rabotyagov and Yakovlev 1980, Mukhortova 1977, 1980). Machine harvesting is being used more commonly, to increase the commercial efficiency of lavender crops. Efficient machine harvesting requires plants with even hemispherical canopies bearing the inflorescences at a uniform height. Immature plants have uneven canopies that are not suitable for efficient harvesting.

There is no evidence in the recent literature of any attempt to treat young plants with growth regulators in order to increase the number of vegetative and floral growth points and hasten canopy development. Such improvements would shorten the time to useful oil production and financial returns on establishment costs.

Each inflorescence arises from the terminal bud of a growing shoot. Apical dominance is strongly imposed by the developing terminal bud in both the vegetative and floral phases of the shoot. It is not until after the inflorescences senesce, later in the season, that some of the leaf axillary buds on the current season's shoots give rise to the shoots that will bear the next season's inflorescences. The rate of increase in the number of inflorescences on the plant, and hence the time required to reach useful oil production, therefore depends on the rate of increase in the production of these new shoots from the leaf axillary buds.

The work reported here describes attempts to break apical dominance by using growth regulator sprays during early spring growth in order to increase the rate of production of inflorescences and growing points from axillary buds in young plants. It was intended that the increased production of floral and vegetative growth points should increase the yield of essential oil and hasten the development of a canopy form that would allow harvesting at an earlier stage of crop establishment.

Materials and Methods

Plants

Three-year-old plants of a *Lavandula angustifolia* × *latifolia* hybrid (Twickle Purple) in their second summer in the field (1 m × 0.6 m row and plant spacing) were randomly assigned to treatment and replicate before spring growth had started. In the first week of October, when most shoots bore four to six leaves, the plants (three replicates per treatment) were treated as follows: control—no treatment of any kind; spray control—distilled water; manual disbudding—all apical buds removed with fine forceps at the same time as the other treatments; Atrinal spray—0.5, 1, and 2% (v/v); P293 spray—0.25, 0.5, and 1% (v/v).

All sprays contained 0.1% Multifilm X77 and were applied once only, to the point of run-off. Atrinal (Dr Maag Ltd.) contains 20% dikegulac sodium (sodium 2,3:4,6-bis-O-[1-methylethylidene]-O-L-xylo-2-hexulofuranosonate) as the active principal. P293 (Uniroyal Chemical) contains 39.2% 2,3-dihydro-5,6-diphenyl-1,4-oxathiin.

Measurements

Counts were made of the number of active growing points on the plants immediately before treatment in 1981. No significant differences between plants were found. Immediately before harvest of the inflorescences, floral and vegetative growth points were counted. After harvest, all plants were allowed to grow on without further treatment. In the following spring (1982), all counts of growth points were repeated to assess the persistence of the growth points induced by the spray treatments. All harvests were made at the same stage of development, when the maximal number of florets were open and the minimum withered (Porter et al. 1982).

The stalks of harvested inflorescences were removed below the lowermost floral node. Oil was obtained by steam distillation and analyzed by gas chromatography as described previously (Porter et al. 1982). Oil composition and yield values are based on samples of oil distilled from 100–300 inflorescences.

To detect any side effects of the spray treatments on inflorescence development, measurements of floret numbers, stalk and inflorescence lengths, and fresh weights of inflorescences were made on 10 inflorescences from each of the three replicate plants. Values for these parameters on a per plant basis were calculated from these data and from the number of inflorescences per plant. These inflorescences were visually examined for any abnormalities of floret development. The results were subjected to analysis of variance. Comparisons between means were made with t tests.

Results

The effects of the treatments on the number of vegetative and floral apices and the yield of oil are summarized in Table 1. Both chemical sprays and manual disbudding induced significantly increased numbers of vegetative shoots and inflorescences from axillary buds lower on the present season's shoots. Fewer of the floral growth points that were present before treatment persisted in the apical position on the shoots. The numbers of vegetative shoots were increased, especially from the more woody tissues of the previous season's growth. The chemical spray treatments and disbudding also delayed the development of the inflorescences to harvest maturity.

The effects of treatments on the essential oil content were not so consistent. The oil content per plant approximately doubled following the Atrinal treatments, while P293 and manual disbudding were ineffective. The chemical spray treatments did not significantly alter the levels of cineole, linalool, or linalyl acetate, or the ratio of linalyl acetate: linalool in the steam-distilled oil.

Oil content as a function of inflorescence fresh weight or inflorescence number was affected differently from oil content on a per plant basis. A possible explanation of this can be found in the data, summarized in Table 2, pertaining to the size and shape of the inflorescences. Atrinal decreased the fresh weight per 100 inflorescences. The number of florets per inflorescence, as well as the lengths of the inflorescence stalk, both below and between the floral nodes, was decreased. The data indicate that the fresh weight of the oil-producing florets was reduced to a greater extent than that of the less desirable stalks. As a result, the number of florets per mm of stalk was also decreased. However, there was a sufficient overall increase in the number of inflorescences, and therefore florets per plant, to produce a significant increase in the fresh weight of inflorescences per plant. All such changes brought about by

Table 1. The effect of growth regulatory sprays and disbudding on the number of vegetative shoots and inflorescences (expressed as a % of the growing points before treatment), oil yield, and maturity date in lavender. Apical inflorescences—developed without being permanently checked by the experimental treatments. Induced inflorescences—developed from axillary leaf buds after spray treatment had checked or eliminated the apical inflorescence from the shoot. (Inf = inflorescence).

		Inflorescences		Oil yield			
Treatment	Vegetative shoots	Apical	Induced	g/plant	g/100 inf	% fresh weight	Maturity date
Control	10.5	101.6	1.6	0.57	0.32	0.44	23.12.81
Distilled water	3.2	99.0	1.7	0.68	0.30	0.41	23.12.81
Manually disbudded	39.5	0.0	88.6	0.48	0.29	0.62	4. 1.82
Atrinal							
0.5%	32.1	43.3	208.0	1.05	0.22	0.66	5. 1.82
(v/v) 1.0%	49.5	4.5	281.7	1.18	0.19	0.48	5. 1.82
2.0%	43.7	0.0	313.3	1.09	0.22	0.66	12. 1.82
P293							
0.25%	0.0	90.8	10.8	0.62	0.41	0.48	23.12.81
(v/v) 0.5%	40.8	31.4	128.9	0.60	0.27	0.68	4. 1.82
1.0%	58.2	1.8	159.9	0.75	0.34	0.75	4. 1.82
Std error	7.8	5.6	32.3	0.14	0.05	0.08	
Comparisons between control and treatment means							
Manually disbudded	+32.7**	−100.8**	+87.0**	−0.15	−0.02	+0.20	
Atrinal	+34.9**	−84.4**	+266.0**	+0.48**	−0.10*	+0.18*	
P293	+26.2**	−62.3**	+98.2**	−0.03	+0.03	+0.21**	

The standard errors shown are derived from the pooled standard deviations for each parameter. The values shown for comparisons between means are the differences between the treatment means and the combined means of the distilled water and control data. An increase or decrease due to treatment is indicated by + or −, respectively. Significance levels for the differences between the means are indicated by ** and *, p = 0.01 and 0.05, respectively.

Table 2. The effect of growth regulator sprays and disbudding on inflorescence characteristics in lavender. Stalk length was measured from the top foliar node to the lowermost floral node and the inflorescence length from the lowermost floral node to the uppermost.

Treatment	F wt g/100 inf	F wt g/plant	Stalk length (mm)	Inf length (mm)	Florets /mm	Florets /inf	Florets /plant
Control	71.9	130.9	151.3	99.8	0.70	68.7	12525
Distilled water	82.7	161.6	156.2	107.3	0.65	69.5	13565
Manually disbudded	47.6	79.4	141.0	97.8	0.50	48.7	8129
Atrinal							
0.5%	33.8	160.7	95.3	69.3	0.39	27.1	12913
(v/v) 1.0%	38.3	238.6	86.3	82.0	0.46	37.2	23008
2.0%	34.1	164.9	68.0	90.9	0.44	41.0	19593
P293							
(v/v) 0.25%	74.8	114.3	153.8	107.0	0.59	62.8	9345
0.5%	40.7	88.6	155.7	105.3	0.63	67.2	14523
1.0%	45.4	101.0	126.3	82.0	0.56	44.9	9994
Std error	2.3	18.5	6.4	8.1	0.04	6.1	2134
Comparisons between control and treatment means							
Manually disbudded	−29.7**	−66.9**	−12.8	−5.8	−0.17**	−20.4*	−4916
Atrinal	−41.8**	+41.9*	−70.6**	−17.5*	−0.24**	−34.0**	+5460*
P293	−23.6**	−23.6	−8.5	−5.5	−0.08*	−10.8	−1758

P293 or disbudding were decreases, and while they were not all statistically significant, they resulted in a net decrease in the inflorescence fresh weight per plant. An examination of the plants failed to reveal any abnormalities in the development or the structure of the florets, vegetative shoots, or the inflorescences.

These results show that the two growth regulators affected the growth of lavender in a similar way to manual disbudding, but were often more effective. The comparisons of the overall treatment means indicate that Atrinal was more effective than P293. Comparisons within treatments suggest that 0.25% P293 was significantly less effective than 0.5 or 1%, and frequently had no effect compared with controls. Future work should include P293 concentrations greater than 1%. Fewer significant differences were found between means of the different Atrinal concentrations, but these suggested 1% to be optimal.

When the plants were treated in 1981, they were all small, with branches and vegetative shoots of irregular length, and so lacked the even hemispherical canopy of the more mature plant. At the end of the 1981 growing season, the chemically affected plants exhibited a much more complete and uniform canopy with branches of more even length. The control and unaffected plants still had incomplete canopies.

To determine the persistence of the treatment effects after two seasons' growth (spring following treatment in 1981 and spring 1982), another set of measurements was taken just prior to harvest in 1982. By this time, the control plants and those less affected by spray treatments had developed a more mature and uniform canopy. In marked contrast with the previous season, no significant differences were found between any of the treatments in the total number of floral or vegetative growth points per plant, the number of florets per inflorescence, or the lengths of the flower stalk or inflorescence, nor were there any differences in the composition or yield of essential oil at full bloom. These results indicated that the less affected plants must have produced considerably more floral and vegetative growth points in the second growing season, to catch up with the marked increase in growth point numbers in the first season induced by the growth regulator treatments. To illustrate this, Table 3 contains the values for the increases of vegetative and floral growth points (as absolute number of 1982 growth points − number of 1981 growth points). Unaffected plants (control, distilled water, and 0.25% P293) had significantly greater growth point increases in 1982 than in 1981. Conversely, the plants affected by the spray treatment had significantly smaller increases in 1982.

Discussion

After such marked enhancement of axillary bud development by chemical sprays in 1981, it was unexpected to find that no significant effect at all persisted through to the 1982 harvest. The differences between affected and unaffected plants were reduced in 1982 by two processes.

First, production of growth points in 1982 was much increased on control plants and those unaffected by the treatments in 1981. This was particularly noticeable with respect to inflorescence numbers (Table 3) and indicates that

Table 3. Increases in the absolute number of growth points of *Lavandula* in the two growing seasons following growth regulator spray treatment in spring 1981.

	Vegetative		Floral	
Treatment	1981	1982	1981	1982
Control	18.3	159.3**	19.3	315.7**
Distilled water	6.0	133.7**	1.7	283.3**
Manual disbudding	74.0	77.3	23.0	282.0**
Atrinal				
0.5%	56.3	87.7	281.3	23.7**
(v/v) 1.0%	109.7	102.3	385.3	13.7**
2.0%	68.3	101.7	325.0	37.7**
P293				
(v/v) 0.25%	1.0	114.3**	3.0	265.3**
0.5%	54.7	85.0	80.0	238.7*
1.0%	78.3	69.7	81.7	230.3*
Std error	10.0	33.0	31.0	52.1

the 1982 growing season coincided with the period of fastest development of the untreated plants. Climatic factors were extremely favorable for lavender growth. Also, the naturally rapid, final stages of canopy development in other nearby plants of this particular cultivar occurred in 1982.

The second process concerns the development of the shoots induced in 1981 by the chemical sprays. The Atrinal-treated plants did not match the natural 1982 growth point production rate of the controls, despite apparently very favorable growing conditions. From examination of these plants, it appeared that perhaps fewer axillary buds capable of producing inflorescences in 1982 were formed on the shoots induced by Atrinal in 1981. These shoots, induced in 1981, were shorter and tended to have fewer leaf nodes than the corresponding shoots in unaffected plants. Alternatively, of the axillary buds that were formed, fewer may have been released in the summer of 1981 from the apical dominance of the terminal inflorescence to produce inflorescences in 1982.

In contrast, the manual disbudding resulted in little more than the replacement of the removed buds, during the first season. Inflorescence production in the second season was the same as for the controls. The lower axillary buds were not stimulated at the time of treatment as much by manual disbudding as they were by Atrinal. Consequently, they were able to contribute significantly to inflorescence production in 1982.

Some treatments therefore induced axillary bud growth and branching in 1981 that normally would have occurred in 1982. The induced shoots did not have the ability to maintain the rapid rate of growth point increase into the second growing season after treatment. It is also worth noting that there was no net loss in 1982 of the shoots induced by chemical sprays in 1981. Spray-induced growth point increases were therefore maintained.

A number of points relevant to the establishment of lavender crops have been demonstrated by the results presented above. The apical dominance, which normally strictly controls the sequence of vegetative and floral growth in lavender, can be temporarily removed by an exogenous growth regulator to give significantly greater numbers of inflorescences. Essential oil yield was doubled by treatment with Atrinal without significantly affecting oil composition. However, before this approach is used to increase oil yields on a routine basis, these results must be confirmed over a longer term because of the effect of Atrinal on the rate of growth point increase into the growing season following treatment.

The growth regulators brought about increased numbers of vegetative growth points arising on the current and previous seasons' shoots. The induced vegetative growth points also persisted into the following year's growing season and, together with the increased inflorescences, represent a useful tool with which to bring about the development of the complete, hemispherical canopy that is characteristic of the more mature plant. Such a tool has two possible uses: first, to encourage the repair of canopies that may have been opened up by damage or disease; second and more important, to hasten the development of the mature type of canopy form and increase the number of inflorescences. The untreated lavender plants used in this study would not have contributed commercially to oil yields until their fourth year, that is, until they had developed the mature type of canopy. This is partly because of low inflorescence number but also because the inflorescences on immature plants are held at uneven heights, making machine harvesting inefficient. The plants treated with Atrinal developed the mature canopy form by harvest time in their third year. Although these plants had not achieved their final mature dimensions, their mature canopy form would have allowed mechanical harvesting, and a return on establishment costs, a full season earlier than normal. It may be possible to achieve an even earlier return by treating 2-year-old plants in their first season in the field.

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