DILL HERB OIL — AN ALTERNATIVE TO TRADITIONAL CROPS?

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ABSTRACT

The production of dill herb oil is used as an example of an essential oil crop that can be grown in Canterbury. Experience from 4 years' cropping is briefly summarised, including crop establishment and management, climatic effects, harvesting and oil extraction.

The ranges of variation of oil content and composition are described for whole plants and for the different parts of individual plants. Seeds were the most efficient producers of essential oil on a fresh weight basis. Oil yield and carvone content peak sharply, necessitating close monitoring and accurate timing of the harvest to set the best return from the crop.

It is suggested that dill crops being grown locally for high carvone oil should be managed to produce maximal seed head and minimal stem material. Preliminary results are presented from experimental manipulation of crop plants to achieve this aim.

Aspects of the development of the dill crop which have relevance to other essential oil crops are summarised.

Additional Keywords: *Anethum graveolens, yield, oil composition, development, manipulation, essential oil.*

INTRODUCTION

Essential oils are produced for the food, pharmaceutical and perfume industries using plants belonging to many different families and climatic zones. Those of most interest to New Zealand are of temperate or mediterranean origins (e.g. Bouisson, 1979). Essential oils for export sales have been produced in commercial quantities in Canterbury from peppermint, dill and parsley. Work on the physiology of oil production and screening of oil composition to establish lavender as an essential oil crop is currently under way (Porter *et al.*, 1982; 1983). A number of herb species, including sage, thyme and tarragon are now grown for fresh herb leaf and production could also be expanded for essential oil extraction. Agronomic expertise in New Zealand is sufficiently good to allow such plants of suitable climatic origins to be seen as potential crops of raw materials for the production of essential oils. They should be regarded as possible alternatives to traditional crops.

Essential oils are complex mixtures of chemicals derived mainly from the terpene group of compounds. Small changes in the chemical structure can lead to marked changes in smell, taste and volatility. Changes in the level of one component of the complex mixture can markedly alter the overall aroma or flavour of the complete oil. Essential oils may be very volatile and are commonly responsible for the characteristic aroma of the plants in which they are found. Commercial production of essential oils usually involves bulk mechanical harvesting procedures. Steam distillation is commonly employed to volatilise the essential oil components and extract them from the plant material.

This paper is an account of the development of a dill herb oil crop. Export market requirements were for an oil high in carvone. The biochemical and physiological work was aimed at defining the optimal harvest time and plant form for maximal yields of such oil. Field observations were combined with these findings to indicate what management tools should be used to obtain optimal returns.

CROP MANAGEMENT OBSERVATIONS

Dill (*Anethum graveolens*) was first grown 4 years ago, northwest of Christchurch, as a commerical crop for the export market — in this case, the food industry. The first year showed that a presentable crop of dill could be established and that oil could be extracted using standard steam distillation techniques. During the next 3 years, these very briefly summarised points became obvious.

Production of the crop

a) Climate

Recent drought conditions have clearly illustrated the need for irrigation to be available to maintain crop growth, especially during seed fill. In 1983, seed size was reduced 25-30% in non-irrigated crops. Wind can cause significant loss of the early ripening seed and so reduce the yield and quality of the oil. High temperatures can greatly accelerate the ripening process in the seed heads and increase the risk of missing the peaks of oil yield and carvone content. Shelter and irrigation must therefore be prime considerations in selecting crop sites.

b) Crop establishment

The dill crops have been established using standard cultivation practices for small-seeded crops and precision seeders. Control of weeds is most important as weed material that is harvested and steam distilled with the crop material can seriously affect the colour, flavour and aroma of the oil. This may lead to a significant reduction in overall quality, and therefore, market price. Pre-emergent weed control must be used (e.g. Trifluralin). A row spacing of 50 cm allows easy mechanical access for inter-row cultivation. Best weed control to date has been achieved by successive post-emergent applications of Linuron and Gesagard (0.48 kg/ha each) between rows during cultivation. Being an annual, dill can be fitted into normal rotation patterns easily. Locally, it has been found that dill has performed well and weed control has been easier when spring-sown into ground fallowed over winter after cereals.

Disease and insect damage have not been a problem in dill so far but have reached significant levels in other essential oil species in Canterbury.

c) Crop management

Observations in the last 2 seasons have shown that the habit of the individual crop plant can vary markedly between the crops at different sites. Analyses of the origin and composition of the oil in the crop plant (see below) indicated that the seed heads were the most efficient and the stems the least efficient producers of oil. It was also found that the timing of fertiliser application and irrigation could have significant effect on the degree of branching and the composition of the oil. Starter fertiliser and irrigation during the early establishment of the crop and again during seed set gave maximal branching, seed head numbers, oil yield and carvone content. Encouragement of stem growth and increase in plant height by fertiliser or irrigation during the vegetative stage before flowering lead to lower levels of carvone and lower oil content on a fresh weight basis.

Such management techniques can be very effective in 'adjusting' the oil composition to market requirements. It is most important that the success and effectiveness of such 'adjustments' is monitored by detailed analyses of composition and yield.

Harvesting and oil extraction

In dill and many similar herb species, the majority of the plant is taken for oil extraction and harvesting can be achieved with standard equipment. The dill crop is cut with a windrower to take all the seed heads but to leave as much stem behind as possible. It is left for a few hours to reduce the moisture content and then picked up and chopped into a large enclosed tub by a standard silage cutter. The tubs are transported and connected directly to a stationary boiler. Steam distillation consists of feeding live steam directly into the tubs, to heat the tub and its contents. The emerging steam and volatiles are led first through a condenser and then into a separator from where the oil is run off into clean storage containers without further treatment.

Obviously, the tubs and boiler are specialised equipment and represent considerable capital investment. Some important aspects of this specialisation must be considered.

To increase returns on the investment, a crop production programme should be planned to have the boiler working as long as possible through the growing season by having a cooperative venture supplying material from different species at different times of the year.

The steam distillation facilities must be available for each crop when it reaches its optimal harvest ripeness. With dill, analyses have demonstrated very rapid and significant changes in oil yield and composition as ripening advances. For the best commercial return, such changes must be monitored by analysis. There should also be some flexibility in the timetable of the distillation plant to allow for changes in the pace of crop ripening.

If, as is the case with this exercise, the boiler is stationary at one particular site, there will be a maximum economic distance from which raw material can be transported to be distilled. This distance will depend on the expected oil yield per tub, the price of oil on the market as well as the running costs of the boiler and transport. This means that essential oil crops will probably be grown in restricted areas defined by the central positioning of the distillation plants.

Marketing the product

Essential oils have some attractive properties. They are low volume products and therefore cheaply and easily shipped. They are processed entirely within New Zealand. Provided they are stored under refrigeration in clean containers and degassed with nitrogen, they will store for a considerable time without serious degradation. The summary above indicates that an enterprising farmer could efficiently produce essential oil for sale, if he is prepared to invest time in the crop and his own education. Selling the essential oil produce is a very different process. I would strongly recommend that oil producers approach marketing specialists to dispose of their product. Prices and demand fluctuate rapidly in the international essential oil markets and this requires the reputable expertise of an established marketing organisation with effective market contacts for successful sales.

There is an equally important function to be served by the marketing organisation and that is to obtain for the grower and the analyst, specifications of the products that the buyers are looking for. The grower and analyst can manage a dill crop to produce very different oil compositions. The best financial returns can only be obtained when the buyer's latest requirements are known accurately by the grower and met by good crop management. This requires detailed knowledge of the different markets and effective contact with commercial firms who are willing to produce information for use by the grower and analyst.

BIOCHEMISTRY AND PHYSIOLOGY

To get the best out of the crop, it requires considerble physiological and biochemical expertise and facilities to tap three areas of information.

Origin of the essential oil

In dill, essential oil may be found in all parts of the plant but the composition, and therefore the character of the oil, may vary markedly from one plant part to another. Oil content, as a function of fresh weight of the plant part, also varies greatly. The grower must know where the most desirable components of the oil are accumulated so that he can adjust his harvesting techniques to leave behind the unproductive or undesirable plant material.

Dill herb oil is extracted from the combined aerial parts of the crop plant. Fig. 1 illustrates how the oil content and composition can differ between those parts. Table 1 contains the calculated values for the percentage contribution of those individual parts to the total oil composition and yield. The stems and leaves contribute virtually nothing towards a desirably high carvone level but constitute a major part of the fresh weight to be passed expensively through the still. For high carvone oils from dill crops, the obvious recommendation is to leave as much stem material behind at harvest and to manage the crop to get the umbel/stem + leaf ratio as high as possible. With steam distillation costs so high, translating such data into crop management technique can lead to significant savings.

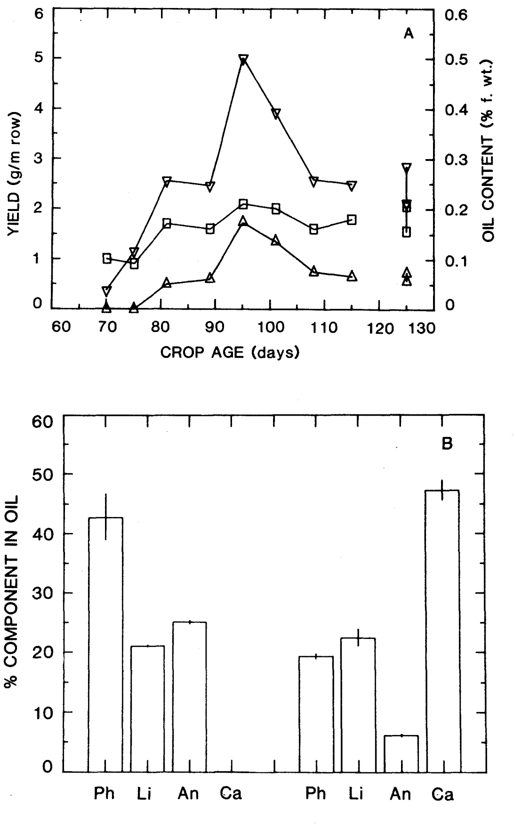

Figure 1: A. Essential oil yield (▽) and content (□) and carvone yield (△) of dill crop plants. The vertical bars represent the least significant differences at the p = 0.05 level.
B. The levels of major components in the essential oil of dill crop plants at flowering (left) and at harvest (right). The vertical bars represent the standard errors of the means. Ph — phellandrene, Li — limonene, An — anethofuran, Ca — carvone.

TABLE 1: Percentage contribution to the harvested total fresh weight, oil and carvone contents of seed heads, stems and leaves of dill crop plants. Within columns, means bearing the same suffix do not differ significantly at the P = 0.05 level. (From Porter *et al.*, 1983).

Plant part	Fresh weight	Oil	Carvone
Primary seed head	26.5 b	60.9 c	70.9 c
Secondary seed head	17.4 a	33.5 b	27.8 b
Stems	41.8 c	4.1 a	1.4 a
Leaves	14.5 a	1.7 a	0.0 a

Timing of the harvest

It is obvious from Fig. 1 that both oil yield and composition of the whole plant vary markedly with time, even from day to day. In intact plants, the yield can change by 50% from the peak measured in a few days. In a season in which wind and a lack of water combined to cause a marked reduction in seed size and a significant loss of the early ripening seed from the seed heads, the oil yield was reduced by over 50% from that of the previous season. As carvone is found only in the seed at this stage, the quality of the oil was markedly reduced. Data from parsley indicates that similar shifts occur in oil content and composition. In both dill and parsley oils, changes in the proportions of the saturated and oxygenated terpene compounds as ripening progresses cause alterations in the aroma of the oil which, in turn, alters the suitability for any given market.

The timing of the harvest must therefore afford the best yield of oil of the composition sought by the market, hence the prime importance of obtaining information from the market place to define this particular composition. With the aid of modern analytical facilities, it is routine to monitor oil composition and indicate when the market composition has been reached.

The growth habit of the crop plant

This aspect of the work includes observations on how the habit can be altered to give optimal yields of the desirable plant material, and how those alterations can be brought about by practical agronomic procedures. As a result of the observation summarised in the crop management section above, a preliminary plant manipulation experiment was set up to force a change in habit which would lead to an increase in branching and in the ratio of seed head to stem and leaf material.

EXPERIMENTAL

Materials and methods

All samples of plant material were taken from commercial crops, sown in early October 1982. Row spacing was 0.5 m and the average plant density was 56 plants per metre of row.

Manipulation of the plant growth was done at two different stages of flower development by two forms of pruning — chopping as an easy method for the grower; and removal of the primary growing point to simulate reduction of apical dominance by spray treatment.

Pruning

— chopped all plants were cut off at 15 cm above ground level.

— disbudded the plants were left intact except for the removal with forceps of the uppermost leaf and the enclosed apical bud.

Timing

— early when the primary umbels were about to emerge from the bud scale (11/1/82).

— late when the primary umbels had expanded and the individual flowers were about to open (20/1/83).

Control plants were not pruned in any way. All these plants were harvested at the same time as the rest of the crop.

Duplicate subsamples of 10 randomly chosen plants were taken from the bulk samples brought in from the field. Data on the umbel, combined stem and leaf fresh weights and umbel numbers were taken from each of the 10 plants. Oil content and composition data were obtained from the combined 10 plants of each subsample. Total fresh weights per metre of row were obtained from the bulk samples and were used to calculate value for the oil and carvone yield per metre of row. Details of oil extraction and analysis have been described (Porter *et al.,* 1982).

RESULTS

Improvements to oil and carvone yield were achieved (Table 2) but these arose from an increase in the total fresh weight per metre of row, rather than consistent increases in the number of seed heads or carvone content of the oil. In the late chop treatment, only a marginal increase in seed head numbers was obtained and these were late to develop, and did not result in an increase in the seed head fresh weight at harvest.

TABLE 2: The effect of pruning on the growth of dill crop plants. Within rows, means bearing the same suffix do not differ significantly at the P = 0.05 level. The parameter Seed head/stem + leaf is the ratio of the seed head fresh weight to the combined fresh weights of the stems and leaves.

		Disbudded		Chopped	
	Control	Early	Late	Early	Late
F. wt./m row (g)	654 a	891 b	1095 c	609 a	649 a
Oil/m row (g)	1.76 a	2.05 a	3.18 b	1.83 a	1.23 a
Carvone/m row (g)	0.49 a	0.61 a	0.93 b	0.54 a	0.43 a
Seed head/ stem + leaf	0.24 a	0.19 b	0.21 b	0.22 a	0.25 a

The reason for the decrease in the seed head/stem + leaf ratio is not clear from the table. The lack of rain and available irrigation during seed development resulted in very small seed that was easily lost from the fully mature primary seed heads. A significant number of seed heads died after failing to set seed. These were not included in the values for seed head fresh weight used to calculate the ratios in Table 2, which are therefore conservative.

Further work suggests that the treatments were applied too late in the plants' development. The response of these dill plants to manipulation must therefore be regarded as the least that could be expected. Despite this, some improvement in total oil and carvone yields were obtained but these must be confirmed on a larger scale under more favourable conditions.

DISCUSSION

This work with dill has emphasized a number of important aspects that must be considered by growers of any essential oil crop, in addition to the usual considerations of actually growing the crop.

1. Definition of what the grower ought to produce requires accurate information about the product specifications required by the market. Such information and contacts must be effective enough to bring about sales. Local experience has shown that it is extremely difficult to obtain such information and clinch sales without the help of reputable intermediaries who are recognised in the market place. In fact, this has proved a more serious problem than being able to produce the oil as efficiently as anywhere else in the world.
2. Analyses must be accurate, accessible and rapid enough to provide the grower with a current picture of the oil content and composition at all stages of crop development.
3. Sufficient analytical data must be rigorously interpreted to define the composition of the oil in the different parts of the crop plant and which part produces the desirable components of the oil most efficiently. Such information is essential to achieve maximal harvest indices. By encouraging dill seed head production and minimising stem material during harvest, local yields have been increased 74% to 86 kg/ha and carvone contents have been improved 30% to 39%. These performance figures compare favourably with Canadian data — 67-88 kg/ha and 37-42% carvone (Chubey and Dorrell, 1976). In contrast, lavender oil is taken only from the inflorescences in full flower and excessive stalk or leaf material confers an undesirable 'grassy' note.
4. Field observations and physiological principles should indicate how much the growth habit of the crop can be altered to encourage maximal production of such efficiently producing material. The present studies have indicated that changes can be made to the habit of the crop plant with the timing of fertiliser and irrigation. The potential of synthetic growth regulators are becoming better defined (e.g. Thomas, 1982). They have proved successful in improving both the oil yield and growth habit of lavender (Porter, in press) and are currently being examined for use with dill. They should be considered for other essential oil crops should section 3 indicate that an adjustment of the growth habit would

be beneficial to crop performance.

5. Experiments on a crop scale should bring the four previous aspects together to indicate if the desired effects can be achieved by practical means, and so result in increased production of a desirable essential oil. The production figures and the market price from the 1982 season give the grower a return of $1420-1720/ha, after distillation and transport costs have been deducted (Rainey, pers. comm.). This compares very favourably with a gross return of $760 for barley grown on the same ground in the season following the dill.

Local experience has therefore shown that an essential oil crop in Canterbury can perform to world standards, and provided it can be sold at prevailing world prices, dill herb oil can be presented as a viable alternative to some of the more traditional crops.

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