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Enhancement of Flavour in Strawberries Grown Under Protection
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Strawberry Production in California
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Organic Strawberry Production
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Sourcing Labour
Ann McCrudden, Dalmac Institute, Rush, Co Dublin

Strawberry Production and Packaging in Scotland
Peter Stirling, Windyhill Farms, Arbroath, Scotland

Fungal Diseases of Raspberries and Related Crops
Brian Williamson, Scottish Crop Research Institute, Dundee

Botrytis, Powdery Mildew and Blackspot of Strawberry
Angela Berrie, Horticultural Research International, East Malling, UK

ENHANCEMENT OF FLAVOUR IN STRAWBERRIES GROWN UNDER PROTECTION

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INTRODUCTION

Good flavour in strawberry fruit is an attribute, which is gaining increasing importance in the production of strawberries. It is possible that the flavour of modern strawberry varieties has been sacrificed to an extent as a result of intensive production, and the tendency towards optimising yields, fruit shape and colour, and breeding resistance to pests and diseases. Flavour is now being ranked as being of equal importance with respect to other quality parameters. A research programme has therefore been put in place to identify the factors that influence flavour. The ultimate objective is to incorporate improved flavour into intensively produced strawberry fruits

The aim of this investigation was to isolate some of the factors which may influence strawberry fruit flavour. This required focusing upon the effects of applying nutrient solutions to the crop over the growing season. The variety selected for analysis was Elsanta. This is still the most widely grown variety in commercial production. For the purpose of this research it was grown under protection.

BACKGROUND

The field grown strawberry has always been judged to possess a far superior flavour in comparison to imported or tunnel grown strawberries. However, the tunnel grown crop is an extended season fruit, and represents an increasing portion of the fresh strawberry market every year. Due to its increasing importance it is necessary to improve fruit flavour so as to equal that of the field grown strawberry. This would result in improved market demand for the early and late season fruit.

In order to establish pointers for the research it was necessary to look at the field strawberries, and to find a common trend which could be associated with the good flavour. Closer examination of the areas used for producing field grown strawberries revealed that the soils are generally derived from shale. Shale soils are high in potassium, low in calcium and low in nitrogen. Applying a similar combination of nutrient levels to tunnel grown strawberries formed an important part of the investigation into improving the flavour. In a further experiment zinc, an element which is known to be involved in the assimilation of carbohydrates and the fruit's ability to sustain adequate sugar levels was included. Other aspects of this research involved focusing upon specific conductivity(SC) levels and different feeding regimes.

ASSESSING FLAVOUR

Flavour of fruits and vegetables is a combination of two aspects, an impression on the tongue (taste), and an impression on the nose (aroma). Taste consists of five main components; i.e. sweet, sour, bitter, salt and quinine. Aroma has numerous dimensions and due to its complexity is a more difficult quality to assess.
In the measurement of taste, sweetness (sugar content), is estimated by refractometric index, sourness (acidity), is measured by titration or pH. From these measurements the sugar-acid ratio was calculated. This is a chemical method of assessment. The sugar-acid ratio portrays a blend of the sweet and sour aspects of the fruit. In fruits the balance between sugars and acids is equally as important as the individual levels of each. It is often considered that the higher the level of sugars, the riper and sweeter is the fruit. Acidity is also important with respect to both flavour and the overall wholesomeness of the fruit.
Aroma can be assessed by using gas liquid chromatography and mass spectrometry, but is assessed most effectively by sensory analysis. The taste panel was therefore an important aspect of this research. Tasters were asked to rank flavour from best to least good. The total rank score for each sample gave an indication as to whether the sample flavour was significantly better or poorer.

NUTRIENT BALANCE IN THE FEED

A control liquid feed (Kinsealy liquid feed) was selected and four specific nutrients were isolated within this feed, i.e., potassium (K), calcium (Ca), nitrogen (N) and zinc (Zn). The concentrations of K, Ca and N were altered to produce a number of nutrient solutions for application to the crop. This gave the opportunity to detect how each element affected fruit flavour. Different combinations of high, medium and low nutrient concentrations were applied. Zinc was simply excluded from one of the nutrient solutions to examine the effect of its absence.
The purpose of the investigation was to assess the effect of a high level of K in the feed on the flavour of the strawberry, or conversely, whether or not a low level of K would result in a reduction in the fruit flavour. Both high and low levels of K were also combined with various levels of Ca and N, in an attempt to establish the ideal nutrient balance in the liquid feed. The exclusion of Zn from the feed was also considered to be important in assessing the factors affecting fruit flavour. These nutrient feeds were examined over four growing seasons from Spring 1997 to Autumn 1999.
Results from both sensory analysis and the sugar-acid ratio identified a significant improvement in flavour for one particular treatment, (Fig.1). This nutrient solution was high in K, and low in Ca. Taste panels found that flavour improved consistently with increasing K and reducing Ca over the four seasons, with an overall average improvement of 15%, when compared to the control feed. A high sugar-acid ratio was also observed for this treatment at 9.34. This ratio was derived from high levels of both sugars and acids, therefore giving an accurate indication of improved flavour in the sample.
The benefits of high K were lost however when combined with high levels of both Ca and N. This feed resulted in a 9% loss of flavour compared to the control, and a lower sugar-acid ratio of 8.79.
The low K, high Ca combination, and the low K, Ca, N treatments resulted in flavour reductions of 2% and 18% respectively. This loss of flavour was also reflected in the sugar-acid ratio measurement.

According to the sensory analysis the absence of zinc from the nutrient solution reduced flavour by 12%. A low sugar-acid ratio was also observed in this treatment, due to reductions in both sugars and acids. This treatment produced the lowest sucrose content of all the feeds, averaging approximately a 5% reduction compared with the control.
Results of both the taste panels and sugar-acid ratio also highlighted that in the Autumn experiments there was an overall flavour reduction in all treatments compared to the Spring experiments. It is probable that this reduction in flavour was due to the reduced light intensity during the August to October period.

SPECIFIC CONDUCTIVITY (SC)

The effects of the different SC levels that were related to changes in the increased strength of K in the feed were investigated. The control feed had an SC value of 160. The second feed that was high in K had a slightly higher SC value of 164. The third feed contained a very high concentration of K, and hence had a higher SC value of 242. The first seasons trial was treated with water as a pre-flowering feed. The starter feed (Table 1) was applied for the second season.
Results of both sensory analysis and the measurement of the sugar-acid ratio, clearly indicate that the high SC of 242 produced the best flavour, (Fig.2). Sensory analysis showed that flavour for this treatment improved by 29% and 43% for seasons 1 and 2 respectively, in sensory analysis. The highest sugar-acid ratios were also observed at 8.67 and 8.17.
The SC of 164 also produced flavour improvements of 5% in the first season, and 17% in the second. The sugar-acid ratio showed only a slight improvement over the control in the first trial. This increased by almost 13% in the second season.
Considerable increases in the flavour of the fruit samples were noted between the first and second trials. This shows the beneficial effects of using a pre-flowering nutrient feed.

FEEDING REGIMES

Different feeding regimes all combining pre-flowering and post-flowering feeds were investigated. Three pre- flowering feeds were used: water, half strength Kinsealy feed (starter) and full strength Kinsealy feed (standard). Each of these treatments were then sub-divided and a further three post flowering feeds were applied. These were the standard, a high K feed and a high K-high SC feed, (Table 1). These combinations produced nine different feeding regimes. The control was regarded as being the starter/standard feeding regime.
Results indicated that the strongest pre-flowering feed, i.e. the standard feed, produced the highest level of flavour when combined with each of the three post-flowering feeds, (Fig. 3). Improvements of 15% and 13% were shown for the standard/standard, and the standard/high K-high SC feeds respectively. A standard/high K regime also produced a flavour improvement of 6%.
For the mid-strength pre-flowering feed, (starter), improvements were also observed. A starter/high K combination and the starter/high K-high SC feed gave flavour improvements of 5% and 4% respectively.
Using water in the pre-flowering phase resulted in the lowest levels of flavour. A combination of water/standard resulted in a 4% loss of flavour. Both water/high K and

water/high K-high SC produced flavour improvements of 2%. This is much lower than the other treatments.
The sugar-acid ratio tended to reflect similar results. The ratio increased with the strength of the pre-flowering feed, and in most cases also increased with the strength of the post-flowering feed.

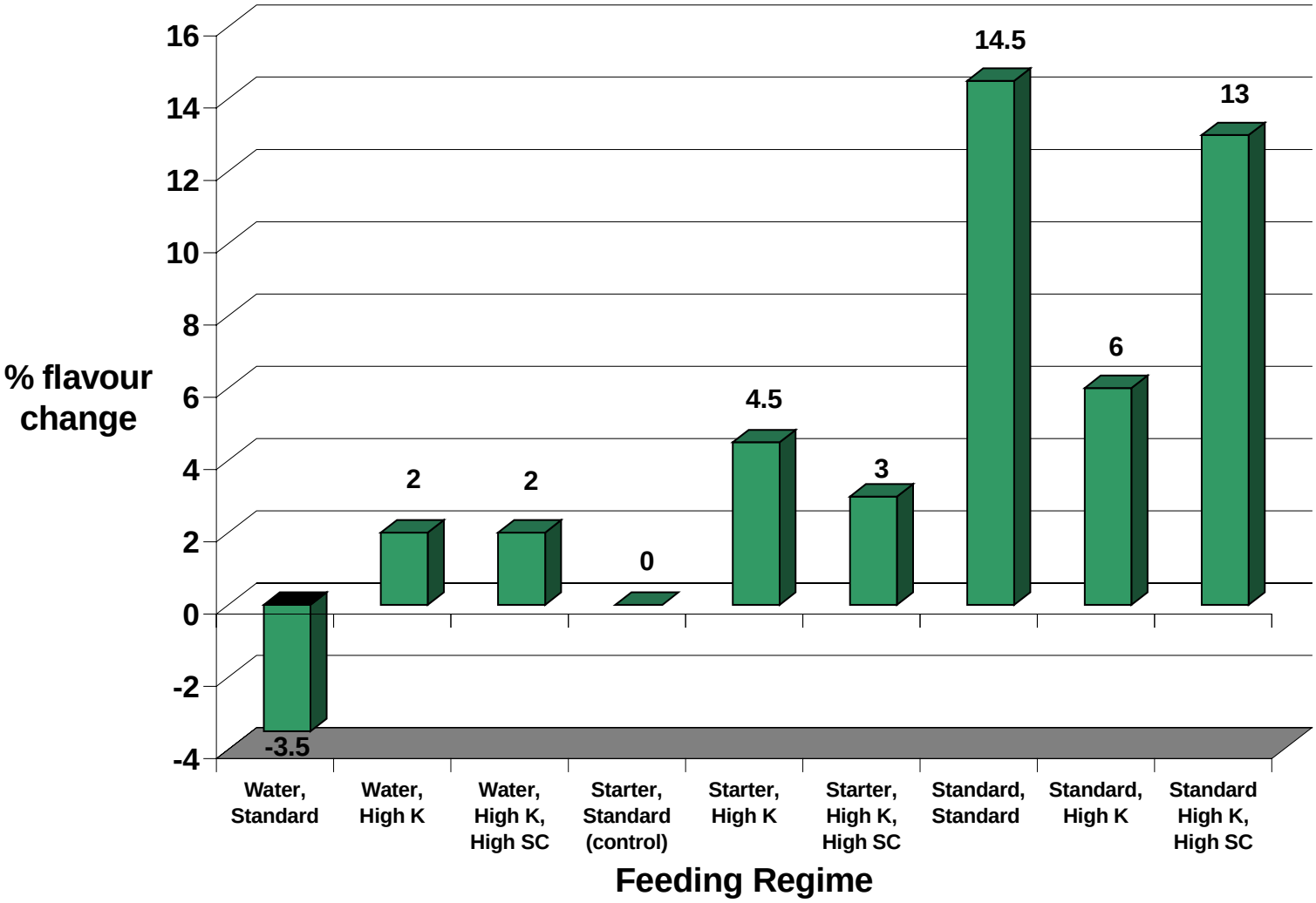
SUMMARY

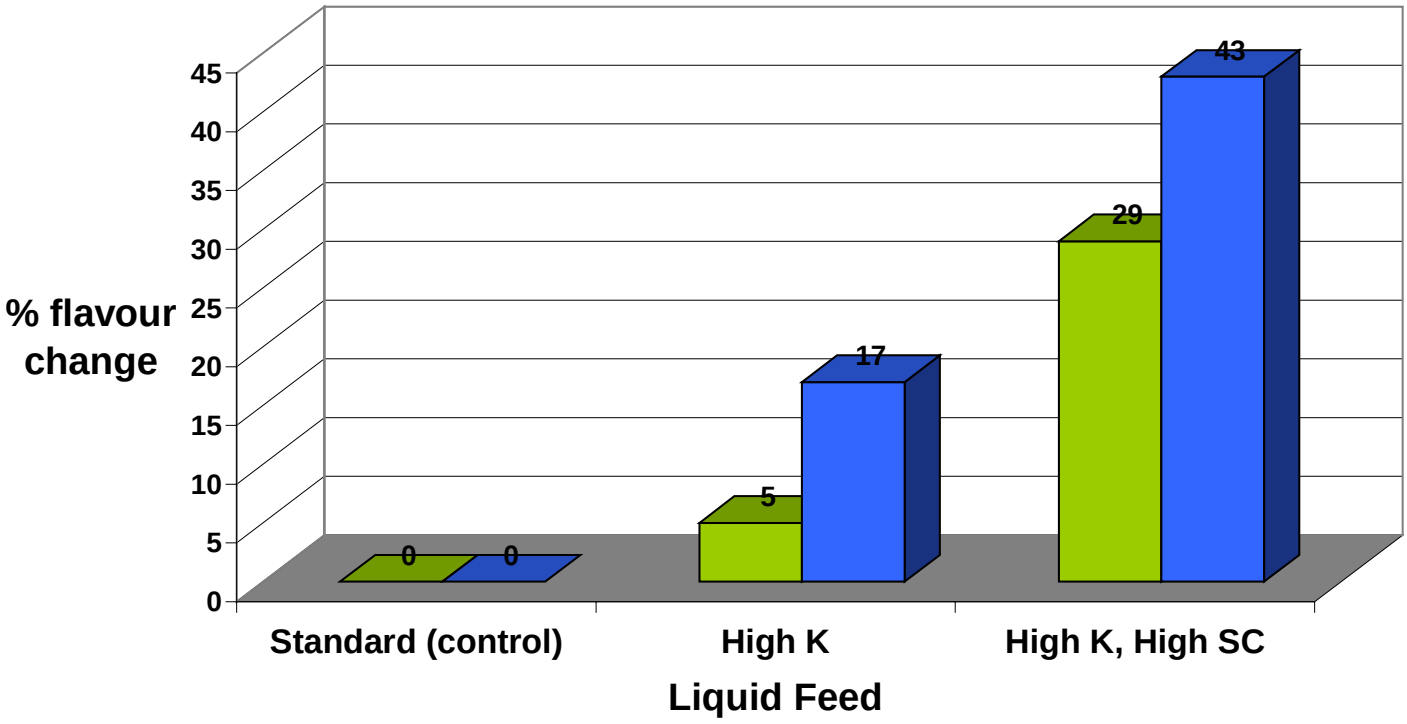
- High K improves fruit flavour and sugar content
- High N and Ca reduces fruit flavour and sugar content
- Zn is required to maximise fruit flavour
- High light intensity may improve fruit flavour
- High SC rates may improve flavour
- Feeding regimes may affect fruit flavour

Table 1 : Macronutrient target composition of feeds

Feed	m equiv/l						
	NO_3^-	HPO_4^-	SO_4^{--}	NH_4^+	K^+	Ca^{++}	Mg^{++}
Starter	5.5	0.65	1.375	0.5	3.5	2.5	1.0
Standard	10.5	1.3	2.75	0.5	7.0	5.0	2.0
Hi K	8.5	1.3	4.75	0.5	9.0	3.5	1.5
Hi K, Hi SC	12.75	1.95	7.125	0.5	13.5	5.25	2.25
	mg/l						
	N	P	S		K	Ca	Mg
Starter	84	20	22		137	50	12
Standard	154	40	44		273	100	24
Hi K	126	40	76		352	70	18
Hi K, Hi SC	185	60	114		528	105	27

Fig. 3 Sensory Analysis vs. Feeding Regime





into November. This late season production is supplemented with a small area of Summer planting in the Oxnard area, located just north of Los Angeles, for Autumn and Winter picking. The key aspects of Californian strawberry production are:

- Production takes place on deep well drained sandy loam soils.
- Fresh plants are planted annually into Methyl Bromide sterilised soils.
- Ground preparation includes ripping and chiselling followed by irrigation to reduce salinity, grading to ensure even irrigation of the crop and the making of high beds to give good air circulation around the plants and to facilitate easier picking.
- Water for irrigation is plentiful in all fruit growing regions.
- Careful selection of the correct variety for the locality.
- High density planting (up to 60,000 plants \ ha) in a two, three, or four row bed system.
- Nutrients supplied from organic matter, base fertilisers \ slow release fertilisers and in a liquid form through ground level tapes.
- The industry has many good varieties and there appears to be many more good new varieties in the pipeline.
- The Californian berry is exceptionally firm and this together with the very high yields per plant allows very fast picking and low picker to area ratios - 1.5 pickers \ acre compared to 12 - 15 pickers \ acre in Ireland.
- The differences in climate throughout the State provide for a very long season with production peaks spread out over a long period.
- The strawberry production areas have a warm climate and relatively low rainfall 250 – 400mm, thus very accurate planning and production forecasting is possible.

Industry Supports

Research and advice is provided from two sources. The University of California at Davis provides research and advice on all aspects of strawberry production. Plant breeding is carried out on campus at Davis and production and variety trials are carried out by Dr Doug Shaw and his colleague Dr Kirk Larson at two field stations located in Irvine and Watsonville. Nearly 600 growers are linked into the U.C. programme which is part funded by the University with the balance coming from the California Strawberry Commission who deduct a levy of 5 cents \ tray (approximately 6½ p) from the growers with 20% of this going to the U.C. research and advice programme. A high proportion of strawberry growers are linked with one or more of the twenty "Shippers" that operate in California. Companies like **Driscoll's** work very closely with their growers, often providing free planting material as well as an intensive programme of education, advice, research, and plant breeding. Growers contracted to Driscoll's must use their varieties and must follow production programmes and quality standards as set out by the company.

The activities of the **Californian Strawberry Commission** fall into three major areas: overseeing and conducting research, promoting strawberries through marketing programmes and issues management. Farmers, shippers and processors serve on the Commission which has a committee structure. This ensures that the activities of the Commission are thoroughly considered and enacted to serve the best interests of the

industry as a whole. The Commission is funded entirely from the grower levy which raises in excess of $2 million annually. In recent years it's role has been expanded to include issues management which could involve anything from dealing with misinformation presented by the media, communicating with policy makers in government or educating the public about modern farming practices.

Markets

In 1985, the industry exported 1.9 million trays of fresh strawberries. In 1995, over 10 million trays were shipped to Canada, Mexico, Japan and a number of European countries including the U.K. In 1999 the export figure is expected to exceed 16 million trays. Even more dramatic expansion has been achieved for frozen fruit with nearly 30,000 tonnes exported in 1998. This is a very important market which provides an outlet for fruit of a lower quality produced at the end of the production cycle. It is also a useful outlet for fruit in times of over supply and declining prices. The uses for fruit sold in this way falls into a number of categories:

*	Bakery	- Pie and pastry fillings.
*	Beverage	- Production of fruit flavoured drinks.
*	Preserves	- Production of a wide range of jams, jellies and preserves.
*	Dairy	- Used to flavour milk based drinks and yogurt.
*	Snacks	- Used in the manufacture of confectionery items.

Threats & Challenges

Global Economy: There is more fruit coming from Latin America and Mexico. Other factors that influence the industry include currency fluctuations and the stability of governments and economies.

Pesticide Legislation: The current position of the US government on the Montreal Protocol is to phase out the use of methyl bromide for soil sterilisation by 2005. At present the industry has a production programme which is almost entirely based on this practice. Research for suitable alternatives is ongoing.

Pesticide Registration: Many pesticide companies are reluctant to develop and register new materials for use on strawberries since this crop does not hold a major position in the agricultural industry. Materials which are registered at present will undergo further scrutiny and may be withdrawn in the future.

Supply of Labour: In parts of California the agricultural labour force is declining. The problem is compounded by the resurgence of the United Farm Workers Union and this organisations efforts to collectively organise the field workers. In recent years, the UFW have organised very public demonstrations, boycotts and strikes.

Food Safety: This has come to the forefront in recent years with the outbreak of Cyclospora and Hepatitis A in Mexican frozen strawberries. Californian strawberry growers are now operating under an industry wide quality assurance programme to highlight field sanitation practices.

Focus on the Driscoll's Organisation

Company Profile

Driscoll's are the biggest "shipper" of strawberries in North America. The company headquarters is located in Watsonville as is the main fruit handling depot. Smaller fruit depots are located in the four remaining fruit growing areas. The Driscoll organisation performs four very different functions:

- Market Research
- Fruit Handling
- Research and the Breeding of New Varieties
- Supply of Materials

Market Research

Driscoll's have a world wide marketing base with customers in South America, Europe, Asia, North America and Canada. The company works very closely with customers to develop new products and packs. In the last five years sales of their large "stem" berries have increased to a point where they are now one of the most important lines handled by the company. Driscoll's have developed many different packs to suit their customer requirements. These vary from the 6 or 12 lb "loose" trays which are frequently used for export to the more standard ½, 1 or 2 lb basket that are more suited to the North American market.

Fruit Handling

Over 600 growers with nearly 8,000 acres of strawberries are contracted to supply fruit to Driscoll's. Depots are located in all of the important strawberry growing areas which means that individual growers can make multiple deliveries each day to their local depot. The Driscoll's fruit depots operate as follows:

- Growers deliver their fruit to the depot between 7am – 11pm.
- On arrival, fruit is checked and then immediately placed in large blast coolers at 3ºC.
- If not being dispatch immediately, the fruit is held in cold rooms at 5ºC.
- If requested by the customer, the pallets of fruit are sealed in polythene sleeves into which CO2 (Carbon Dioxide) is injected. This process is used to enhance keeping quality during transport to the final point of sale – this can take up to 7 days with overland travel across the U.S.A.
- Fruit is normally dispatched on refrigerated lorries within 24 hours of arrival at the depot.

Research & Plant Breeding

Dr Tom Sjulin heads the breeding and research team which also has its headquarters in Watsonville. The main focus of this side of the company is:

- Plant Breeding.
- New Variety Trials.
- Research into Disease Resistance.
- Control of Plant Health and Pesticides.
- Storing and Recording Germplasm.

-4-

The breeding of new varieties is without doubt the most important function of this unit. Over the years Driscoll's have introduced a number of very successful varieties. **Coronado**, **San Miguel** and **E26** are the most important varieties in the Oxnard area while **Commander** continues to be the most important variety in the Watsonville area. In the last two years Driscoll's have introduced a number of new varieties which may be suited to European conditions, so Irish growers should be on the look out for **Alta Vista**, **Lido** and **Baeza** over the next few years. Breeding a new variety can take up to 10 years and there is considerable pressure from the industry to introduce large fruited varieties with improved yield, extended picking season, better flavour and improved shelf life. In recent years there has been considerable interest in varieties which have an aromatic flavour. The new variety **Lido** was selected mainly for this feature.

Supplying Materials

When growers are contracted to Driscoll's, they undertake to adhere to production programmes using Driscoll's varieties and they must agree to supply all of their production through Driscoll's depots. In return, growers receive their plants free of charge and during the course of the production year they will receive all the necessary support and advice from Driscoll's personnel. Market containers (trays and punnets) are supplied by the company and are available for collection at all depots. Growers can collect the required containers each time they deliver fruit thus removing the need to carry a large stock back at their farms.

Other Activities

The Driscoll's company engages in a number of other important fruit related activities, the most important of which are:

- Production research – Currently the most important issue facing the industry is to find a suitable replacement for Methyl Bromide used for soil sterilisation.

- Supporting the production of other fruits – The production of raspberries and blackberries is expanding in the Watsonville area and Driscoll's have a world wide marketing campaign for these fruits.
- Development of production programmes for new fruits – Blueberries are not widely grown in California. Driscoll's have undertaken a programme to test varieties and assess their suitability to local conditions.

The Role of the "Shipper" in the Californian Strawberry Industry
"Shippers" , like Driscoll's are essentially wholesalers who contract to take fruit from local growers and to sell it on their behalf. Huge sums of money are invested by these companies in:

- Market Research.
- Plant Breeding & Production Research.
- Supply of Planting Material.
- Provision of Fruit Handling Facilities.
- Education and Advice.

This gives rise to a very simple situation whereby a grower who is contracted to the company can devote all their energy to growing the crop in the knowledge that the marketing and handling of their fruit will be taken care of by professionals. The majority of growers in California do not have, or need, their own cold rooms or packhouses as fruit is dispatched straight from the field to the depot so capital costs associated with strawberry growing are very low. In return, the "shippers" demand 100% loyalty and failure to meet this requirement will result in the termination of the contract. Growers whose fruit continually fails to meet the standards as set out by the company will suffer a similar fate.

My Impressions of the Californian Strawberry Industry and what are the possibilities for Ireland

The strength of the Californian Strawberry Industry is due to many factors, the most important of which are the ideal climatic conditions, the availability of many suitable varieties that produce fruit over a long season and the nature of the marketing which allows the grower concentrate on production in the knowledge that companies take responsibility for market research, marketing and distribution. At the start of the production cycle great care is given initially to the choice of soil and site and then to ground preparations, ensuring uniform growing conditions for the crop. In the main strawberry growing regions, farm size varies from 20 acres to 400 acres with most farms in the 40 – 60 acre range. This scale of production allows the grower invest in very specialised equipment capable of high output and high quality work. However one of the problems that the industry faces is the scarcity of suitable land, particularly in southern California (Orange County). This means that there is little or no possibility of rotation resulting in the high reliance on methyl bromide for soil sterilisation.

Creating More Suitable Growing Conditions

If the Irish strawberry industry is to expand, it must be in conjunction with an increase in the usage of protective covers. A typical Irish yield of 6 – 8 tonnes \ acre compares very unfavourably with the 20 tonne + yields which are possible in Southern Europe and the USA. The use of polythene tunnels will have a dual effect, as the picking season will be extended and better growing conditions will be provided resulting in higher yields.

Introducing New Varieties

Introducing new varieties, similar to those used in California, offers the best potential for a major improvement in the home industry. At present Ireland has a great reliance on the variety - **Elsanta**. It is no secret that the home industry needs some new varieties and we must look towards a greater use of the 'everbearer' types which will produce higher yields over a much longer period than the existing June bearing types. It is interesting to note that US companies like Driscoll's are currently testing some of their new varieties in parts of Europe. If results are good, it may not be long before some of these new 'everbearer' varieties are available to Irish growers.

Picker Organisation

It is in the area of picking and fruit handling that the Irish grower can learn a lot form their counterparts in California.

The key aspects of picker organisation in California are :

- Due to the greater fruit firmness of the Californian varieties, the rate of picking is 4 – 5 times faster than in Ireland.
- The number of pickers required per acre is very low (1 – 2 \ acre)
- Californian strawberry growers operate under an industry wide quality assurance programme and all growers must maintain high standards and proper sanitation in their fields. Growers are subjected to frequent on the spot field inspections during the season.
- The warmer climate and absence of rain allows for labour planning and the possibility of picking for longer periods of the day – 12 - 14 hour days are the norm during harvest peaks.
- Californian strawberry growers deliver their fruit to the depot directly from the field so they do not have to provide labour for further handling, grading, quality control and packing as happens in Ireland.
- On California strawberry farms, the following facilities are provided for the pickers on site:

    - Toilets (male & female)
    - Hand basins (minimum of two)
    - Drinking water.
    - Food storage facilities.
    - Seating and tables for eating.

Annual Production Cycle

The annual production cycle used in California offers many advantages to the grower. Each year growers plant new certified plants and because they are planting into

sterilised soil, the risk of infection with pests and diseases is lessened. On many farms, where the growers are contracted to some of the major shippers, plants are provided free of charge resulting in a big saving in establishing costs. The production programmes used are designed to maintain vigour in the plant for eight to ten months and thus maximise yields.

Conclusion

In California, strawberry growers make the maximum use of the resources presented to them. Plant propagation takes place at high elevation in remote areas of northern California where plants receive natural chilling. Fruit production is carried out in areas with a mild climate and low rainfall on light soils, ideally suited to strawberry growing. Production is on a very large scale allowing growers to make the maximum use of the latest technology. It is in the area of fruit handling and marketing that Californian growers have many advantages over Irish growers. Fruit handling systems are simple and uncomplicated allowing growers to deliver fruit from the field directly to the depot without any further handling. This allows growers concentrate on crop management in the knowledge that all aspects of fruit handling and marketing will handled by one of the many “shippers” operating in their region.

Organic Strawberry Production

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Introduction

The area under organic food production is increasing rapidly. From 1987 to 1993 the area in organic production in Ireland increased from 1300 to 1600 hectares. In 1994 the area in organic production in Ireland was 5500 hectares. By 1997 this area had increased to over 18000 hectares and by the end of 1999 a further expansion to 29000 hectares had occurred. The demand for organic food continues to increase also. In 1987 the UK organic market (our main customer) was worth £40 million. This had reached £267 million in 1997 and it is expected to surpass the £500 million mark during the year 2000. Approximately 70 per cent of the organic food requirements of the UK are imported. This affords an important market opportunity for Irish organic food producers and more specifically for organic strawberry producers.

Organic strawberry production involves the drafting of a rotational plan to reduce the incidence of soil borne diseases and to achieve a nutrient balance. The main source of nutrition is farmyard manure. This may be recycled from other parts of the farm or bought in. Pests and diseases are controlled by biological means and by good crop hygiene. Weed control is achieved by mechanical methods or by the use of crop mulches. Organic strawberry production requires a high level of management skills in order to achieve success. It is not possible to remedy problems which arise during production by resorting to the use of agrochemicals and a high degree of forward planning is necessary. This is achieved by the use of well-balanced rotations, nutrient budgeting and good crop husbandry techniques.

Conversion

Before converting to organic strawberry production one should contact one of the official certification bodies. There are three of these. These are:

(1) Irish Organic Farmers' and Growers' Association (IOFGA)
(2) The Biodynamic Association (BDAAI)
(3) The Organic Trust.

These three bodies are recognised by the Department of Agriculture and Food and by the EU as bodies, which can inspect and certify applicants who qualify for symbol status. These bodies have their own sets of regulations for conversion to organic production and can also provide information on the do's and don'ts of organic strawberry production. The EU standards for organic crop production (2092/91) are minimal standards and the restrictions imposed by the different certification bodies are more severe. It is important to remember that the use of peat based compost is not allowed for strawberry production. The use of black polythene mulch is allowed. Irrigation by T-tape or drip units is allowed but the application of artificial fertilisers or agrochemicals through the irrigation system is not permitted. Crops must be grown in the soil either in the open field or under polythene. The conversion period normally takes three years but may take longer if serious non-compliances are noted. In practice, once in conversion to organic production the implementation of the required standards does not present very many difficulties for the competent grower and good farm manager.

Infrastructure

Good fencing and shelter are essential for organic strawberry production. Good farm roadways, sheds, cold store and packaging facilities are also necessary. A reliable source of irrigation is also very important. These requirements do not differ greatly from those of a conventional producer and can be supplied on a co-operative basis. When conventional production is involved it is not permitted by

regulation to mix the two enterprises and separate facilities will be required when the produce is being marketed as organic. Well maintained hedgerows and field margins are an important addition to the infrastructure on an organic farm. Dry banks and ponds are also an advantage. These provide protection and a good habitat for birds, small animals and insects, many of which act as predators and parasites on crop pests. Parasitic wasps, predatory beetles and mites, arachnids, gall midges, nematodes, bacilli and fungii all exert a controlling influence on many of the pests and diseases of strawberries. These are discussed in more detail in the sector on pest and disease control. Hedgerows and field margins provide a good haven for these organisms.

Ground Preparation and Planting

Runners propagated from certified stock should be used to ensure that the plants are free of disease. The ground used should not have been planted with strawberries for a period of ten years at least to avoid the risk of root disease and ellworm infection. Strawberries grow best in slightly acid (pH 6.5) deep, well-drained soil with a loam texture. Brown earth soils derived from shale are the most suitable. These contain high potassium (K) concentrations. The yield and flavour of strawberries is much improved by high available soil K. Strawberries also grow well in soils derived from sandstone. The ground is ploughed to a depth of 20-25 cm using a digger plough. A strawberry plantation will remain productive for two to three years and a relatively heavy dressing of farmyard manure (FYM) is required to supply adequate plant nutrients over this period. The FYM is applied to the soil surface and ploughed in. Raised beds 1.0m wide mulched with black polythene are constructed at 1.5m centres. The runners are planted in double rows spaced at 45cm at a spacing of 40cm in the row. The use of the polythene mulch allows for a more rapid increase in soil temperature and earlier fruit. Fruit yields are also increased.

Crop Rotation

Crop rotation is necessary to reduce the incidence of soil borne diseases, to reduce weed populations and to retain a nutrient balance throughout the farm. It is also used to build up the soil fertility and to reduce nutrient losses through leaching and volatilisation.

Soil borne diseases: Red core root rot is a serious soil borne disease of strawberries, which persists in the soil for a number of years. A minimum seven-year rotations required to control this disease. Experienced growers prefer a 10-year rotation for good control of this and other soil borne strawberry diseases.

Weed population: Particular weed types are suited to thrive in particular crops. Some crops such as cabbage and potatoes suppress weeds in general. Arable weed seed populations decrease quickly in a grass sward. A rotation, which includes the above crops, can give a significant reduction in weed populations.

Soil fertility: Particular crops have particular nutritional requirements. Crop rotation provides a good nutrient balance throughout the farm. The soil organic matter acts as a storehouse for plant nutrients in the soil. Continuous tillage can reduce the soil organic matter content and the soil fertility. The inclusion of a grass sward allows the soil organic matter to build up again to the benefit of the strawberry crop.

Which Rotation?

A wide choice of rotations can be used to produce organic strawberries. Two rotation types, the first based mainly on arable crops and the second based mainly on grassland are shown below. The period of the rotations is ten years. A small ten hectare farm is used in both cases.

Table 1. Rotations with strawberries based on grassland and arable crops.

Year	**Rotation 1. Grassland**	**Rotation 2. Arable crops**
1	Grass/Clover – Mown 20 t/ha FYM	Wheat
2	Grass/Clover - Grazed	Potato - 50 t/ha FYM
3	Grass/Clover - Mown 20 t/ha FYM	Barley
4	Grass/Clover - Grazed	Oil seed rape

5	Grass/Clover - Mown 20 t/ha FYM	Arable silage - 15 t FYM
6	Grass/Clover - Grazed	Beans
7	Grass/Clover - Mown 20 t/ha FYM	Grass clover - mown 15 t/ha FYM
8	Grass/Clover - Grazed	Grass clover - grazed
9	Strawberries - 20 t/ha FYM	Strawberries - 35 t FYM
10	Strawberries -	Strawberries -

The strawberries are planted as early as possible in the previous autumn in order to allow the development of strong crowns for a good crop in the following summer. It is important to ensure that the strawberry crop is not preceded by potatoes as this can give rise to Verticillium wilt infection. Less FYM is needed for the strawberry crop in the grassland rotation. The high level of soil fertility is more easily maintained in grassland than under an arable crop rotation.

Nutrition of organic strawberries

Strawberries remove less nutrients from soil than most other crops. With the standard plant population of 27,000 plants per hectare only 38 kg of nitrogen (N), 5 kg of phosphorus (P) and 44 kg of K is removed annually from the soil. Although the nutrient offtakes are low the strawberry crop benefits from a high level of soil fertility. A soil analysis should be carried out so that the appropriate dressing of FYM can be calculated. Due to the small size of the root system the root zone is relatively restricted. The strawberry plant is a poor forager and grows best when the nutrient content in the root zone is high. In the sixty days between flowering and fruit production the fresh weight of the strawberry plant is increased by 125 per cent and sufficient nutrients must be available during this peak demand period to support the plant growth. The strawberry crop will occupy the ground for a period of two to three years and sufficient FYM must be applied during that period to support the crop. The strawberry plant extracts over 90 per cent of its nutrient requirements from the soil within a 25 cm radius of the central crown of the plant. One tonne of FYM contain 5 kg N, 1 kg P and 10 kg K. When all the above factors are taken into consideration a dressing of 35 t/ha FYM is required to support the strawberry crop for a period of three years. In order to achieve a good nutrient balance this application must be made in the context of a nutrient budgeting plan. The grower must remember that the 35 t/ha FYM dressing is adequate only in cases where the soil fertility levels are sufficiently high to rule out the necessity for a maintenance dressing – i.e. Soil Index 4. At lower soil indices, proportionately larger dressings of FYM will be required.

Nutrient Budgeting

In organic strawberry production the nutrient offtakes by the crop must not exceed the nutrient inputs; otherwise the overall fertility of the farm will fall and yields will decline in the long term. The nutrient inputs are obtained from farmyard manure and legumes. In a grassland rotation clover can supply a large amount of nitrogen (N) (Table 2). In an arable rotation where grass/clover is used the amount of N supplied

Table 2. The relationship between clover dry matter and nitrogen production in a grassland.

Percentage clover (dry matter)	Nitrogen supplied (Kg/ha)
10	35
20	80
30	140
40	280

by the clover over the period of rotation is small. The nitrogen supply is relatively easily controlled by the use of clover and other legumes because in the case of strawberries the nitrogen requirement is relatively small. It is important to keep the nitrogen supply to a minimum. High N inputs can lead to an increase in pests and diseases. On farms with livestock the source of FYM is from the farm itself. On stockless arable farms all of the FYM is bought in. In either case the management of the manure is of the utmost importance. High soil potassium (K) is essential for strawberry production. The potassium in FYM is mostly in the urine. FYM stored under cover contains high concentration of K. The K in FYM, which is stored in the open, will be leached by rainfall over time (Table 3). For best results FYM that is stored in a compost house, barn or other structure, which keeps the rain off, should

be used. In order to develop a good nutrient budgeting system it is necessary to know the nutrient offtakes by the various crops so that the inputs can be calculated. The offtakes by the different crops is dependent on the fertility level on the particular farm

Table 3. Nutrient concentrations in covered and uncovered FYM stacks.

Manure Type	pH	NO_3	P	K	Mg	Ca	Sc
Covered	7.2	1199	1292	11047	2256	8953	731
Uncovered	6.4	844	1135	2484	2281	5400	558

and the efficiency of the nutrient budgeting system already in place. The nutrient offtakes by different crops grown on a moderate to high fertility farm is shown in Table 4. In order to calculate the nutrient imputs required to replace these offtakes in

Table 4. The nutrient offtakes of six crops grown on an organic farm.

	Nutrients removed (Kg/ha)		
Crop	**N**	**P**	**K**
Silage	110	16	130
Cereal	93	16	47
Arable silage	80	9	90
Oilseed rape	83	13	99
Potato	110	14	131
Beans	74	16	137
Strawberries	38	5	44

the course of a rotation it is necessary to carry out an analysis of the FYM to be applied. In the case of the farm on which the above crops were grown the FYM produced contained 5 kg N, 1 kg P and 10 kg K per tonne. Nitrogen losses by leaching and volatilisation and nitrogen gains by mineralization and atmospheric deposition must also be taken into account with nutrient budgeting. The nutrient balance in a 10-year arable and grassland rotation including strawberries is shown in Table 5. In both cases the potassium supply is in excess. Under grassland there is excess N in the system. In practice these excess nutrients do not occur because these are taken up by the current year's crop. When large amounts of N and P are allowed to build up these can cause environmental pollution.

Table 5. Nutrient balance in a 10 year grass and arable rotation with strawberries.

Offtakes	**Rotation 1. Grassland/strawberries**			**Rotation 2. Arable/strawberries**		
Offtakes	**N**	**P**	**K**	**N**	**P**	**K**
Livestock	30	53	15	-	-	-
Crops	535	76	630	738	112	791
Leaching	70		-	70	-	-
Volatilisation	159	-	-	159	-	-
INPUTS						
FYM	500	100	1000	575	115	1150
Clover (30%)	240	-	-	60	-	-
Mineralisation	340	-	-	340	-	-
Deposition	70	-	-	70	-	-
Balance	+356	-29	+355	+78	+3	+359
Annual Balance	+35.6	-2.9	+35.5	+7.8	+0.3	+35.9

Weed control

Weeds are controlled by the use of the black polythene mulch under the crop and the use of straw in the interrows. When straw is not available mechanical means of weed control are used in the interrow. The “tearaway” spring tined harrow, the Kelmink rotary harrow and the brush weeder are adjustable cultivators which are suitable for this purpose.

Pests and diseases

Soil borne diseases are controlled by rotation. When the use of soil sterilants and fungicides is discontinued organisms, which parasitize or compete with disease organisms build up in the soil over time. These reduce the infection levels of most diseases to a tolerable level. Examples of these organisms are trichoderma, protozoa, fungii, bacteriophage and bacteria. Trichoderma is active against root diseases, some protozoa species feed on bacterial disease organisms, fungii attack nematodes, bacteriaphage infect and kill bacteria and some bacteria species control fungal diseases, e.g fusarium. Some of these organisms are at present being developed as a biological method of disease control. The cultivars Florence, Eros, Emily and Everest have shown good tolerance to red core root rot and crown rot. Symphony is very resistant to soil borne diseases.

Botrytis: Botrytis is one of the most virulent diseases or organic strawberries. Due to the low concentrations of soil nitrogen organic strawberries are less susceptible than conventional crops. This disease can cause considerable crop losses in a wet year. The use of raised beds with black polythene encourages moisture runoff and will reduce the level of infection. Irrigation by T-tape rather than overhead irrigation also reduces infection. Removal of all ripe and infected fruit also reduces the source of infection. This disease is less severe in well-ventilated crops grown under cover than in field crops. The losses commonly recorded due to botrytis infection are 10-15%.

Mildew: Powdery mildew does not infect field crops and occurs in protected crops only in the autumn. The most susceptible cultivars are Elsanta and Tango. The newer cultivars Florence, Everest and Symphony are resistant to this disease.

Redspider: This pest occurs regularly in protected strawberries in dry, warm summers but is not a serious pest in field crops. Good control is achieved by the application of Phytoselius persimilis in protected crops.

Vine weevil: This pest can cause severe damage to strawberry crops in the second and third year of cropping. The application of Heterorhabditis megidis (parasitic eelworm) gives good control of this pest. Several species of carabid beetles feed on vine weevil. These carabids build up to a considerable population under organic production due to non-use of pesticides. As a result vine weevil is a less serious pest in organic crops. Other common pests of strawberries are less prevalent in organic crops. This is due to the exclusion of pesticides and the build up of natural predators and competitors and a more gradual supply of nutrients such as N, which promote soft, lush growth, which is more attractive to pests.

Crop management

The main crop management issues, which arise, are runner control and crown thinning. Runners are produced from mid-summer onwards. These are produced at the expense of fruit yield and quality and must be removed. In the case of mulched beds these runners must be removed by hand. In the second and third year of production individual plants begin to produce additional crowns. These crowns produce large numbers of flowers and fruit. The fruit size and quality is reduced when too many crowns are produced. In the second and third year the number of crowns should be reduced to two in the case of normal plants and to three in the case of large plants.

Economics

Investigations in the EU has shown that yields of organic strawberries can be as high as 12-15 tonnes/ha. The premium paid on organic strawberries is 50 to 100%. On this basis profit margins for organic strawberries compare favourably with those of conventional crops.

Conclusion

1. The area under organic production is increasing rapidly. Markets are growing and are under supplied. Premia of more than 50 per cent are available for organic strawberries. In these circumstances the area under organic strawberries is likely to grow.
2. A grower who intends to convert to organic production should contact one of the official certification bodies for information on the regulations.
3. Choice of site is important. Acid brown earth soils are the most suitable. A well sheltered south facing slope is best.
4. Crop rotation is essential. A seven year rotation is adequate but a 10 year rotation is advisable for good control of soil borne diseases and weeds.
5. Clover and other legumes are used to supply nitrogen. Farmyard manure is applied to supply potassium, phosphorus and trace elements. The introduction of a system of nutrient budgeting is necessary for sustainable production.
6. Weeds are controlled by using black polythene mulch on beds and straw or mechanical methods in the interrow.
7. Pests and diseases are controlled by biological methods, proper crop and nutrient management, keeping the soil organic matter high and using resistant cultivars.
8. The high premium combined with the low input costs can make organic strawberry production a profitable enterprize.

Sourcing Labour

Ann McCrudden
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As Ireland edges towards full employment, employers are experiencing the crippling effects of both skilled and unskilled staff shortages.

We constantly hear of employers fearing for the future of their business. Reliable motivated staff is the most vital part of any business in order to sustain it and allow it to develop and expand. For many employers in today's current climate, development and expansion are unattainable as they struggle to cope with the daily problems of maintaining commitments that they already have.

It is well documented that the "well is dry" as far as skilled, motivated, and reliable staff for the agricultural and horticultural sectors are concerned. David McWilliams, the economist who coined the phrase the "Celtic Tiger" says that we, in Ireland, have in the last 10 years gone from a country who had loads of people and no money, to a country who now has loads of money and no people, and that this situation has moved the goal posts dramatically.

Staff shortage is a symptom of the booming economy. From an economic perspective he suggests the simple solution is to import people from places like Eastern Europe, where there is a huge number of unemployed / underemployed people, because they currently have what we had here in the 1960s. He reminds us that the single most important factor in our growing economy is people.

Millions of pounds have been invested by the government into possible solutions to the problem – retraining schemes, incentive schemes, apprenticeship courses, community employment, early school leavers and long term unemployment schemes, are currently in place, but all to little or no apparent benefit.

Most recently Mary Harney's Department of Enterprise, Trade and Employment invested hugely into a FAS scheme called EURES. It is an E.U. computer database designed specifically to facilitate potential employers and employees to advertise throughout the entire E.U.

E.U. nationals have the right to live and work in Ireland without a work permit. Those nationals working in Ireland have the same rights as Irish nationals with regard to salary, work conditions, access to housing, vocational training, social security and trade union membership. Families and immediate dependants are entitled to join them and have similar rights.

The EURES network is, in theory, quite plausible, but it has been Dalmac's experience to date that the entire FAS/EURES service is, at present, ineffective and potentially hindering to what is frequently, for the employer, an urgent need for staff recruitment. Under the FAS/EURES scheme employers must, by order of the Department of Trade, Enterprise and Employment, advertise each position for a minimum of four weeks.

The concept behind the EURES system is understandable, in that, it was set up to ensure that an EU member is given first priority to any position available in a member country. Once again, I can only quote from the personal experiences of my clients which indicates that at the outside, as few as six Curriculum Vitaes exist on the current EURES network and these are circulated to all employers who are currently advertising on EURES. The C.V.s in question proved to be unsuitable to any of my clients to date, thus allowing them to apply for a permit for a non-EU national.

Although acknowledged on a daily basis, by all sectors of Irish business and political parties, that the Irish staff shortage is at a crisis point, employers understandably feel frustrated at the length of the "red tape" procedure recently implemented by the Department of Enterprise, Trade and Employment. However, on a positive note, once the criteria have been adhered to, staffing problems can be solved by recruitment from non-EU countries.

The procedure for such recruitment can be done directly by the employer to the D.E.T.E., or alternatively, he may engage the services of a professional recruitment agency such as ourselves, at Dalmac Language & Recruitment.

Dalmac Language Institute was founded in 1989, and has been specialising in the teaching of English as a foreign language to people from around the globe. We are members of MEI-Relsa Ireland and are approved by the Department of Education and Science.

Latest figures show that close to 185,000 foreigners arrive to Ireland annually to our MEI-Relsa schools for short-term stays to study the English language. A business currently generating in excess of £230 million in foreign exchange earnings.

As part of our language business, in 1998, we developed an Au Pair product, which subsequently led us on to our current path, i.e. the addition of Dalmac Recruitment, licensed by the D.E.T.E. Many candidates on this programme and some partaking in our other study programmes, approached us requesting that we would find part time work to subsidise their meagre student earnings. I approached my family and local friends, all involved in the horticulture business, as I was acutely aware of their staffing problems, and arranged and organised the placements. Word spread very quickly, as it does in a small community and soon we had local farmers in our office requesting part-time and full time staff.

Recognising the niche in the market, we launched Dalmac Recruitment, known today as Dalmac Language & Recruitment, and our decision was to specialise in the recruitment of foreign staff. As we moved into non-EU countries, great reluctance was felt from both the D.E.T.E. and the Immigration Department. However, we currently enjoy a good relationship with mutual respect from all parties involved in the paperwork procedure.

We initially targeted Latvia as our first non-EU country. Our investigations and research found a licensed professional agent who had already been working in the field with Germany and Sweden. Today this agent remains the only fully licensed and

approved agent in Latvia and I am pleased to say that we have an exclusivity contract with him, hence, the name "Latvian worker" became the popular term for foreign staff and often new enquiries ask for "Latvian workers" before any others.

Today we have agents in most EU countries, such as, Spain, France, Germany, Italy, Austria, Denmark, Portugal, and from outside the EU in countries such as, Russia, Ukraine, Lithuania, Poland, Belarus, Bosnia, Uzbekistan, and China to name but a few.

C.V.s arrive to us on a daily basis from backgrounds as diverse as mechanics to masons, agriculture to catering. Each C.V. must include an original medical certificate report, complete with an AIDS test and police clearance certificate.

At present, we work with employers from an equally diverse range, farmers, market gardeners, pack house workers, fruit farms, forestry, hotel and catering, builders and tradesmen – the list grows daily. While all steps and procedures are clearly outlined in Dalmac's information pack, it is worth mentioning that employers considering hiring foreign staff from non-EU countries should be aware that it is a 6-8 week process. We recommend employers to apply for staff three months before they are required as this allows a " time safety net" for unexpected delays that can occur.

Dalmac will request a clear job specification, with terms and conditions offered, before a selection of C.V.s will be offered for approval. The first and most important step for the employer is to advertise the position on the FAS/EURES network and in the local or national newspaper. The D.E.T.E. will not consider any application for a permit until this has been done. Evidence of all such advertising will be requested by the D.E.T.E. at the time of application.

Once the various forms and documents contained in Dalmac's information pack have been signed and returned to us, together with the selected C.V.s – Dalmac will submit an application to the D.E.T.E. on your behalf within 48 hours. The application will remain in the D.E.T.E., usually without any communication, for a further four weeks approximately. If the D.E.T.E. is satisfied that the application is genuine, has been sufficiently advertised and offers fair terms and conditions of work, a work permit will then be granted. Notice of intent to grant a permit to the employer will be issued to either the employer or the Dalmac Language & Recruitment office. At this point, a cheque will be requested from the employer for the issuing of the permits by the D.E.T.E. Permits are never issued by the D.E.T.E. without full payment by the employer.

Once the employer has received the permits, arrangements will then be made for their new employee's flights. From the time that Dalmac receives the original permits, foreign workers can arrive within 2-10 days (10 days only applies when a visa is required for a worker and a visa can only be applied for after a work permit has been issued.

It is important for our clients to know and understand a little about the background of these people. It is vital to the success of the placement that understanding and mutual respect is always the common ground. These people are not refugees, they are often well educated, with multiple skills, who come from a country that is economically

deprived, offering little chance of self improvement and few rewards - unemployment is high and wages are low.

Most of our foreign workers come here with one purpose – to earn money. This money can be needed for university fees for a younger member of the family, to pay for a treatments/operation for a parent/sibling, to help buy equipment/livestock for their own farms, to buy property, to get married, and so on. Some travel here in the hope that they will learn enough English to improve their chances of employment once they return home, while others apply in the hope that their employer will be so delighted with his/her work, that they will be invited back to work here again for another year.

Foreign workers often don't have sufficient funds or access to funds to pay local agents fees and cost of flights to travel to Ireland, hence, money is often borrowed, at exorbitant interest rates from money lenders. Once here this repayment will be priority until it is cleared in order to avoid the interest. Some foreign workers already working in Ireland help to finance friends and family to travel here, thus avoiding such interest rates. Very few, if any, have experience of banking, or of being a bank account holder. They often mistrust such institutions, as in their home country, these institutions tend to go into liquidation every other day.

Foreign workers often make huge personal sacrifices to come to Ireland. Mothers leave young babies, in the care of grandparents or a husband, depending on whom is first chosen for work placement. Young husbands leave their young wives and sometimes not so young husbands leave their wives and family to forge a better future for the next generation.

We have a moral responsibility to treat these people as we would any other Irish worker. I don't suggest that they should be singled out and treated differently, just that they be treated the same, with the same chances and opportunities.

Experience has shown me that Irish employers are decent and fair. I know of incidents where money gifts have been quietly sent back to their workers family to help them buy fuel for the winter months, or to help towards medical costs for a family member. These little incidents rarely make news headlines, but within the foreign workers "grapevine", it can be said that Irish employers are enjoying positive reports.

Careful consideration must be given to the type of accommodation provided by farmers to foreign staff. Run down, converted sheds or dilapidated caravans are not acceptable homes. Wintertime can be cold and damp and a fair standard of accommodation is essential. Dalmac will remove, without refund, employees who are expected to live in unacceptable conditions. Where on-site accommodation is not available, we recommend local host family accommodation or local shared, rented accommodation.

We ask employers to meet and greet their foreign staff at the airport upon their arrival, and invest a little time for the first day or two on induction. It is worth mentioning that apart from work training, many of these people will not be well travelled. They will need to be shown where, when and how to shop locally, what local business

hours are and what to do if they are ill or need a doctor or medication, and so on. If conditions require special clothing, e.g. outside work or all weather work, we suggest that the employer should provide suitable clothing.

Throughout the stay of your foreign staff, Dalmac offers an on-going backup service for any changes, problems or developments that may arise. The first few weeks can be difficult if the workers English level is poor. We always recommend that in the event of a single placement, good English skills should be requested. When a "group" is placed with an employer it is less important as we always ensure at least one of the group will have a good level of English.

It is a requirement of the law that each foreign worker, once here, within four weeks of his/her arrival must register with the nearest Alien's office for application of his/her green card. This process usually takes about 4-6 weeks. Your foreign worker may not leave the country until this green card has been issued. Once it has been issued the foreign workers may go home or travel to other countries without restrictions. This card must be returned to the local police station when the person's contract time has expired and they have returned home.

Likewise, original permits must be returned to the D.E.T.E. when the worker's contract has expired.

In the event of an employer wishing to extend the length of the contract, or if he would like to offer another contract to his foreign worker, the old permit should be returned to Dalmac who will make the renewed application on your behalf for a nominal fee.

Employers should note that non-EU staff may not "job-hop". Once they are here they may only work for the employer whose name is on the permit. Equally, employers may not "pass on "foreign workers" to fellow farmers for work. When applying for a permit the employer undertakes to guarantee work for the foreign worker for a specified period of time. Should unforeseen circumstances arise, and an employer finds him/herself in the situation of being overstaffed and no longer in a position to keep his foreign staff, he should immediately contact Dalmac who will, at their discretion, replace the displaced worker, subject to the approval of the D.E.T.E.

STRAWBERRY PRODUCTION AND PACKING
IN ARBROATH, SCOTLAND

Peter Stirling
Windyhills Farm, Arbroath, Scotland

Introduction – Background

I grow and pack soft fruit in Arbroath, Scotland. The topics of my presentation will be an overview of my strawberry production and the trials and tribulations of establishing a purpose built central packhouse this year.

Firstly some background to the business – I am from a farming family, who are based in the Arbroath area of Scotland. My father gave me the opportunity to start farming independently at 21, when we purchased Windyhills Farm 13 years ago.

I started growing strawberries and raspberries not long after I started farming and there were a few good reasons for growing soft fruit in the Arbroath area. Whenever I look at a new venture, I always look for some natural advantages to give me an edge. If you're gambling, it is not much fun having to win card tricks with 6's and 7's, it is far more enjoyable if you have got a few kings and aces in your hand!

Arbroath's advantages included and abundance of quality picking labour due to being one of Scotland's highest unemployment areas, and of having a traditional link with agriculture work.

The climate suited soft fruit as well, being one of the driest areas of Scotland – 24" annual rainfall. Being situated on the coast, it enjoyed a temperate climate. The soils were also good, and because the vast percent of our land is in arable and vegetable production, we have the luxury of not needing to sterilise the soil.

In the early years I basically, "arable farmed" the soft fruit and used to punt everything down to the wholesale markets in England with no refrigeration. Gradually I got more conscious and started supplying supermarkets. I joined Kentish Garden four years ago. They are a growers Co-op with over seventy farmers spread out through England and Scotland. They are the UK's largest fruit marketing company and sell to all the leading supermarkets. Kentish Garden, sell all my supermarket fruit. I became a director of Kentish Garden last year.

Strawberry Production Overview

I stopped growing raspberries four years ago and concentrated solely on strawberries. At present I have five fruit farms around Arbroath, giving me a total of approximately 120 acres of strawberries. In 1998, I established joint ventures to grow strawberries on two farms at both Forfar and Montrose. Next year they will harvest approx. sixty acres of strawberries, giving me a combined total of 180 acres, we've probably got potential to expand to around 200 acres and 95% of which is Elsanta at present. Our season begins around the 20th April with production from a two acre heated greenhouse. Production then carries on continuously until the end of December.

We purchase our plants from Holland. We have a strong relationship with Dutch propagators.

With margins being squeezed and the infrastructure costs increasing, it is crucial to procure the best planting material; poor quality plants are a financial disaster.

We produce everything on polythene raised beds with computerised irrigation and fertigation systems. Over the last two years we have invested heavily in Spanish tunnels and next year 60 acres will be covered, approx. 50% of the fruit produced at our Arbroath farms.

Establishing a purpose built, central packhouse – Abbey Fruit

About two years ago I realised I was going to need a new packhouse. Like most of the UK producers, I had been using a farm shed, which was converted in the summer to pack soft fruit. However, due to increased production, there was a bottleneck at the packhouse and my ability to pack the necessary volumes was restricted.

Initially I planned to build another shed on the farm, but after taking a long-term view, I realised that I needed a facility that would conform to the retailer's health and hygiene standards necessary for the 21st century.

It soon became apparent that the best location was an industrial estate on the edge of Arbroath. Again, were there any natural advantages? Yes, there were a few. The industrial estate was an enterprise pack with full development status due to the town's high unemployment, so there was a raft of substantial grants available. There was a large residential estate nearby, so I was taking the work to the people, rather than transporting them to the farm. People who, generally were not involved with fruit harvesting would also staff it. This was a big help because our farm based packhouse staff could now be released for fruit harvesting, greatly enhancing the operation. Having a purpose built structure meant I could design it perfectly, so it was both efficient and could incorporate the retailer's "wish list" of health and hygiene facilities. With an existing building there are always compromises. Lastly,

having it situated in a modern industrial park, gave it a more professional and independent image, compared to the farm. It also avoided possible health and safety problems associated with farm pesticides and machinery.

The necessary finance and grants were put in place and the project was also supported and encouraged by Kentish Garden, who gave it a soft loan. A prominent 3½-acre site at the front of the estate was purchased and the building of the 32,000ft$_2$ facility began in November last year.

However, there was one major, fundamental problem with the project. How to financially justify and staff a state of the art facility over a relatively short fruit season. Creating a centralised packhouse that is big enough to cope with a substantial amount of fruit from other growers requires a provision of talented, skilled staff. To attract the proper calibre of staff you need challenging and satisfying work for twelve months of the year. We needed work twelve months of the year. Having thought of the ideal partner, I contacted
Kettle Produce, Scotland's largest salad and vegetable processing company. Supplying all the major UK retailers with traditional and ready prepared products and employing up to 800 staff, they seemed ideal. I entered discussions with Kettle's creator, Managing Director and Chairman, Mr Clouston McIntyre.

The result was Clouston joined Abbey Fruit as Senior Partner, with myself becoming Managing Partner.

Abbey Fruit formed a legal partnership with Kettle Produce to create a company called "Sproutco". Sproutco would provide Abbey Fruit with approx. seven months work from September - April, grading and preparing Brussels sprouts. This business enabled
Abbey Fruit to go out and recruit talented staff, and also upgrade the planned facility to a superb standard. The eventual cost of which spiralled to around £2 million.

Abbey Fruit opened in June 1999. Within a few weeks we were at the harvest peak, which created a steep learning curve for the new staff. Five growers supplied fruit to the facility and we packed fruit for Tesco, Sainsbury, Marks and Spencer, Safeway and Somerfield, which was all marketed via Kentish Garden. There was no quality or packing problems and the growers and customers all seemed happy with our first season.

The facility boasts a variety of state of the art equipment. Each pallet is weighed and QC checked at intake and issued with a bar code, all of which is linked to the admin computers. The fruit is then cooled in rapid chill tunnels, which house 48 pallets and can reduce the temperature by up to 15c / hour in 96% humidity air. This can increase the shelf life by up to 50%. Each punnet on the packing line is computer weighed and the grower receives a print out of the packing details.

Hygiene facilities include; knee operated wash troughs throughout, medical room with bed, disabled toilets and a well-appointed canteen, with separate smoking

room, which has an air change every two minutes. There is also a well-used staff training room.

If I was being absolutely honest I have had a huge slice of luck in finding a partner in Clouston McIntyre and Kettle Produce, without that Abbey Fruit could have been an expensive mistake. Life tends to have a limited supply of good fortune and we have had our share of disappointments. The last two fruit harvests have been the worst, climatically in my thirteen years of fruit growing and our harvest yields have been critically low. With infrastructure costs ever increasing, it is paramount to achieve budgeted yields.

Surely next year cannot be as bad??

Fungal Diseases of Raspberries and Related Crops

B. Williamson

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Raspberries and related fruit crops are subjected to infection by many fungal diseases that severely affect growth, survival or productivity. These diseases are particularly serious in regions with poorly drained soils, frequent rainfall and high humidity. The perennial nature of the plant with a biennial cane growth cycle leads to a build-up of fungal inoculum within the plantations over its 8 to 12-year life-span. It is therefore important to obtain healthy stock for planting on disease-free, well-drained soils and to identify fungal pathogens at an early stage to delay the on-set of serious fungal attacks.

Raspberry root rot (*Phytophthora fragaria* var. *rubi*) can be avoided by having soils tested for the pathogen before planting and only planting canes derived from root rot-tested stocks. Once introduced into a field, this fungus cannot be eradicated and only by continued 6-monthly applications of fungicides to soils can this disease be alleviated. Cane spot (*Elsinoe veneta*), a disease affecting all parts of the plant above soil level, can be particularly serious under Irish conditions. Spur blight (*Didymella applanata*) and cane botrytis (*Botrytis cinerea*) affect the emergence of lateral shoots in the season following infection of mature leaves. The latter pathogen, well known as the cause of grey mould disease of fruit, survives in the over-wintering canes and generates inoculum from sclerotia for subsequent infection of flowers and berries. *Leptosphaeria coniothyrium*, the cause of cane blight, is a common soil fungus that attacks young canes wounded during the growing season mainly by harvesting operations. This fungus is also one of several others that infect young canes at sites damaged specifically by the larvae of the raspberry cane midge (*Resseliella theobaldi*) resulting in the cane disease complex termed 'midge blight'. Other foliar and fruit diseases, such as powdery mildew (*Sphaerotheca macularis*), downy mildew (*Peronospora rubi*) and raspberry yellow rust (*Phragmidium rubi*) are also more serious under humid conditions.

All these pathogens can be reduced in importance by maintaining a high standard of crop husbandry. The aim should be to increase soil drainage and the movement of air through the crop canopy to hasten drying of foliage, flowers and berries after dew or rain. Therefore, the control of cane number and density by rigorous pruning, coupled with high standards in weed control are essential features of an effective control strategy.

BOTRYTIS, POWDERY MILDEW AND BLACKSPOT OF STRAWBERRY

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INTRODUCTION

Botrytis and powdery mildew are the most important aerial diseases of strawberries in the UK reducing yield and fruit quality and requiring frequent applications of fungicides to achieve control. Blackspot is a more recent disease of strawberries in the UK, but is rapidly becoming a serious problem, particularly on everbearer crops. The diseases and their management are described below. The information given on fungicides is based on products available in the UK. Some results from recent research in the UK on these diseases are also included.

BOTRYTIS

Botrytis or grey mould is caused by the fungus *Botrytis cinerea*. It attacks all above ground parts of the strawberry plant but is most important as a fruit rot, both pre and post-harvest. The fungus overwinters as mycelium in dead leaves, mummified fruit and other debris in strawberry crops, and in the spring sporulates giving rise to conidia during periods of high humidity, which are spread by wind and rain. Flowers are the main pathway by which the fungus infects the fruit. They are susceptible to infection after they have opened. Senescent flower parts are important sources of mycelium, which can invade the developing fruit, giving rise to the characteristic calyx end rot. Botrytis rot develops rapidly as the fruit begins to ripen.

Control – June-bearer strawberry crops.

Successful control of Botrytis is dependent on an integrated approach, incorporating cultural measures as well as fungicides.

- In early spring, before appreciable growth, remove overwintered debris from plants to reduce inoculum. Cleaned up plants may be more vulnerable to frost damage.

- In late March/early April apply a drenching spray of a fungicide such as dichlofluanid (Elvaron) to suppress Botrytis inoculum.

- During flowering apply a protectant fungicide programme starting at first flower and continuing at 7-10 day intervals.

- Alternate fungicides with different modes of action to avoid the development of fungicide resistance.

- Further fungicide sprays will be required during fruiting and harvesting, the frequency depending on weather conditions.

- During harvesting, pick the crop frequently to prevent the build up of over ripe fruit.

- Encourage pickers to collect rotted and unmarketable fruit as well as sound fruit to reduce the build up of inoculum in the crop.

- Rapidly cool harvested fruit to reduce the risk of the development of post-harvest Botrytis rot.

- After harvest mow-off the old leaves and remove all debris from the field where possible, to clean up the crop.

Control in protected and everbearer crops

- In protected crops the integrated approach is still important, but the risk of Botrytis is usually less. Ensure that the crop is well ventilated to reduce humidity.

- Botrytis control in everbearer crops is particularly challenging because of the long continuous cycle of flowering and fruiting requiring fungicides with short harvest intervals. Cultural control measures are of more importance, particularly ensuring that any rots and unmarketable fruit are removed during harvesting, otherwise the build up of inoculum during the prolonged production period considerably reduce the success of fungicide sprays.

Other approaches to control

The use of intensive fungicide programmes to control Botrytis in strawberry crops is becoming less acceptable to the consumer. There is, therefore, a need to explore alternative strategies for control.

Biological control

Biological control based on the use of antagonistic fungi has been developed in other countries (Canada, Israel, The Netherlands, Belgium) as an alternative to chemicals. Fungi used as biocontrol agents include *Trichoderma* sp, *Gliocladium roseum* and *Ulocladium*, some of which are available as commercial products.

Disease warning systems

The use of disease warning systems provide one alternative approach to the routine use of fungicides for control of Botrytis. Several such systems are in development in Europe, including at HRI-East Malling. The Botrytis warning system (BOTEM) in development at East Malling is a PC-based system and gives warnings of Botrytis infection during flowering. The model is driven by weather variables including daytime vapour pressure deficit (a measure of relative humidity), night time temperature and rainfall. The weather data are recorded in the crop by an automatic weather station (e.g. METOS, Skye Minimet) and downloaded to the PC directly or via a lap top computer. The model output is displayed graphically showing estimated

% flower infection, the predicted % fruit infection resulting from the flower infection and the Botrytis inoculum potential. An initial action threshold for the warning system is triggered when the predicted fruit infection reached 10%.

The warning system was evaluated in strawberry crops (cv Elsanta) for the first time in 1999. In the trials, three management programmes incorporating the warning system were tested and compared to a conventional routine programme and an untreated. The risk of Botrytis during flowering was low. Consequently fewer sprays were applied to the managed plots compared to the conventional. The incidence of Botrytis rot at harvest was negligible, but in post-harvest tests upto 27% Botrytis developed in untreated plots. All spray treatments reduced Botrytis rot, but the treatments incorporating BOTEM achieved this with reduced fungicide inputs. The results from the initial testing of the warning system are promising but further evaluation is required before the software is finalised and the system commercially available.

POWDERY MILDEW

Powdery mildew, caused by the fungus *Sphaerotheca macularis*, can be a serious disease of strawberry. All parts of the plant above ground are attacked, but it is the damage done to the flowers and fruits at all stages of development that can result in heavy losses. Infected flowers are either killed or deformed, green fruit become hard and fail to ripen and ripe fruit are more prone to Botrytis attack.

In the UK, mildew is most severe on everbearers and in protected strawberries where flowers and fruits can be severely attacked. Control of mildew with fungicides in everbearers is particularly difficult because of the continuous cycle of flowering and fruiting and the need for fungicides with short harvest intervals. Some success has been achieved with the introduction of cultivars, such as Evita, which are resistant or partially resistant to mildew, but this resistance appears to be short-lived.

Under UK conditions on susceptible June-bearer cultivars such as Elsanta, control of mildew pre-harvest is generally good. The attack is most severe post-harvest, usually on the regrowth of mown-off strawberry plants, where in commercial crops, despite fungicide sprays, the average incidence of mildew can be as high as 30% of the leaf area mildewed.

Previous work indicates that mildew mainly overwinters as mycelium on green leaves and that fungal fruiting bodies (cleistothecia) which are not commonly found in crops play no part in the perennation of the disease. In the spring once conditions become warm and humid, the fungus sporulates on the overwintered green leaves and spores are spread by wind to infect new leaves and flowers. Warm, dry conditions favour rapid development of mildew epidemics.

Control

- Cultivars vary in their disease susceptibility. Elsanta and most everbearers such as Calypso, Bolero and Tango are susceptible. Evita shows good resistance to

mildew. Plants are most susceptible to mildew under protection and cultivars which are resistant outdoors may become susceptible under protection.

- Removal of crop debris in spring will reduce overwintered inoculum.

- On susceptible cultivars, a routine programme of fungicide sprays from first flower should give good control. In the UK a programme based, on a DMI fungicide such as myclobutanil (Systhane), alternated with a non-DMI product such as bupirimate (Nimrod) should give good control of mildew. Sulphur or dinocap (Karathane) may also be used, but these may be harmful to predatory mites used to control two-spotted spider mite on strawberry.
- In The Netherlands and Belgium, sulphur evaporators are used in protected strawberries to control powdery mildew.

- Good spray cover, especially of the young leaves, flowers and developing fruits, is essential for fungicides to be effective.

- Everbearers should be sited well away from June-bearers to avoid inoculum carryover (see recent research results below).

Recent research on powdery mildew on Elsanta

At HRI-East Malling, MAFF-funded research has concentrated on powdery mildew on June-bearer Elsanta. The research has targeted the post-harvest mildew epidemic and the overwintering of the fungus. The results are summarised as follows:

- In two experiments over four years post-harvest epidemics of powdery mildew had no significant effect on the yield in the following season on strawberry cv. Elsanta.
- In most seasons, under weather conditions in the UK, strawberry plants continue to grow slowly throughout the winter whereas the post-harvest mildew epidemic ceases with the onset of cooler weather in the autumn. Consequently leaves infected with mildew in the autumn have senesced and died by the following spring and are therefore not usually important in initiating new mildew epidemics in spring.
- Mildew fruiting bodies (cleistothecia) appear to play a part in the epidemiology of mildew and spores (ascospores) released from these in spring are probably responsible for initiating early mildew epidemics.
- The incidence of cleistothecia in strawberry crops varies, but where they are absent mildew is not usually recorded in the crop the following season until after harvest.

These results mean that a simple management system for decisions on fungicide sprays in June-bearer Elsanta can be devised, based on the presence of cleistothecia in the crop the previous autumn.

- Control of powdery mildew post-harvest on June-bearer strawberries is unnecessary.
- In autumn inspect crops for the presence of cleistothecia, which can be seen, with

the aid of a x10 hand lens, on the underside of mildewed strawberry leaves amongst the mildew as pinhead sized bodies.

- Where these are present, protectant sprays for mildew will be required in spring.
- If no fruiting bodies are found, then no sprays are needed in spring, but continue to check for mildew in spring as a precaution.

STRAWBERRY BLACKSPOT

Symptoms and epidemiology

- Blackspot is caused by the fungus *Colletotrichum acutatum.*
- It attacks all above-ground parts of the plant but it is primarily a disease of ripe fruit, causing black circular lesions covered with pink/slimey spore masses on fruit.
- Petioles, stolons and crowns may also be colonised. These infections may remain symptomless until conditions favour further spread.
- Blackspot is favoured by warm, wet weather.
- Long distance spread is usually by symptomless infected planting material.
- Local spread is by rain splash of slimey spore masses.
- Local spread on pickers hands and clothes.
- The fungus can also survive on debris in soil. The survival time is dependent on conditions, but some tests in USA have shown that dried spore slime can survive for several weeks on clothing.
- The fungus can also survive on weeds.

Control

Often the first indications that a crop may be infected with blackspot are when infected fruit are seen during harvesting. Effective control at this stage is almost impossible, particularly on everbearers. Therefore control must be based on an integrated approach from the start, particularly on crops thought to be at risk from blackspot.

Cultural methods

- Healthy planting material.
- Restrict nitrogen inputs e.g. 40 kg/ha/year for June-bearer crops and 80 kg/ha/year for everbearer crops.
- Straw mulch between plant rows and on plastic mulch to reduce rain splash and spread of blackspot.
- Short picking intervals to reduce the build up of ripe fruit.
- Maintain good weed control.
- Avoid the use of paraquat for weed and runner control as this chemical is known

to encourage sporulation of *C. acutatum* and hence increase spread.
- At the end of the season, remove crop debris etc. from the field and burn.
- If blackspot is found in the crop, then at the end of the crop's life, burn or bury the strawberry plants (depending on whether the disease is covered by Plant Health Regulations as it is in the UK) and sterilise the land.

Chemicals

- Dichlofluanid (Elvaron), chlorothalonil (various products) and thiram (Unicrop Thianosan) have some suppressive/protectant effects on *C. acutatum*. Use of these products for Botrytis control will give some protection against blackspot.
- Fenpropimorph (Corbel) and myclobutanil (Systhane) also give some control of blackspot.
- Iprodione (Rovral) is ineffective.
- The efficacy of other Botrytis fungicides, such as pyrimethanil (Scala) and fenhexamid (Teldor) in controlling blackspot is not clear.

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