The International Society for Horticultural Science and the Queensland Strawberry Growers Association.

SYMPOSIUM BOOKLET

FOR THE

5th International Strawberry Symposium

5th INTERNATIONAL STRAWBERRY SYMPOSIUM

5-10 SEPT 2004
COOLUM AUSTRALIA

Sunday 5th to Friday 10th September 2004

Hyatt Regency Resort, Coolum Beach, Queensland, Australia.

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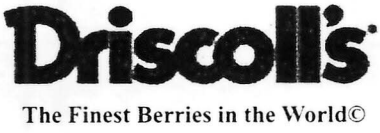

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Research and development by competent and committed scientists is the corner stone on which delighting the consumer is based. Growers, marketers, retailers and consumers have greatly benefited from the effort of dedicated R&D teams and eagerly await new developments.

We know that everyone attending this symposium will have an informative and enjoyable experience. We are glad to be able to share it with you.

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Essential Information

Registration Desk
The registration desk will be open from 8.00 am each morning.

For Sunday 5 September, it will be located in the Lower Lobby close by the Hyatt's check-in and guest reception area. From Monday 6 to Friday 9 September, the registration desk will be located in The Pavilion foyer in front of the poster and trade display area.

Name Badges
Please wear you name badge throughout the symposium program. Your badge identifies you for venue staff, the organising team and fellow delegates. It will provide admission to the symposium sessions, lunches and morning and afternoon teas and any other social activities for which you are registered.

Assistance for Delegates
Should you require assistance of any kind, please ask a member of the organising team. They will be wearing MAROON shirts and YELLOW badges for easy identification.

Messages
A message board will be located at the registration desk. Please check it regularly.

Buses
Delegates not staying at the Hyatt will be provided with a shuttle bus service to and from their accommodation (delegates staying in accommodation listed on the website only). Schedules outlining pick up times and locations will be available from your accommodation/resort host. Make sure you are ready to board the bus at least 10 mins before nominated departure time.

Catering
Your registration fee covers morning and afternoon teas and lunches, for each day you are registered. Arrangements have been made for those who have indicated special dietary needs on their registration form. This will be discussed with you when your register. If you have not already indicated you have a special dietary requirement, please do so as soon as possible after registering.

Complimentary Social Events
Your registration includes participation in the Welcome Reception (Sunday night), Food and Beverage Showcase (Monday night), Mid Week Technical Tour and Beach Spit Roast BBQ (Wednesday), if you indicated on your registration form that you wish to participate. If you have not already indicated your participation, please do so as soon as possible.

Welcome Reception
Welcome reception commences 6.30pm Sunday evening for drinks and nibbles, and a chance to get to know your fellow delegates. This event is not meant to be a meal. We recommend you make you own dinner arrangements for after the event. If you would like to have dinner at one of the Hyatt restaurants, please check with Hyatt staff and book early.

Food and Beverage Showcase
We have arranged for producers of regional wines and beverages, cheeses, nuts, fruits, chocolates, ice-cream, honey, and more to provide you with taste samples of their products during this event. You also have the opportunity to order or purchase some of these products. This event is not meant to be a meal. We recommend you make you own dinner arrangements for after the event. We will return to the Hyatt by 9.30pm. If you would like to have dinner at one of the Hyatt restaurants, please check with Hyatt staff and book early.

Symposium Banquet
We have arranged a gourmet banquet for Thursday evening to celebrate the symposium. Only those who have registered for the banquet can attend. If you have not registered for the banquet, please do so as soon as possible after arrival. We can not accept more banquet registrations after Monday evening. Please dress smart-casual.

Program

SUNDAY 5 SEPTEMBER

14.00 **Registration Opens**

18.30 **Welcome Reception** – The Pavilion

21.00 Free Time – make own arrangements for dinner.

MONDAY 6 SEPTEMBER

8.30 **Welcome** – G Neil Greer, Department of Primary Industries & Fisheries, Queensland, Symposium Convenor

Greetings - Walther Faedi, Chair of ISHS Strawberry Culture & Management Working Group

Official Opening - John Chapman – General Manager Horticulture & Forestry Science, DPI&F, Queensland

Session 1 - Physiology & Production 1

9.00 **Session Introduction:** Chair - Dr Fumiomi Takeda (W. Virginia USA).

9.10 *Root growth and architecture in strawberry.* D. Neri (Italy).

9.30 *Morphological changes of the shoot apex during night-cold/short-day treatment.* T. Kurokura (Japan).

9.50 *Effect of the application of Trichoderma harzianum on top and root growth of Fragaria chiloensis grown under abiotic and biotic stress.* J. Retamales (Chile).

10.10 *Finding a temperature optimum for optimised long season cropping in the everbearing strawberry 'Everest'.* A. Wagstaffe (UK).

10.30 *Deficit irrigation, overhead sprinkling and strawberry fruit bronzing in California.* K. Larson (Calif. USA).

10.50 Morning Tea

Session 2 -Poster Session 1

11.20 Poster Inspection – The Pavilion

12.40 Lunch

Session 3 - Physiology & Production 2

13.30 *Strategies for the management of sustainable strawberry production through the effective monitoring of nutrition and irrigation.* J. Moisander (Qld, Australia).

13.50 *Experiences with plant and sap testing for nutrients in strawberry production in Western Australia.* D. Phillips (W.A. Australia).

14.10 *Impact of different production and fertilizer systems on yield and quality of strawberries.* M. Martinsson (Sweden).

14.30 *Possible role of water channels in water stress (drought, flooding or salt stress) responses of strawberry.* M. Blanke (Germany).

14.50 **Summary -Physiology & Production Sessions 1 & 2**

15.10 Afternoon Tea

Session 4 – Crop Protection

15.30 **Session Introduction:** Chair - Nabeel Gnayem (Israel).

15.40 *Modern pest management in Queensland strawberries: the result of farm-oriented research and evolving grower perspectives.* G. Waite (Qld Australia).

16.10 *Getting a grip on thrips.* M. Steiner (NSW Australia).

16.30 *Sympatric subpopulations of Botryotinia fuckelina on strawberries depending on the content of transposable elements and their connection with resistance to Botricides.* B. Duralija (Croatia).

16.50 *Screening strawberry plant resistance to Phytophthora cactorum in NFT.* P. Parikka (Finland).

17.10 *Response of selected strawberry cultivars to anthracnose fruit rot and Botrytis fruit rot.* C. Chandler (Florida, USA).

17.30 **Session Summary – Crop Protection**

18:00 **Bus Leaves from the Hyatt for Food & Beverage Showcase at Sunshine Plantation Woombye**

TUESDAY 7 SEPTEMBER

Session 5 - Soil Disinfestation – Is There Life After MB?

8.30 **Session Introduction**: Chair - Geoff Waite (Qld Australia).

8.40 *Impact of global methyl bromide phase out on the sustainability of strawberry industries.* J. Banks (ACT Australia).

9.10 *Understanding Increased Growth Response – A Key to Developing Integrated Strawberry Disease Management Systems.* S. Mattner (Vic. Australia).

9.30 *Effects of bio-fumigation on typical weeds of strawberry fields.* N. Lopez-Martinez (Spain).

9.50 *Ethanedinitrile (C_2N_2) – a novel disinfestant for strawberry production.* S. Mattner (Vic. Australia).

10.10 *Testing alternatives to methyl bromide in subtropical strawberries.* D.Hutton (Qld Australia).

10.30 **Summary – Soil Disinfestation**

10.40 Morning Tea

Session 6 - Nursery & Propagation Factors Affecting Plant Quality & Performance – General Factors

11.00 **Session Introduction**: Chair – Dr. Kirk Larson (Calif. USA).

11.10 Strawberry transplant production and performance in annual plasticulture production system. F. Takeda (W. Virginia USA).

11.30 *Strawberry mother plant propagation by in-vitro sub-culturing and their performance in nursery and fruiting fields in Israel.* N. Gnayem (Israel).

11.50 *The Performance of Strawberry Plugs in Queensland, Australia under a winter/spring fruiting system.* C. Menzel (Qld Australia).

12.10 *Northern Vigour® in strawberry crowns.* K. Tanino (Canada).

12.30 *Effect of prohexidione-Ca on establishment and yield of green-top bare-rooted strawberry transplants.* J. Duval (Florida, USA).

12.50 *Influence of NPK fertilisation on stolon and crown formation per mother plant during ontogeny in strawberry (Fragaria x ananassa Duch.) cv. Camarosa in a highland nursery.* E. Brandan (Argentina).

13.10 Lunch

Session 7 - Disease Factors - Colletotrichum

00 ~~13.30~~ *An overview of Anthracnose in North America.* B. Smith (USA).

30 ~~13.50~~ *Interaction, survival strategies and host range of Colletotrichum acutatum on strawberry.* S. Freeman (Israel).

15:00 Afternoon tea

20 ~~14.20~~ *Anthracnose on strawberry in France and perspectives.* B. Denoyes-Rothan (France).

40 14.50 *Pathogenicity of UK isolates of Colletotrichum acutatum and relative resistance among a range of strawberry cultivars.* D. Simpson (UK).

00 ~~15.10~~ *Development of a rapid, reliable screening method for pathogenicity of Colletotrichum spp. on strawberries.* S. Freeman (Israel).

20 ~~15.30~~ *Successful management of colletotrichum crown rots in runner production in subtropical Australia.* D. Hutton (Qld Australia).

~~15.50 Afternoon Tea~~

40 ~~16.10~~ **Panel Discussion, Audience Participation Activity & Summary**

40 ~~17.10~~ Free night for delegates to explore local restaurants and night life

00 Bus to Big Pineapple

WEDNESDAY 8 SEPTEMBER

TECHNICAL TOUR ALL DAY

8.00 Will include visits to farms of all sizes, a farm catering to the tourist trade and another applying advanced sustainability principles.

We will also visit the DPI&F's Maroochy Research Station, the major strawberry research site in Australia and inspect breeding trials, pest and disease management trials, MB replacement trials, organic options trials and so on. We will also view the wide range of subtropical crops studied at MRS such as mango, lychee, custard apple, macadamia, banana, pineapple, passionfruit, paw paw (papaya), low chill stone fruit and persimmon.

The day will end with a Spit Roast Dinner at Moffats Beach, Caloundra.

21.00 Return to Coolum.

THURSDAY 9 SEPTEMBER

Session 8 – Postharvest Physiology, Quality & Flavour

8.30 **Session Introduction**: Chair – Dr. Michael Blanke (Germany).

8.40 *Effects of nitrogen fertiliser on sensory attributes of strawberries.* D. Phillips (W.A. Australia).

9.00 *Quality and antioxidant activity changes during low temperature storage of strawberry fruits.* C. Hansawasdi (Thailand).

9.20 *Pre-harvest calcium effects on sensory quality and calcium mobility in strawberry fruits.* A.Able (S.A. Australia).

9.40 *The effect of nitrate:ammonium ratios on fruit quality of strawberry cultivar 'Selva'.* T. Taghavi (Iran).

10.00 **Summary – Postharvest Physiology, Quality & Flavour**

10.10 Morning Tea

Session 9 Poster Session 2

10.30 Poster Inspection – The Pavilion

12.00 Lunch

Session 10 – Protected Production

12.50 **Session Introduction:** Chair – Dr. Saila Karhu (Finland).

13.00 *High density vertical hydroponics growing system for strawberries.* G. Linsley-Noakes (South Africa).

13.20 *Out-of season strawberry production in Norway: yield responses to cv, Korona to photoperiod preconditioning treatments.* A. Sonsteby (Norway).

13.40 *Positive effect of sorghum grown as a soil improving crop on CO_2 environment in greenhouses and photosynthesis of strawberry.* Y. Yoshida (Japan).

14.00 *Polyethylene greenhouse film affects soil and temperature, photosynthetically active radiation (PAR) and yield performance of strawberry in high tunnels.* K. Larson (Calif. USA).

14.20 *Chilling unit model for greenhouse production of strawberry cv. 'Elasnta'.* P. Lieten (Belgium).

14.40 **Summary –Protected Production**

14.50 Afternoon Tea

Session 11 – Industry Development

15.10 **Session Introduction:** Chair – Lawrence Ullio (NSW Australia).

15.20 *The Better Berries Program – a novel approach to strawberry industry development in Australia.* G. N. Greer (Qld Australia).

15.40 *Strawberry production in South America.* R. Pertuze (Chile).

16.00 *Economics of post seasonal strawberry production in Croatia.* B. Duralija (Croatia).

16.20 *How to convert the Chilean native strawberry into a new crop?* J. Retamales (Chile).

16.40 *Assessing the information needs of Australian strawberry growers.* N. Vock (Qld Australia).

17.00 **Summary – Industry Development**

19.30 **Symposium Banquet**

FRIDAY 10 SEPTEMBER

Session 12 – Breeding 1 - Programs & Cultivars

8.40 **Session Introduction:** Chair – Dr. David Simpson (UK).

8.50 *Strawberry breeding in a subtropical environment.* Mark Herrington (Qld Australia) and Craig Chandler (Florida USA).

9.20 *Progress in strawberry breeding in Italy.* W. Faedi (Italy).

9.40 *Breeding ornamental strawberries.* G. Bentvelsen (Netherlands).

10.00 *Recent progress in strawberry breeding in China.* Y. Zhang (China).

10.20 *USDA-ARS strawberry anthracnose resistance breeding program.* B. Smith (Mississippi, USA).

10.40 Morning Tea

Session 13 - Breeding 2 – Genetic Diversity & Manipulation

11.10 The *genetic basis of diversity in the genus Fragaria.* D. Sargent (UK).

11.30 *Genetic engineering of strawberry cultivars Firework and Selekta, for taste improvement and enhanced disease resistance by introduction of thau II gene.* S. Dolgov (Russia).

11.50 *Pedigree Genotyping: A New Pedigree-based Approach to QTL Identification and Allele Mining.* W.E. Van De Weg (Netherlands).

12.10 *Differential expressed genome fractions and transcriptional factor isolation in Fragaria spp.* G Martelli (Italy).

12.30 Lunch

Session 14 - Breeding 3 – Techniques

13.30 *Characterization of Strawberry Genotypes by PTR-MS Spectral Fingerprinting: a Three Years Study.* F. Biasioli (Italy).

13.50 *Usefulness of some strawberry genotypes for breeding of late ripening cultivars.* E. Zurawicz (Poland).

14.10 *Cross breeding with accessions of Fragaria chiloensis resulting in clones with outstanding characteristics of resistances and fruit quality.* K. Olbricht (Germany).

14.30 **Breeding Session Summary & Future Directions**

14.50 Afternoon Tea

15.20 ISHS Strawberry Culture and Management Working Group meeting

16.30 **Symposium Summary and Closure**

Oral abstracts

Root Growth and Architecture in Strawberry

Davide Neri and Gianluca Savini

Dipt. of Energetics, Polytechnic University of Marche, Ancona, Italy

Roots show a dynamic growth with alternate phases of expansion and rest, strictly related to the above-soil plant behaviour. During the first weeks after transplanting, the primary roots explore 20-30 cm of soil or substrate, using the reservoir stored in the crown and in previously formed primary roots, which quickly decay. They are positively geotropic, and grow downward very rapidly.

The root system at the end of this phase is fasciculate, bell-shaped with the single roots well separated, but seldom grouped in clusters. Depending on the variety and substrate conditions, the secondary roots emerge 5 to 10 cm from the apex. It can be argued that the root apex exerts a type of dominance on lateral meristematic formation up to a certain distance. The secondary roots grow a few centimetres horizontally, and then gradually assume a geotropic behaviour, producing a wider lateral expansion. Because they are ephemeral, they are likely to be involved in absorbing nutrients. When fruits are maturing, root growth and expansion slow down.

If soluble extracts from strawberry residues are applied locally, primary roots develop a reddish colour and have no root hairs. They may be clumped and penetrate to deeper levels faster, and laterals are not formed. This behaviour exactly simulates the rapid 'soil oldening', induced by root exudates and residues deriving from normal root activity. It produces rapid growth of migratory roots, possible new primary roots to other available fresh niches, and it assumes the role of allelopathic control, distancing the roots and efficiently guiding space occupation.

Morphological Changes of the Shoot Apex during Night-Cold/Short-Day Treatment

Takeshi Kurokura[1], Nobuo Sugiyama[1], and Yukio Inaba[2]

[1]Graduate School of Agricultural and Life Sciences, University of Tokyo, Tokyo, Japan
[2]Tochigi Prefectural Agricultural Experiment Station, Tochigi, Japan

Strawberry consumption in Japan increases significantly around Christmas and in the New Year season. Thus, Japanese strawberry growers conduct Night-Cool/Short-Day (NCSD) treatments in summer, to accelerate flowering and harvest strawberries before the end of the year. However, little is known about the relationship between NCSD treatment and flower initiation and flower formation. In this study we studied morphological changes of the shoot apex during NCSD treatment of the main Japanese cultivar 'Tochiotome'.
We established 23°/18° 10h day length (NCSD) and 25°/20° 16h day length (High-Temperature/Long-Day, HTLD) treatment conditions. We treated potted strawberries for 8, 16, 24 or 32 days under NCSD conditions, and then transferred the plants to HTLD conditions. Although no morphological differences were observed between the shoot apex of plants treated for 8 and 16 days, 16 day NCDS treated plants flowered 24 days after they were transferred to HTLD conditions. In contrast, the 8 day NCSD treated plants never formed flower organs under HTLD conditions. Our results indicate (1) flower initiation needs more than 9 days of NCSD treatment, and if NCSD treatment is shorter than 9 days then HTLD counteracts the NCSD effects (2) flower initiation occurred considerably earlier than is apparent from morphological observations.

Effect of the Application of *Trichoderma Harzianum* on Top and Root Growth of *Fragaria Chiloensis* Gown Under Abiotic and Biotic Stress

Rafaela P. Riquelme[1], Jorge B. Retamales[1] and Gustavo A. Lobos[2]

[1]Universidad de Talca, Facultad de Ciencias Agrarias, Casilla 747, Talca, Chile
[2]Bio Insumos Nativa Ltda., Casilla 16-D, San Javier, Chile

Fragaria chiloensis l. Duch. is a native species that has been cultivated for centuries by local farmers in South-Central Chile. With the advent of European and North American cultivars during the last century, the area planted has decreased dramatically. *F. chiloensis* has low productivity partly because it faces diverse environmental stresses, both biotic and abiotic. The genus *Fragaria* has long been recognized as one of the fruit species most susceptible to salt stress. Even though accessions of *F. chiloensis* have been found growing along the seashore, the impact of salts on cultivated white *F. chiloensis* has not yet been studied. On the other hand, *Rhizoctonia* is a fungal disease frequently found in fields planted with the commercial strawberry (*F. x ananassa*). In southern Chile, farmers usually plant white *F. chiloensis* in fields that previously grew potatoes, which would greatly increase the incidence of this fungal disease. *Trichoderma* belongs to a group of fungi that develop mutualistic interactions with plants. It has controlled diverse diseases and may increase plant growth and the root/shoot ratio, and expand the availability of nutrients through chelate formation, especially when plants are subject to stress. Scientists of the University of Talca have isolated three strains of *Trichoderma spp.* (Trailes, Sherwood and Queule) and are studying their effects on horticultural crops. The objective of this research was to determine the effect of *Trichoderma harzianum* (Queule strain) on top and root growth of *F. chiloensis* plants subject to biotic (*Rhizoctonia*) and abiotic (salt) stresses. To study the effect on biotic stress, a field experiment was initiated in Contulmo with *F. chiloensis* plants grown on a site that previously grew potatoes, and was expected to have high incidence of *Rhizoctonia. Trichoderma* solution was applied at planting and again at bloom, and the plants were subjected to differential salt levels. At Talca, plants were set in a plastic greenhouse and grown in 30x40x2cm glass containers filled with a 1:2 mixture of sand, and previously-sterilized Contulmo soil. Three levels of salt (0, 0.4, or 0.8gr NaCl/1water) and two levels of Queule strain (0 or 0.2ml *Trichoderma* solution/1.2 l water) were established. Plants were irrigated based on their needs, watering with 100 ml/plant of salt solution/day in Talca, and 100 ml/plant/ week in Contulmo. In Talca, salt was applied starting one month after transplanting, while in Contulmo salt treatments were initiated immediately after *Trichoderma* application. In Talca, root length is being measured weekly, while dry weight roots, crowns, fruit and leaves will be determined at the end of the experiment. In Contulmo, in March, at the end of the growing season, root length and dry weight of plant organs will be measured.

Finding a Temperature Optimum for Optimised Long-Season Cropping in the Everbearing Strawberry 'Everest'

Alexandra Wagstaffe[1] and Nick Battey[1]

[1]School of Plant Sciences, The University of Reading, Reading, United Kingdom

The prolonged season of everbearing strawberries causes vegetative growth and fruiting to coincide. Therefore, the influence the environment has on the balance of assimilate partitioning between vegetative and reproductive growth, is of importance for optimised long-season production. Fruiting patterns were evaluated over three seasons for the everbearing strawberry cultivar 'Everest', as part of a UK DEFRA Link research project. A range of temperatures (15 – 27°C) was studied in the first season to establish a temperature response curve. Detailed transfer treatments in the second and third seasons were used to study heat-induced cropping troughs ('thermo-dormancy'). The relative importance of day and night temperatures was explored. The highest yields of 1713g per plant were recorded for plants grown between 18°C and 23°C. With increasing temperature, fruit number increased but fruit weight decreased. Assimilate partitioning to fruit (harvest index) was optimised at a higher temperature in this everbearer than that previously reported for the June-bearer, 'Elsanta'. The role of temperature in optimising long-season fruit production has significance for commercial production, in which protected cropping tends to increase average temperature through the season.

Polyethylene greenhouse film affects soil and air temperature, photosynthetically active radiation (PAR), and yield performance of strawberry in high tunnels

Kirk D. Larson, Christina J. Smith and Joaquin Esparza Palacios

Department of Pomology, University of California, Davis, USA

Strawberry production in the Mediterranean basin is based on protected culture with the use of polyethylene tunnels. Despite a similar climate and use of identical cultivars, California strawberry production is based entirely on use of outdoor production systems. During the 2003 production season, we compared PAR, soil and air temperatures, and yield performance of 'Camarosa' and 'Ventana' strawberry grown outdoors, and under two greenhouse films: Tufflite IV ("T4", Tyco Plastics, Inc.) and IR Thermal ("IRT", Ginegar Plastics, Inc.) Individual tunnels measured 4.9m wide, 25m long and 3.7m high, and covered three planting beds. Bare-root transplants were planted in early October. Tunnels were covered on 2 December 2002, and tunnel sides were left open to a height of 1.2 m. Fruit were harvested 1-2 times weekly from mid-December through 1 April.

For tunnels covered in T4 and IRT films, mid-day PAR was 74% and 60%, respectively, of that of outdoors. Use of tunnels resulted in higher air and soil temperatures compared to outdoor plots, with little difference between tunnel treatments. However, use of T4 film resulted in 1.3- to 1.4-fold greater early season yield (to 1 March) than outdoor plots, while use of IRT film provided little or no early season yield enhancement. For all treatments, 'Ventana' had consistently greater early season yield than 'Camarosa', with better fruit appearance scores. Also, tunnel culture resulted in enhanced early season fruit appearance scores for 'Ventana', more so than for 'Camarosa'. Results of this study suggest that tunnel films may have significant effects on light quality, and that this may be an important factor in strawberry yield performance in tunnels.

Strategies for the management of sustainable strawberry production through the effective monitoring of nutrition and irrigation

J.A. Moisander[1] and D. Lyons[2]

[1]Department of Primary Industries and Fisheries, Redlands Research Station, Cleveland 4163 Queensland, Australia
[2]Natural Resource Sciences Chemistry Centre,Department of Natural Resources, Mines and Energy, 80 Meiers Rd., Indooroopilly 4068 Queensland, Australia

The application of excess nitrate fertiliser and the excessive use of water have been shown to result in losses of over 80% of the nitrate fertiliser applied to strawberry (*Fragaria spp.*) plants through a trickle irrigation system. The fine-tuning of recommendations for commercial soil test interpretation data, and the greatly improved adoption of soil testing services by growers over the last 10 years, has lead to a much greater understanding of the requirements of strawberry plants throughout the season. The adoption of the practice of monitoring leaf sap nitrate levels in plants throughout the different growth stages in the season has greatly reduced the amount of nitrate fertiliser applied during the season. This has been achieved over the last 10 years through the establishment of desirable sap nitrate levels for more than 15 commercial strawberry varieties, and these predetermined levels provide added guidance to growers in their monitoring program. After demonstrating to growers the potential water savings to be had by using trickle irrigation systems in preference to overhead systems, the further step of instructing them in the use of various soil moisture technologies such as tensiometers, Enviroscan®, has greatly reduced water consumption on farms and reduced the leaching effect on their applied fertilisers. The adoption of these technologies has resulted in growers attaining optimal yields, reduced fertiliser and water use, and reduced environmental impact from their strawberry enterprises.

Experiences with plant and sap testing for nutrients in strawberry production

Dennis Phillips[1], David Gatter[1] and Kelly Hulcup[2]

[1]Department of Agriculture Western Australia, Perth, Australia
[2]formerly Department of Agriculture Western Australia, Perth, Australia

Plant testing has for many years, been used in commercial horticulture as a diagnostic aid in crops when problems are experienced, and to a lesser extent as a monitor of ongoing crop health. Methods commonly used are laboratory tests, with results reported as a percentage of the dry weight of plant tissue, and fresh sap testing. Both methods suffer from the weakness that the results are only as good as the standards available to compare them to, and time delays in testing can inhibit rapid responses to identified problems. A common problem with standards for strawberries and other crops is that they may vary with variety, and current relevant data is not kept up to date as varieties change. Another problem, which is rarely recognised, is that the adequate level of many nutrients in a particular plant part or leaf may change naturally over the life of the crop.

This paper reports on studies aimed at correcting some of these deficiencies for six commercial strawberry cultivars commonly grown in Western Australia, and to establish the potential of rapid sap testing with Merckoquant® test strips as a crop monitoring and diagnostic tool. The report is a compilation of results from crop surveys and replicated fertiliser trials conducted on sandy soils of the Swan Coastal Plain near Perth WA between 1996 and 2002.

Different strategies for fertilizing strawberries, where fertigation is the winner

Anke Kwast[1], Rolf Kopper[2], Grezegorz Cieslinski[3], Waldemar Treder[4], Mats Martinsson[5]

[1]Yara Gmbh & Co.KG Hanninghof 35/D-Dylmen, Germany
[2]Institute of Fertilization, University of Hanover, Germany
[3]Yara, Poland Sp. Z o.o. al. 3 Maja 1. 70—214 Szczecin
[4]Research Institute of Pomology and Floriculture ul. Pomologiczna 18, 96-100 Skierniewice, Poland
[5]Yara AB, 261 24 Landskrona, Sweden

Over several years, Yara (Hydro) has conducted a number of trials to determine how best to fertilize strawberries, both in the open field and in greenhouses. We have compared broad distribution of fertilizers with fertigation.

A field trial was conducted at the Institute of Fertilization, University of Hanover, Germany, in cooperation with Yara Experimental Station, Hanninghof, Dylmen, Germany.
The effect of different fertilization systems on frigo plants of the Cv. Elsanta, was investigated. In this trial, the performance of 'Elsanta' grown conventionally in the field with broad distribution of fertilizers NPK and Mg and with overhead irrigation, was compared with different regimes of fertigation applied to raised beds with plastic mulch. The application of different amounts of nitrogen was tested and results recorded to determine the optimum level of nitrogen required. Also, the uptake of different essential nutrients was recorded during the growing period.

The effect of extra calcium applied to the strawberry plant was demonstrated on sandy soil and clay soil in a trial in Poland. Calcium affected total yield, fruit size, fruit firmness, root system etc. of 'Elsanta' A+ grade. In this trial we also compared different nitrate forms (CN, KN, AN) for their effect on strawberry fruit quality. In an experiment conducted on potted srawberry poants in the greenhouse, we attempted to determine the concentration of the soil nutrient solution for strawberry plants with respect to the effect of soil type, sand or clay.

Possible role of water channels in water stress (drought, flooding or salt stress) responses of strawberry

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Strawberry (*Fragaria x ananassa* Duch.) cvs. 'Flrika' and 'Cambridge Favourite', were subjected to the three different forms of water stress caused by drought, flooding or salt stress. Control plants were well watered. Strawberry leaves with ca. 300 stomata mm^{-2} transpired ca. 5.6 mmol H_2O m^{-2} s^{-1}. Midday water potentials of stolons were always less negative than in leaves, enabling nutrient ion and water transport via or to, the strawberry stolons. Drought stress, but not flooding, decreased stolon and leaf water potential from –0.7 to -1 Mpa, and from –1 to -2 MPa, respectively, with a concomitant reduction in stomatal conductance from 75 to 30 mmol H_2O m^{-2} s^{-1}. However, leaf water potentials remained unchanged after flooding. Similarly, membrane vesicles derived from stolons of flooded strawberry plants showed no change in water channel activity. In these stolons, turgor may be preserved by maintaining root pressure, an electrochemical and ion gradient and xylem differentiation, assuming water channels remain open. By contrast, water channel activity was reduced in stolons of drought-stressed strawberry plants. In every case, the effect of flooding on water relations of strawberry stolons and leaves was less pronounced than that of drought, which cannot be explained by increased ABA. Stomatal closure under drought could be attributed to increased delivery of ABA from roots to the leaves. However, stomata closed more rapidly in leaves of flooded strawberry despite ABA delivery from the roots in the xylem to the leaves being strongly depressed. This stomatal closure under flooding may be due to release of stress ethylene. In the relative absence of stomata from the stolons, cellular (apoplastic) water transport in strawberry stolons was primarily driven by water channel activity, with a gradient from the tip of the stolon to the base, concomitant with xylem differentiation and decreased water transport potential from the stolon tip to its base. Reduced water potential in the stolons under drought is discussed with respect to reduced putative water channel activity. To our knowledge, this is the first report of water channels in strawberry.

Pest management in Queensland strawberries: reality bites, and growers' perspectives change!

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Prior to the 1980s, arthropod pest control in Queensland strawberries was based entirely on calendar sprays of insecticides (mainly endosulfan, triclorfon, dimethoate and carbaryl) and a miticide (dicofol), which because of the frequency of use, were a major cause of spider mite outbreaks. The concept of IPM had not been introduced to the growers, and the suggestion that an alternative to the standard chemical pest control recipe might be available, went unheeded. Circumstances changed when the predatory mite, Phytoseiulus persimilis Athios-Henriot, became available commercially in Australia, providing the opportunity to manage spider mites, the major pest of strawberries, with an effective biological agent. Trials conducted on commercial farms in the early 1980s indicated that a potential revolution in strawberry pest management was at hand, but the industry generally remained sceptical and afraid to adopt the new strategy. Lessons are learnt from disasters and the consequent monetary loss that ensues, and in 1993 such an event, relating to ineffectual spider mite control, spawned the revolution we had to have. Farm oriented research and evolving grower perspectives have resulted in the biological control of spider mites, based on the use of Phytoseiulus persimilis and the 'pest in first' technique, forming the basis of an IPM system that is used on more than 80 percent of the Queensland strawberry crop.

Getting a grip on thrips in strawberries

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Strawberry fruit is damaged by a variety of insects and diseases, and by vagaries of weather and nutrition. Matching symptoms with causes is not always easy. This paper outlines results from a three-year study in a hydroponic strawberry crop near Sydney, which began with management of western flower thrips, *Frankliniella occidentalis* (Pergande) as its goal, and ended with a better appreciation of the nature of thrips damage, thresholds for action, the interaction of the environment and damage severity, and tools for managing populations below economic threshold levels.

Two distinct periods of damage to fruit with different symptoms, were recognised. The most severe damage was manifest as a network of surface russeting on young green fruit about two weeks post-flowering, with secondary damage caused to late green and red fruit in the form of browning around the seeds. Action thresholds and monitoring methods that are based primarily on flower counts, were developed, though yellow sticky trap counts can provide supporting information. An action threshold of 45% of flowers with 5 or more adult western flower thrips, or 40% with 10 or more plague thrips, *Thrips imaginis* Bagnall, was established, with a greater tolerance during cool wet periods. For western flower thrips, the action threshold also corresponded with a sex ratio of thrips caught on sticky traps of 60-65% females (20-30 females per trap).

Overhead misting during hot dry periods was found to reduce damage severity and thrips population density. Familiarity with local thrips species and natural enemies and their seasonal occurrence is important, as management approaches will need to be adapted to them.

Sympatric Subpopulations of *Botryotinia fuckelina* on Strawberries Depending on the Content of Transposable Elements and their Connection with Resistance to Botriticides

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Botryotinia fuckeliana (anamorph *Botrytis cinerea*) is the cause of grey mould on strawberries, which is one of the most widely occurring diseases wherever the strawberry crop is grown. The fungus manifests extraordinary genotype and phenotype variability and adaptability. One of the causes of variability is attributed to transposable elements (TE) from the transposone and retrotransposone groups. In connection with this fungus, two TE have been discovered so far: retrotransposons (Boty) and transposons (Flipper), based on which the fungus, *B. cinerea*, has been divided into two sympatric subpopulations: *Botrytis transposa*, which contains both TE (Boty+Flipper-), and *Botrytis vacuma*, which contains none (Boty-Flipper-). In order to determine the connection between these subpopulations and resistance to botriticides, we identified 184 isolates from strawberry fields that had been treated with botriticides, from the groups consisting of dicarboximides, phenylsulfamides, anilinopyrimidines, and hydroxyanilidines. Based on this research, we determined four sub-populations of the fungus with the following content of TE: Boty+ Fliper+, Boty - Flipper -, Boty + Fliper- and Boty -Flipper+. The representation of the sub-population *Botrytis transposa*, was 41 %, sub-population *Botrytis vacuma*, 23%. The remaining two sub-populations, with one of each of these elements, were represented by 26 % (Boty –Flipper+) and 9 % (Boty+Flipper-). Most of the isolates proved to be resistant to at least one of the mentioned botriticides, with most of them being resistant to phenylsulfamides and benzimidazoles.The ratio of the sub-populations to botriticide resistance was different.

Screening strawberry plant resistance to *Phytophthora cactorum* in NFT

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Crown rot, *Phytophthora cactorum*, caused severe plant damage in Finland in 1990. The resistance of strawberry cultivars has been tested at MTT Agrifood Research Finland, Plant Protection, since 1993 using a crown test. Up to 2003, about 60 cultivars had been subjected to greenhouse tests. In controlled conditions, the crown test gives quite reliable results, but infection through a wound in the crown is not typical of the way the pathogen naturally penetrates the plant.

The NFT system makes it possible to use small, unwounded strawberry runner plants in screening. By rooting the runners in rockwool cubes and putting the *Phytophthora cactorum* inoculum as sporangia in circulating irrigation water, the inoculum is spread rapidly and evenly to all the plant material tested. The screening methods were compared by simultaneously inoculating the same strawberry cultivars with the crown test, and with NFT in similar greenhouse conditions. The standard cultivar used in the tests was 'Jonsok', which has proved to be very susceptible to crown rot. It showed the same level of susceptibility under both test methods, and the results were not affected by the amount of inoculum in the circulating irrigation water. Cultivars with high resistance like 'Senga Sengana', did not show symptoms in the NFT tests. Most of the cultivars tested showed the same level of resistance in both tests, and the cultivars that had high resistance in the crown test did not show wilt symptoms in the NFT system. There was, however, internal browning also in the crown tissues of those cultivars that had less wilting.

The NFT system gives results as rapidly as the crown test when small fresh runner plants are used. There is no need for extra humidity in the greenhouse in order to obtain infection. The NFT system, once it has been established and calibrated with the control cultivars, is easy to use in screening plant material.

Response of selected strawberry cultivars to anthracnose fruit rot and Botrytis fruit rot

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Strawberry cultivars were evaluated for resistance to anthracnose fruit rot (*Colletotrichum acutatum*) and Botrytis fruit rot (*Botrytis cinerea*) in 2001-02 and 2002 at Dover, Florida. Resistance to each pathogen was evaluated in separate trials. Anthracnose was allowed to develop in one trial by applying fenhexamid, which controls Botrytis but not anthracnose; and Botrytis in the other trial by applying azoxystrobin, which is active against anthracnose, but only suppressive to Botrytis. Fruit were harvested and evaluated for disease during a 4- to 5-week interval in February and March of each season.

The incidence of anthracnose fruit rot in the anthracnose cultivar trials ranged from 2.4 to 75.2% in 2001-02 and 8.1 to 95.9% in 2002-03. In both trials, 'Carmine', 'Sweet Charlie', and possibly 'Earlibrite' were resistant; 'Strawberry Festival' was intermediate in reaction; and 'Camarosa' was highly susceptible. 'Aromas', 'Rosa Linda', and 'Treasure' also appeared to be highly susceptible, but were only tested one season. The incidence of Botrytis fruit rot in the corresponding Botrytis cultivar trials ranged from 5.1 to 18.7% in 2001-02 and from 2.1 to 6.7% in 2002-03. It was more difficult to separate cultivars with respect to Botrytis fruit rot. However, disease incidence was relatively low in 'Carmine' and 'Gaviota', and higher in 'Sweet Charlie' and 'Earlibrite'. 'Festival' was intermediate in reaction in 2001-02, but similar to 'Sweet Charlie' in 2002-03. Data for cultivars Aromas, Camarosa, and Rosa Linda, and Treasure were confounded by anthracnose fruit rot, which was not adequately suppressed by applications of azoxystrobin.

Impact of Global Methyl Bromide Phase-out on the Sustainability of Strawberry Industries

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Yields of the modern strawberry have risen by around 300% since the 1940s due to improved varieties, virus elimination through certification schemes, and the use of methyl bromide (MB) for soil disinfestation. However, the use of MB in soils is due for phase-out in 2005 in non-Article 5 countries, under the *Montreal Protocol*. Only those industries that can justify that there are no technical alternatives may be granted a 'Critical Use Exemption' (CUE) from the MB phase-out. If approved, this would enable industries to have an allocated amount of MB available to use after 2005, for a defined period. The first applications for CUE were considered by the 'Parties to the *Montreal Protocol*' in November 2003. The implications of these decisions on world strawberry industries will be discussed at the Symposium.

Without adequate soil disinfestation, yields of strawberries will fall by between 20–80%. This paper will also review the major chemical and non-chemical alternatives being considered by strawberry industries worldwide, as alternatives to MB. In general, strawberry industries are adopting chemical alternatives as short-term replacements to MB, although there is a move towards hydroponic production in cooler regions of the world.

The phase-out of MB has already delivered significant benefits and opportunities to global communities and industries. Evidence shows that reductions in the use of MB by growers since 1998 has had an immediate impact on bromine levels in the troposphere, an important step towards ozone restoration. Additionally, the phase-out of MB has provided a unique opportunity for industries to critically examine the sustainability of their production systems. The question is, which industries will take advantage of this opportunity?

Understanding the Increased Growth Response – A Key to Developing Integrated Disease Management Systems for Strawberry

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Soil disinfestation can cause an increased growth response (IGR) in strawberries of up to 35%, even when soils contain low levels of pathogens and pests. To investigate the reason for the IGR, we characterised the changes in soil biology and chemistry following soil disinfestation.

Typically, disinfestation reduces populations of most soil organisms immediately after treatment (eg fumigation with methyl bromide can kill over 90% of culturable soil fungi). Soon after treatment, however, disinfestation causes a flush of ammonium-N (increases by up to 15-fold) and soil bacteria (particularly Gram negative bacteria), and these effects may persist for over a year. A pot study demonstrated that there was a significant, positive correlation ($r = 0.815$) between the concentration of ammonium in soil caused by disinfestation and the total fresh weight of the indicator plant *Calendula*. In three field trials, however, replacement of the N-effect with artificial fertilisers in non-disinfested soils consistently failed to increase strawberry yields compared with those in disinfested soils. This suggests that changes in soil chemistry and biology after disinfestation both contribute to the IGR.

To further understand biological aspects of the IGR, we examined the rhizoplane of strawberries in disinfested soils using SEM. Soil disinfestation reduced populations of fungal and bacterial colonists on the rhizoplane by 95 and 65%, respectively. There was also a significant relationship ($r = -0.55$) whereby strawberry root growth increased as the colonisation on the rhizoplane by bacteria decreased. This increased root growth might be explained by a reduction in competition from bacteria for resources and/or a change in the proportion of beneficial and detrimental organisms on the rhizoplane.

Understanding the IGR is a key to developing successful IDM systems for managing soil-borne diseases of strawberry. We proposed an IDM system for strawberries based on: (1) a biocidal runner dip and soil amendment with BCDMH (bromochlorodimethyl hydantoin) to replace the fungicidal effect of disinfestation and its effect in reducing microbial colonists on the rhizoplane; (2) ammonium fertiliser to replace the nutrient flush induced by disinfestation; and (3) pre-emergent herbicides (napropamide and metolachlor) to replace the herbicidal effects of disinfestation. The IDM system reduced the incidence of crown rot in strawberries by 66% and increased yields by 10%. In comparison, soil disinfestation with methyl bromide increased yields by 25%. Furthering our understanding of the mechanisms of the IGR and designing treatments that mimic them will narrow this gap.

Effect of Biofumigation on Typical Weeds of Strawberry Fields

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Biofumigation is a process in which volatile toxic gases released directly from degrading organic amendments, control diseases, nematodes and weeds. For this reason, research was carried out in order to evaluate the effect of biofumigation with fresh organic matter, on typical weeds found in strawberry fields in Southern Spain. Field experiments consisted of treatment with fresh hen droppings applied at a rate of 3 kg m^{-2} during 45 days, alone (BF) or in combination with solarization (BF+S), in an experimental randomized block design. Results showed good control of main weeds species such as *Poa annua, Portulaca oleracea* and *Lolium rigidum*, with results of control/BF/BF+S of 42/4/8, 18/9/12, and 15/0/1 plants m^{-2} respectively.

Twenty seeds of several weeds were sown inside cloth bags and were submitted to treatment. The results demonstrated the efficacy of biofumigation combined with solarization in the control of *P. oleracea, C. dactilon* and *E. crus-galli*, with a percentage germination of control/BF+S of 77/0, 50/15 and 30/2.

Laboratory experiments consisted of simulating field conditions, using a mix of soil, water and different fresh organic matter in a plastic bag, into which different seeds were sown and kept under controlled conditions. Fresh organic matter used included whole strawberry plants, horse manure, hen droppings, and combinations of these. Best results were obtained with hen droppings, which showed an efficiency control of *Malva parviflora*, *Medicago* sp., *Echinochloa crus-galli*, *Amaranthus retrofluxus*, *Chenopodium album* and *Portulaca oleracea.*

In conclusion, the results obtained from the biofumigation and solarization experiments using fresh hen droppings for their herbicide action, is under research, after promising results were obtained in preliminary experiments.

Ethanedinitrile (C_2N_2) – A novel soil disinfestant for strawberry production

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For the last 50 years, soil disinfestation with methyl bromide has underpinned land-based production of strawberries worldwide. Despite its efficacy, the use of methyl bromide in soils will cease in developed and developing countries in 2005 and 2015, respectively, due to its ozone depleting potential. Evidence shows that without a suitable replacement for methyl bromide, yields of field grown strawberries will fall by 20–80%.

Our studies on a new fumigant, ethanedinitrile (EDN, cyanogen, C_2N_2), have demonstrated its potential for soil disinfestation for strawberry production. In the laboratory, EDN diffused and penetrated soils in loosely packed columns faster and further than methyl bromide. Furthermore, EDN was sorbed by soil particles more rapidly and strongly than methyl bromide, thus minimising atmospheric emissions. EDN was stable in soil for 3–5 hours, with separate glasshouse trials showing that the required plant-back time for strawberries was as short as 24 hours.

In field studies, EDN killed buried inoculum of several soil-borne pathogens of strawberry as effectively as methyl bromide, including: *Pythium ultimum*, *Phytophthora cactorum*, *Fusarium oxysporum*, *Rhizoctonia solani* (mycelium and sclerotia), a binucleate *Rhizoctonia* sp. and *Sclerotium rolfsii* (sclerotia). Additionally, EDN controlled naturally emerging weeds in field soils to the same level as methyl bromide. Currently, the first field trials of EDN are established in the strawberry nursery and fruit industries in Victoria, Australia. These trials will determine potential of EDN against a range of other fumigants for soil disinfestation and strawberry production. Results will be reported at the Symposium.

Testing alternatives to methyl bromide in sub tropical strawberries

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Methyl bromide (MB) and its mixtures with chloropicrin (CP) have been used by the Queensland strawberry industry to fumigate runner nurseries and fruiting fields since 1981. The ongoing benefits in the control of soil-borne diseases and weeds, along with its plant growth promotion effect, established MB as an important management tool for up to seventy percent of the Queensland strawberry growing area. The impending MB phase-out in January 2005 required that alternative technologies including fumigants, soil ameliorants and alternative production systems, be tested. This paper reports on experiments that compared the efficacy of some alternative fumigants, soil ameliorants and soil solarisation options.

When compared to untreated controls, Telone C35 (TC35) was as effective as MB+CP mixtures in increasing yield or enhancing control of crown rot, *Macrophomina phaseoli*, and Fusarium wilt, *Fusarium oxysporum* f. sp. *fragariae*. Soil solarisation with plastic being laid in December or January was also effective. The use of metham sodium and metham potassium generally did not result in increased yields or enhanced disease control. Dazomet and calcium cyanamide had some yield benefits, but their use was not pursued further because of cost. Mustard meals were largely ineffective.

Issues associated with TC35 as a viable replacement for MB at this time are discussed.

Nursery and Propagation Factors Affecting Plant Quality and Performance - General Factors

Strawberry Transplant Production and Performance in Annual Plasticulture Production System

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TC-propagated 'Chandler' plants were grown in a protected environment to produce stolons. July plantlets were immediately stuck in cell packs and placed under mist sprinklers, or cold stored at 2 °C for 30 days and then plugged. Among the July transplants, some were kept in the greenhouse until field planting in mid September, and others were moved to a cold room in early August. Plantlet size and position on the stolon affected rooting and quality of transplants. Cold stored plantlets developed fewer roots than plantlets plugged fresh in July or August. In the field, % plant survival was reduced by cold treatment. Transplants that were produced from plantlets harvested in July and cold stored, developed more stolons than transplants from July- and August-harvested plantlets that were not exposed to cold treatments. All transplants from plantlets harvested in July and propagated without cold treatment, bloomed by November. Fruit production ranged from 521 to 703 g per plant during a 4 week harvest in the spring. 'Chandler' plants from plantlets that weighed 10 g produced only 10% greater yield than those that weighed < 1.0 g. Plants generated from plantlets plugged in July produced 26% more fruit than those plants plugged in August. Greenhouse soil-less systems can be used to grow 'Chandler' mother plants for generating plantlets and transplants for the annual plasticulture in colder climates. 'Chandler' plants produced in July can yield a late fall crop under high tunnels, and more fruit in the spring than August-plugged transplants.

Strawberry mother plant propagation by *in vitro* subculturing, and their performance in nursery and fruiting fields in Israel

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This research was aimed at examining the performance of micropropagated strawberry mother plants and their runners as fruiting plants, regarding pests and diseases, mutations, flowering pattern, yield level and fruit quality. Three common commercial cultivars were examined in nursery and fruiting fields, in trials conducted over four years during the period 1996 to 2002.

Ten to twenty mother plants were prepared by micropropagation, and four subculturings in Rahan nursery, for each treatment and cultivar. These mother plants were planted in plots for runner production. The resulting runners were planted in a fruiting field. Data regarding pests, mutations, flowering and yield were collected in the nursery and the fruiting field.

The data show that the micropropagation method with four subcultures, for the production of strawberry mother plants, is safe to be used as a method for production of mother plants, according to seed low of 1988 in Israel. This method would be an optional complementary technique to controlled production methods, which ensure horticultural reliability in 'true to type' tests.

The Performance of Strawberry Plugs in Queensland

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Plugs or containerized plants offer several potential advantages over traditional runner plants for strawberry (*Fragaria x ananassa*) production. Some of these benefits include easier planting, better establishment, fewer pests and diseases, lower water use after planting and therefore less leaching of applied fertilizers. Plugs also offer the potential for mechanical planting. In some areas of Europe and northern America, plugs provide earlier production, greater productivity and larger fruit over runners. Research has also shown that the plants can be grown under controlled conditions (short days and low temperatures) to manipulate flower initiation and fruiting. Plugs are more expensive compared with runner plants, and will only be adopted by industry if the extra costs are matched by increased fruiting and returns to producers. We investigated the productivity of 'Festival' and 'Sugarbaby' propagated by plugs (33 cm^3 containers) and runners from Stanthorpe in southern Queensland (elevation of 872 m), and grown at Nambour on the Sunshine Coast (elevation of 29 m). At planting, the plug plants weighed 0.8 ± 0.1 g compared with 5.3 ± 0.5 g for the runner plants. 'Sugarbaby' was also larger than 'Festival' (dry weights of 3.3 ± 0.6 g versus 2.9 ± 0.6 g). There was a strong relationship between the growth of the different plant parts, with small and large plants having similar proportions of leaf, crown and roots. The differences in growth at planting were maintained until the third week of July (day 94), with the plants propagated by plugs weighing 17.8 ± 2.2 g, and the runner plants, 21.4 ± 2.3 g. The proportion of plant dry matter allocated to the leaves increased over time from 59 to 70%, while the proportion allocated to the roots decreased from 21 to 10%. The harvest season commenced after 60 days, with the plug plants yielding only 60% of the yields of the runner plants up until 8 August or day 109 (14.2 ± 1.4 g $plant^{-1}$ $week^{-1}$ versus 23.6 ± 1.9 g $plant^{-1}$ $week^{-1}$). 'Festival' (22.2 ± 2.0 g $plant^{-1}$ $week^{-1}$) also had higher yields than 'Sugarbaby' (15.5 ± 1.5 g $plant^{-1}$ $week^{-1}$), even though plants of the latter were larger. Average fruit weight was 15.6 ± 0.3 g, with no effect of cultivar, plant type or harvest time. In other words, the differences in yield between the various treatments were mainly due to differences in fruit set. The lower yields of the plug plants probably reflect their small size at planting. Future research should determine whether plugs grown in larger cells (75 to 300 cm^3 as in the USA and Europe) are more productive. The tips grown in larger containers would need to be harvested earlier than those in small cells to maximize root growth before planting. This will probably extend the time required to harvest the tips and pot them from the current four to five weeks, to eight to ten weeks.

Northern Vigour® in Strawberry Crowns

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Northern Vigour® was initially observed in seed potatoes where seed potatoes sourced from northern regions (Saskatchewan, Canada) outperformed seed potatoes sourced from more southern sites. Subsequently, the potential Northern Vigour® response in strawberries (*Fragaria* x *ananassa* Duch.) was examined with the primary objective to develop Saskatchewan as a supplier of high quality, superior yielding planting material for national and international markets. Twelve greenhouse and field studies were conducted over an eight year period. The project coordinated research between several U.S. cooperators and from up to nine Canadian sites. 'Camarosa' crowns were mass produced and tested in southern regions for Northern Vigour® potential. Cultural practices were examined, including timing of harvest, the influence of hormonal application, fertility, de-blossoming and sizing of crowns, for their effect on subsequent yield. In the first 3 years of observation, Canadian-sourced crowns consistently produced higher yields in the first two months of marketable fruit production. In the following 2 years, results were more variable, depending upon Canadian source and U.S. location of fruit production. In the most recent fruiting years, yields from Canadian-sourced crowns were again higher than for California-sourced crowns. Fruit size was, on average, 7% greater by weight in Saskatchewan-sourced crowns over a 5 year observation period. Since the northern vigour phenomenon is environmentally-regulated, it is important to continue to profile yield and fruit size response over a number of years. Simple accumulation of total chilling hours is not directly related to total yield but may be more important to advancement of flowering. Results from this study and recent greenhouse plug production will be presented.

Effect of Prohexidione-Ca on Establishment and Yield of Green-Top Bare-Root Strawberry Transplants.

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Bare-root transplants received from high latitude nurseries for Florida production, have very long petioles and limited root systems that wilt after planting. Further desiccation occurs when leaves come in contact with black plastic mulch used in the annual production system. Conventional irrigation practices for the establishment of bare-root transplants of strawberry consist of overhead water application for at least 8 hours/day for10-14 days after planting.

Plant growth regulators (PGRs) have been used to modify the growth characteristics of many plants species. A split-block experiment was implemented at the GCREC-Dover, Dover FL, USA to determine the effect of the use Prohexidione-Ca (PC), NAA (naphthaleneacetic acid), and IBA ((indole-3) butyric acid) on growth, yield and establishment of strawberry. Main blocks consisted of overhead establishment irrigation for 4, 8, and 12 days, and sub-plots consisted of treatments of PC applied in the nursery at a rate of 62.5 mg L^{-1} 4 weeks before digging, PC applied in the nursery at 125 mg L^{-1} 2 weeks before digging, a combination of the two previous treatments, and a root dip of transplants in 100 mg L^{-1} of NAA or IBA just prior to transplanting. Data were recorded for marketable yield, number of marketable berries (> 10g), and disease incidence. Significant differences were detected for duration of establishment irrigation and growth regulator treatment. No interaction was shown between establishment irrigation and growth regulator treatment.

Influence of NPK fertilization on the production of stolons and crowns by mother plants during ontogeny in strawberry (*Fragaria* x *ananassa* Duch.) cv. Camarosa, in a highland nursery

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The Influence of NPK fertilization on stolon and crown formation during ontogeny in strawberry cv. Camarosa in a highland nursery, was studied during 2002/03. Strawberry plants were grown under different levels of NPK: 1: Control 2:100 kg N/ha 3:100 kg N/ha and 90 kg P/ha 4:100 kg N/ha and 150 kg K/ha 5:100 kg N/ha, 90 kg P/ha, 150 kg K/ha 6:54 kg N/ha and 190 kg P/ha 7:50 kg N/ha. The production of primary stolons and crowns per mother plant at three dates (2 December 2002, 3 February and 2 March 2003) was evaluated. The results were treated to ANOVA and Test of Tukey (p=0.05) and they showed significant differences in number primary stolons between the three dates, considering the primary stolons per mother plant (3rd date: 10.8; 2nd date 9.2; 1st date: 3.0, respectively). The interaction between treatments and dates was significant (p=0.02). Between treatments, 5 (9.8 primary stolons per mother plant) was significantly different to 1 (6.2), 2 (6.5), 4 (6.4), 6 (7.7), and 7 (7.6).
Number of crowns per mother plant differed significantly (p=0.0000) between the 3 dates: 3rd: 3.9 2nd: 2.8 and 1st date: 1.5. Between treatments, 4 (3.1) differed from 2 (2.4). There were no significant interactions between dates and treatments (p=0.9).

The increase in the number of stolons seemed to be explained by the incrase in rooth growth, vigor and disease resistance of plants conferred by the equilibrium of the three nutrients, NPK, rather than the application of just NK. It increases only the number of crowns per mother plant in the nursery.

Disease Factors - Colletotrichum

An Overview of Anthracnose in North America

Barbara J. Smith

USDA-ARS, Small Fruit Research Station, Poplarville, Miss. USA

Invited paper

Interaction, Survival Strategies and Host Range of *Colletotrichum acutatum* on Strawberry

Stanley Freeman

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Anthracnose is one of the major fungal diseases of strawberry occurring worldwide. In Israel, the disease is caused primarily by the species *Colletotrichum acutatum* Simmonds. The pathogen causes black spot on fruit, root necrosis and crown rot resulting in mortality of plants in nurseries and transplants in the field. In order to maintain a disease-free crop, nuclear and foundation stock material, as well as field nurseries must be routinely monitored and tested for presence of the pathogen.

The pathogen is also isolated from apparently healthy, asymptomatic weed species. This indicates that although *C. acutatum* causes disease on strawberry, the pathogen can persist on many other plant species. Therefore, plants that are not considered hosts of *C. acutatum* may serve as a potential inoculum reservoir for strawberry infection and permit survival of the pathogen between seasons.

Invited paper

Anthracnose on Strawberry in France: Situation and Perspectives

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Anthracnose on strawberry (*Fragaria x ananassa*), caused by *Colletotrichum acutatum*, was first reported on fruit in France in 1981. Damage was later recorded on stolons, petioles, foliage and crowns. We report the results of 10 years of research in France. The evolution of disease control methods, the molecular variability of *C. acutatum*, the study of the interaction between pathogen and host, the different techniques of inoculation, and lastly, the results concerning QTLs linked to resistance to *C. acutatum* are reported.

Pathogenicity of UK isolates of *Colletotrichum acutatum*, and relative resistance among a range of strawberry cultivars

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Twenty isolates of *Colletotrichum acutatum* were collected from strawberry plants or fruit in the UK. The isolates were tested for their pathogenicity on a set of five cultivars: Elsanta, Chandler, Dover, Valeta and Seascape. Of the 20 isolates, five had very low pathogenicity and produced only mild symptoms on the most susceptible cultivars, Elsanta and Valeta. Three isolates were pathogenic on all cultivars including Dover, which has been reported to have a major gene for resistance to one group of isolates. The remaining 12 isolates varied in aggressiveness, and showed a differential response to the five cultivars.

Using a subset of five isolates, a range of cultivars grown in northern Europe was screened for resistance, along with advanced selections from the East Malling breeding programme. Some genotypes showed a useful level of resistance, even against the most aggressive isolates.

Development of a Rapid, Reliable Screening Method for Pathogenicity of *Colletotrichum* Species on Strawberry Seedlings

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A forward genetics approach to isolate nonpathogenic mutants for identification of pathogenicity-related genes requires rapid and reliable screening procedures. This study reports on the development of a rapid bioassay enabling large scale screening and isolation of nonpathogenic *Colletotrichum acutatum* and *C. gloeosporioides* mutant isolates on strawberry seedlings. Inoculation was carried out on strawberry seedlings (cv. Malach, susceptible to anthracnose) at two developmental stages: 12-week-old (young) and 15-week-old (older) seedlings. A comparison was made between two inoculation techniques (i) foliage immersion and (ii) continuous root dip, at two incubation temperatures (19°C and 25°C). Mortality of young seedlings was observed 4 days after inoculation, reaching 50% within 10 days, using both techniques. However, mortality of older seedlings was delayed by 4 days compared to that in young seedlings when using the root dipping method. Disease incidence was delayed in young and older seedlings inoculated by both techniques at 19°C, compared to 25°C. Of three different inoculum concentrations tested, 10^5 conidia per ml caused a moderate disease response producing typical anthracnose symptoms, enabling discrimination between pathogenic and nonpathogenic isolates. The proposed method enabled screening of more than 980 REMI mutants, resulting in the selection of a number of reduced-virulence isolates. Putative mutant isolates were evaluated on mature strawberry plants, and their nonpathogenic phenotype was confirmed. Initial characterization of some of these mutants revealed large differences in germination and appressorial formation compared to pathogenic isolates. Mutants impaired in pathogenicity will enable us to characterize pathogenicity-related genes, leading to more efficient control strategies.

Successful management of Colletotrichum crown rot in runner production in sub-tropical Australia

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Crown, stolon, and petiole rots (CCR) as well as leaf spots caused by *Colletotrichum gloeosporioides (Cg)* [IMI 332464; BRIP 16621], were first identified in the Queensland Approved Runner Scheme (QARS) runner beds in February, 1989. The disease subsequently appeared annually in strawberry runners grown in the QARS summer runner production areas from 1990 to 1994.

CCR was associated with poor establishment and high post-establishment losses of green-leaf QARS runners planted on commercial fruit farms in south-east Queensland in 1989, 1990 and 1994. Post-establishment losses of such plants exceeded 50% in 1994.

Cg was present in symptomless petioles taken from nucleus plants in 1994. At the same time, field trials showed that Octave® (prochloraz) was highly effective in reducing the incidence and recovery of *Cg* from symptomless petioles.

QARS ptotocols were changed after the devastation of 1994. Foundation plants that originated from tissue culture, and that were symptomless and tested negative for the presence of *Cg*, were the only plants allowed onto QARS sites. The application of Octave® at fortnightly intervals to all QARS nursery runners has reduced the level of visible symptoms and the disease to almost zero.

The use of tissue cultured foundation plants, together with the regular use of Octave® and monitoring for the presence of *Cg*, continues at all stages of the QARS, and has resulted in the virtual elimination of the disease from runner beds and fruiting fields.

Effects of nitrogen fertiliser on sensory attributes of strawberries

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Strawberry fruit of Kiewa, a new 'short day' cultivar bred in Australia, were tested for quality attributes and sensory characteristics by consumer taste panels at the Curtin University sensory laboratory in 2002. The fruit was harvested from a replicated field experiment grown on sandy soil at the WA Department of Agriculture Research Station at Medina (32°S lat.). The experiment compared seven rates of nitrogen applied via fertigation, and a grower control. Fruit from four of these treatments representing the range of nitrogen rates was tasted by consumers on three dates at monthly intervals, commencing in September 2002.

Strawberries were harvested at the fully ripe stage, and graded for uniformity of size. Samples were evaluated for sweetness, sourness, juiciness, texture, flavour and overall acceptability.

Harvest results showed a positive linear relationship between the rate of nitrogen applied and marketable yield of fruit, up to the highest rate tested. While marketable yields almost doubled with increasing nitrogen rates from 50-900 kg/ha (N), consumer ratings of the fruit for sweetness, flavour and overall acceptability fell in almost a direct proportion. Some parameters of quality were unaffected by increasing nitrogen rate, but those that influence consumer preference were most seriously affected.

Quality and Antioxidant Activity Changes During Low-Temperature Storage of Strawberry Fruits

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The changes in antioxidant activity measured as the scavenging effects of DPPH radicals, total phenolic, anthocyanin, vitamin C content, and quality attributes in fresh strawberry cultivars, Prarajathan No. 50 and 72, that were grown in northern Thailand and stored at 0°C for up to 16 days, were investigated. There was a slight change in colour ('L' and 'a' value) of the strawberry fruit during storage. The firmness of No. 72 declined sharply after 8 days of storage, while No. 50 changed slightly. Reducing sugar content, and the ratio of total soluble solid content and titratable acidity of both cultivars, increased for 12 days. After harvesting, the antioxidant activity in No. 72 (63%) was higher than that in No. 50 (50%), and it increased during low temperature storage in both cultivars. On the other hand, total phenolic content, calculated as mg of gallic acid/g fresh weight, was lower in No. 72 than in No. 50. The result also showed that total phenolic content gradually decreased during storage. Anthocyanin content decreased rapidly, particularly in No. 72. In addition, there was loss in vitamin C content in No. 72 after 12 days, but it was constant in No. 50 throughout storage. These results indicate that changes in total phenolic, anthocyanin and vitamin C contents probably enhance the antioxidant activity.

Pre-harvest Calcium Effects on Sensory Quality and Calcium Mobility in Strawberry Fruits

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Plants of the strawberry cultivar 'Selva' were planted in Mount Compass sand treated with three different calcium sulphate treatments (300ppm, 900ppm and 1800ppm), to assess effects on post-harvest strawberry fruit quality. Sensory panellists were asked to evaluate appearance, texture, and flavour, while objective analysis was performed on the same fruit using a penetrometer, titratable acidity, yield and total soluble solid measurements. Strawberry fruit obtained from plants receiving a low calcium treatment (300ppm) were consistently larger than those obtained from other calcium treatments. These fruit also consistently had greater total soluble solids (°Brix) and titratable acidity. However, fruit produced from the medium calcium treatment maintained the highest level of quality during storage. This directly correlated with its greater firmness (as measured both subjectively and objectively) and factors such as surface colour at harvest. However, none of the treatments were identified as ideal for obtaining desirable strawberry fruit surface colour, flavour, or texture by panellists.

The concentration of macro- and micro-nutrients present in petiole, leaf and strawberry fruit tissues was analysed, to assess calcium mobility. Calcium concentrations in fruit tissues were not affected by the different application levels. However, increased calcium concentrations were identified in leaf tissues, from the low to high treatments. A number of other nutrients such as boron, were significantly affected. We will discuss the impact of calcium mobility issues on fruit quality and other related nutrient effects.

The effect of nitrate: ammonium ratios on fruit quality of the strawberry cultivar 'Selva'

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Strawberry plants (*Fragaria x ananassa* Duch. cv.Selva) were grown in a mixture of 30% peat moss and 70% perlite, under greenhouse conditions for two successive growing seasons, at Tehran University, Faculty of Agriculture. The plants were fertigated daily with complete nutrient solutions, in a non-recirculating drip irrigation system, to determine the effect of four different nitrate: ammonium ratios (7/0, 6.5/0.5, 6/1, 5.5/1.5 mM) on some strawberry fruit quality characters. Strawberry quality parameters, including fruit firmness, vitamin C, titratable acidity, pH, colour and soluble solids, were determined at a specified ripening stage of the fruit (28 days from fruit set), which is the best stage for determining quality characteristics of fruit for consumption. Different nitrate: ammonium ratios had different effects on fruit quality factors measured in this experiment.

High density, vertical hydroponics growing system for strawberries

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An innovative, vertical hydroponics growing system was developed for Outeniqua Berry Ventures, a large berry growing company based in George, on the southern tip of South Africa. The system is based on a moulded 2400ml polystyrene pot, which has places for four plants. These pots are supported on a 50 mm diameter PVC pipe, which also provides drainage through drainage slots cut into the pipe. Each pipe supports nine stacked and lidded pots, providing 36 planting sites. Each column is connected to a drain at the base, and a support wire at the top. Columns are spaced in rows 1000mm apart and 750 to 1000mm in the row, to give plant densities of 36 to 48 plants.m^{-2}. The plants are fertigated using 2000ml h^{-1} button drippers with a four-way adapter supplying each plant with solution through a length of spaghetti tubing. Arrow drippers at the ends of the spaghetti tube (fitted into lid) ensure equal flow to the four chambers, and are used to anchor the spaghetti tube above the medium to prevent penetration by roots. The rooting medium used was commercial coconut coir medium from Sri-Lanka. George has a very similar climate to Oxnard in California, but has year round rainfall. The systems were developed to maximise the utilization within poly ethylene-clad, single and multi-span tunnels, to keep the plants and fruit dry, as well as to provide a picker- and spray-friendly growing system.

In the course of the 2003 season, the Israeli strawberry varieties, Tamar, Buba, Yael and Malah, and University of California varieties, Camerosa, Aromas, Gaviota and Diamante, were compared. Of the Israeli varieties, only Tamar produced the required size, number of fruit and quality, but the variety is very susceptible to powdery mildew, *Sphaerotheca macularis*. The Californian varieties performed very well using this system, but tended to be more vigorous than 'Tamar'. The lower plant density of 36 plants m^{-1} is recommended for these varieties. Disease tolerance under the high humidity within tunnels was also superior to the Israeli varieties.

During the 2003 season, various medium mixes, seaweed extract and Trichoderma drenches and sprays were investigated, and these will be discussed, together with experience on nutrition and water requirements during the growing period.

Out-of-Season Strawberry Production in Norway: Yield Responses of Cv. Korona to Photoperiod Preconditioning Treatments

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In Norway, one grower has produced winter glasshouse strawberries since 1992. 'Korona' strawberry plants (*Fragaria* x *ananassa*) are 'artificially' induced to flower with applied short-day treatments. The plants are induced three times during the season, and are harvested from November until June.

To increase productivity, the response of photoperiod preconditioning treatment to plug plants was studied. Non-conditioned plugs were used as controls, together with large, cold-stored 'tray-plants'.

'Korona' strawberry plug plants, two to three weeks old, were subjected to fourteen 12-hour short days in May, followed by four weeks of natural long days in June, and four weeks of 12-hour short days in July (first flower induction). Photoperiod treatment was provided by covering the plants with light-proof black plastic. The plants were planted in peat substrate bags in a horizontal system for winter greenhouse production. The plants were given a second flower induction in September, and a third induction in December.

Conditioned plug plants produced a significantly higher number of branch crowns than non-conditioned control plants, when assessed in July, but had a lower number of branch crowns than the cold-stored 'tray-plants'.

Conditioned plants produced more fruits than did non-conditioned control plants through the whole season, but the difference was not significant. Cold stored 'tray-plants' had the highest total yield.

When productivity is considered on an area basis (kg m^{-2}), productivity over a 7-month period was 11.2 kg m^{-2} for control plants, 13.0 kg m^{-2} for plug plants given photoperiod preconditioning treatment, and 13.6 kg m^{-2} for the cold-stored 'tray-plants'. When considering that large multiple-crowned, cold-stored 'tray-plants' available in Norway are expensive, and have variable quality, conditioned plug plants offer the potential for increasing strawberry productivity, and therefore, the profitability of a winter greenhouse production system such as this.

Positive Effect of Sorghum Grown as a Soil-improving Crop on CO_2 Environment in Greenhouses, and Photosynthesis of Strawberry

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That soil productivity is improved with the application of organic substances such as farmyard manure, rice straw or soil-improving crops, is well known. Organic matter is decomposed, and serves as a source of CO_2 derived from the soil. The contribution to the CO_2 environment of freshly applied sorghum, grown as a soil-improving crop, was determined in soils containing different amounts of organic carbon. The soil of two growers who applied different cultural practices for more than 10 years, were studied. Grower A had been applying 20 t/ha of commercial farmyard manure, while Grower B had been growing sorghum in the summer and applying the same amount of manure. Soil carbon content was significantly higher in greenhouses of A (2.4%) compared to that of B (1.5%). In June 1993, sorghum seeds were sown in one greenhouse of each grower and the plants grown for 2 months, and another was left without sorghum. The Strawberry cultivar, 'Nyoho', was planted in mid September, and grown according to commercial practice. From December to the following March, the rate of CO_2 evolution from the soil, and CO_2 assimilation of the strawberries in each greenhouse, were estimated, as described previously. CO_2 evolution rate was higher in greenhouses of B than of A. Sorghum increased the rate of CO_2 production by ca. 100 ml-CO_2 m^{-1} hr^{-1} in A throughout the measurement period, and consequently the CO_2 concentration before sunrise, by 300 ppm. Although the effect of sorghum was smaller in B compared to A, the CO_2 concentration in greenhouses of B was 500-1000 ppm higher before sunrise, than for A. Consequently, net CO_2 assimilation and light conversion efficiency of strawberry were highest in the greenhouse of B with sorghum, and lowest in A without sorghum.

Polyethylene greenhouse film affects soil and air temperature, photosynthetically active radiation (PAR), and yield performance of strawberry in high tunnels

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Strawberry production in the Mediterranean basin is based on protected culture with the use of polyethylene tunnels. Despite a similar climate and use of identical cultivars, California strawberry production is based entirely on use of outdoor production systems. During the 2003 production season, we compared PAR, soil and air temperatures, and yield performance of 'Camarosa' and 'Ventana' strawberry grown outdoors, and under two greenhouse films: Tufflite IV ("T4", Tyco Plastics, Inc.) and IR Thermal ("IRT", Ginegar Plastics, Inc.) Individual tunnels measured 4.9m wide, 25m long and 3.7m high, and covered three planting beds. Bare-root transplants were planted in early October. Tunnels were covered on 2 December 2002, and tunnel sides were left open to a height of 1.2 m. Fruit were harvested 1-2 times weekly from mid-December through 1 April.

For tunnels covered in T4 and IRT films, mid-day PAR was 74% and 60%, respectively, of that of outdoors. Use of tunnels resulted in higher air and soil temperatures compared to outdoor plots, with little difference between tunnel treatments. However, use of T4 film resulted in 1.3- to 1.4-fold greater early season yield (to 1 March) than outdoor plots, while use of IRT film provided little or no early season yield enhancement. For all treatments, 'Ventana' had consistently greater early season yield than 'Camarosa', with better fruit appearance scores. Also, tunnel culture resulted in enhanced early season fruit appearance scores for 'Ventana', more so than for 'Camarosa'. Results of this study suggest that tunnel films may have significant effects on light quality, and that this may be an important factor in strawberry yield performance in tunnels.

Chilling Unit Model for Greenhouse Production of Strawberry cv. 'Elsanta'

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Four successive trials were conducted to determine the chilling requirement of cv 'Elsanta'. After harvest in December under greenhouse conditions, container grown strawberry plants were transferred to growth chambers. Chilling was applied at constant temperatures (-2 °C, +1°C, +3°C, +5°C, +8°C and +12°C) for different intervals (0, 380, 456, 504, 636, 770, 924, 1008 and 1260 hrs). After the chilling treatments, all plants were moved to a heated glasshouse. Vegetative development, fruit weight, fruit set and fruit yield were recorded.

In the absence of chilling, dormancy was not broken, and strawberry plants had reduced leaf area and petioles, and flower trusses with small misshapen fruits. Multiple regression analysis showed that the chilling optimum was different for vegetative development and fruit production. Length of petioles and inflorescences increased with greater chilling durations, and were saturated with 1229 hrs at -0.87 °C and 1158 hrs at -0.96 °C respectively. The percentage of misshapen fruits was minimized after a chilling duration of 947 hrs at -0.68 °C, while in terms of yield, 932 hours at 1.39 °C was considered optimum. Multiple regression revealed that after 808 hrs chilling at 1.14 °C, plants produced the highest fruit number, which declined thereafter, with longer duration of chilling.

As there was no significant interaction between chilling duration and chilling temperature for yield and fruit number, these data were converted to a chill unit model for 'Elsanta' . In this model, the chilling intensity is taken into account as an alternative to the classical cumulative method of hours below 7°C. The efficiency of temperatures both above and below the optimum temperature was calculated as a proportion of the yield at the optimum temperature, and resulted in a second degree polynomial : $CU=0.9827 + 0.024699*T - 0.00888*T^2$ ($R^2 =0.88$).

Industry Development

The Better Berries Program – a novel approach to strawberry industry development in Australia

G Neil Greer

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Ten years ago, the Department of Primary Industries and Fisheries, Queensland initiated a new approach to strawberry research and development, following intensive consultations with the Queensland strawberry industry. This resulted in the formation of "The Better Berries Program". The program provides a coordinated approach to strawberry industry research and development and efficient management of the resources needed. Our objective is the ongoing development of a profitable, sustainable strawberry industry with strawberries that meet the identified needs of consumers.

Results have been outstanding. Better Berries bred cultivars are up to 25% of total Queensland plantings. Our cultivar specific, nutrient management system based on a sap analysis is now used by 70% of industry, providing increased yields with much lower fertiliser inputs and reduced impact on the environment. A system to manage *Colletotrichum* crown rot has neutralised the impact of this disease. A program to replace Methyl Bromide has been developed. A "pest-in-first"/ "simultaneous release" mite control system has been developed and has been adopted by 70+% of the industry. A recent information needs analysis survey has helped identify information priorities for all segments of the industry.

Although the DPI&F's Better Berries Program can't take all the credit, it has played a significant role in building the industry from $8 million in 1990 to $85 million in 2003 and an estimated $100m in 2004. Research, development and extension activities will change as priorities identified by the strawberry industry evolve. It would not have been possible to undertake the range of activities covered before the adoption of the coordinated Better Berries Program approach. The program has also allowed us to be flexible and responsive to changing issues and emergency situations. This approach has enabled the Better Berries Team to turn research results into sustainable profits for the Strawberry industry and to enhance the "strawberry experience" for consumers.

Strawberry production in South America

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Although strawberry production from South American countries as a whole accounts for only 5% of the 161,478 tons produced world wide, production in countries such as Brazil, Chile, and Argentina has increased significantly. The state of development of agricultural production in these countries currently is such, that one can foresee an even stronger development in the next few years. This is an issue that should be taken into account by investors in the area.

The growth in the production of the species not only increases the exports of frozen strawberries, but also affects positively domestic consumption in the respective countries. The following aspects are analyzed in relation to the main growers in the region: production, evolution of the cultivated area, productive regions, growth seasons, main varieties, and growing techniques, among others.

Economics of Post Seasonal Strawberry Production in Croatia

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Strawberry production in Croatia, despite favourable agro-ecological conditions, does not satisfy current market demand, which arises from tourism and the Zagreb market of about one million consumers. Due to an identified market potential for post seasonal strawberry production, we have commenced a research project. Capital and labour intensity, and unused land capacity, provide an opportunity for farm commercialisation, increasing farm income, and new employment possibilities for the rural population.

This paper presents economic results of the project. It includes a feasibility and risk analysis of post seasonal strawberry production in Croatia. Budgeting methods and business analysis methods were applied. Standard indicators such as break-even, revenue/cost indicators and profitability, were calculated. Comparative analysis of seasonal production was conducted.

The experiment had six different combinations. Two different varieties, two types of plants and two types of plastic mulch were taken into consideration. Yield was the factor that influenced revenues. Realized market prices were about US$4.70 per kilogram. The direct costs of plants, mulch and labour were the main factors that influenced production costs. Preliminary results showed that new plants on white plastic mulch, of the cultivar 'Raurica', gave positive economic results. Revenue-cost indicators were above 1, and break-even was below real yields. In all other combinations, economic results were negative.

Future steps will include implementation of the results with farmers by extension workers, and proposals for the development of more efficient farm systems and organisation types.

How to convert the Chilean native strawberry into a new crop ?

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The international market is increasingly demanding exotic products that are cultivated with minimal use of agrichemicals. To achieve that, there is a requirement to have plant material resistant to the various pests and diseases, and where possible, tolerance to a number of environmental stresses. The Chilean native strawberry, CNS; *Fragaria chiloensis* (L.) Duch., has been collected growing in the most diverse ecological conditions, and thus there exists tolerance/ resistance to various biotic and abiotic stresses. CNS is a species endemic to Chile, which has been used for many generations of native Chilean people for food and ceremonial purposes. The massive introduction of European and USA varieties of the commercial strawberry *(F. x ananassa)* displaced CNS, mainly due to the higher yield of the hybrid. Even though *F. x ananassa* has higher yields (20-70 ton/ha), the organoleptic quality of the fruit is lower than that of CNS, especially with regard to flavor and aromas. However, the higher yields of the hybrids means that nowadays, culture of CNS is restricted to small plantings of white-fruited accessions in areas with coastal influence, between latitudes 34° and 42° S, by poor small-holder farmers in rural areas of low crop diversity and degraded ecosystems. Even though CNS commands high prices (US$1-4/kg), it produces low yields (3-5 ton/ha) of non-uniformly sized fruit. This might be due to the limited use of good horticultural practices (irrigation, fertilization, weed control, etc.), as well as the habit of the species of generating a large number of stolons to improve its competitiveness in the ecosystem. The harvest season extends from mid-November to mid-January, but lasts for only one month per year at a given site, which complicates establishment of potential markets. Up to now, there have been isolated efforts in R&D for CNS. Thus, only with an integrated approach that includes generating cultivars, dedicated propagation facilities, horticultural practices, postharvest handling, market studies and technology transfer, in collaboration with the private (growers, exporters) and public sectors (municipal governments of the sites where the species is grown), can the Chilean strawberry be converted into a commercially-viable crop. The long term objective is to provide fruit of high and consistent quality obtained through sustainable cultural practices, to local and foreign markets (Europe, USA and Japan, with a total population of 800 million people in 2000), during four months of the year. Once R&D is fully operating, we expect to have 100 ha planted with CNS cultivars generated from the breeding program (10% of the national acreage planted with *F. x ananassa*), in poorer Regions of South-Central Chile, with production that will exceed 8 ton/ha, provide fruit for 4 months of the year, and will return average prices of US$3/kg). Additional benefits are that the genetic resources currently under risk will be preserved and scientific productivity will be increased. Other possible targets could be high potential levels of phenolic compounds such as ellagic acid (anticancer agent) already found in the commercial strawberry, diversification of crops exported by Chile, and making available improved germplasm of CNS that could improve *F. x ananassa* . Among critical aspects for success are

1. Availability of genetic variability in material used for breeding, in order to create pest and disease resistance, an increased yield and harvest season, good post-harvest life, etc. 2. Acceptability of white fruit in potential markets 3. Capacity of buyers to differentiate CNS from *F. x ananassa* 4. Capacity to maintain quality/price despite larger volumes 5. Reduction of damage during transport, especially over unsealed rural roads 6. Ability to maintain the cold chain through post-harvest handling. As a result of the project, not only will there be a higher profitability from the fields, but it will activate local economies (labor, transport, commerce, etc.), as well as increase diversification of crops. In institutional matters, international experts will participate in collaboration with Chilean specialists and will develop undergraduate and graduate theses, publications and seminars. Technology transfer will involve technical staff from private companies and municipalities for field days, courses, and leaflets.

Assessing the Information Needs of Subtropical Strawberry Growers in Australia

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The timely access to effective technical information is a key ingredient of profitable strawberry production. Through the Better Berries Program, a joint RD&E initiative of government and industry, DPI&F is a major provider of technical information to Australia's subtropical strawberry industry. Products and services have included the Agrilink Strawberry Information Kit, the Agrilink Strawberry Information Online CD and the Better Berries annual grower field day/seminar and information booklet. However, there is a lack of knowledge of how well these are meeting the information needs of growers, both in content and delivery. This is being researched through a current project.

The project involves detailed face-to-face on-farm interviews with a random sample of approximately 10% of the industry (40 growers). The sample has been stratified to ensure that all sectors of the industry are represented, including large and small, and novice and experienced growers.

Results so far indicate that information sought by growers and the style in which it is best presented varies significantly with grower experience but much less so with farm size. New growers have a wide range of needs while the needs of experienced growers are focussed mainly on problem identification and new production developments. Interestingly, the overwhelming majority, across all sectors, still prefers paper-based information products despite their extensive use of computers for business purposes. The findings are being used to develop an improved range of technical information products and services which are more accessible, easier to use, more timely and more relevant to the needs of growers.

Breeding 1 - Programs and Cultivars

Strawberry Breeding - in a Subtropical Environment

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Strawberry breeding aims to provide cultivars that maximise consumer satisfaction and producer profitability in a changing environment. In this paper some concepts of profitability, consumer satisfaction and sustainability are explored for a subtropical climate using Queensland Australia and Florida USA as examples. The typical production environment is annual autumn planting of bare rooted runners into polythene covered raised beds at about 40000 plants/ha. Harvesting is late Autumn to early Spring with fruit arriving within 1-4 days of harvest at the major markets, up to 2000km away from the production area. The basic premise in the breeding work is that consumers must enjoy the experience of eating strawberries, and that perceived flavour, sweetness, and juiciness are the major contributors to this experience. Using market chain information, we developed a basic value model comprised of costs, returns, and sustainability of market. To this basic outline are applied operational descriptors, such as 'speed of harvest', and associated plant characteristics, such as 'fruit display'. The expression of each plant characteristic is ascribed a value or level and together numerically describe the phenotype. This description is mathematically manipulated to provide a 'value index' for the cultivar. Nine cultivars including 'Strawberry Festival', 'Kabarla', 'DPI Rubygem' and 'Sweet Charlie' are described, and environmental issues that may impact on the subtropical strawberry breeding objectives are discussed. Product differentiation and the use of exotic germplasm as a new source of genes for flavour and resistance to disease and environmental stress will likely be the cornerstones of future progress in subtropical strawberry breeding. This approach should satisfy both consumers and producers.

Progress in Strawberry Breeding in Italy

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The Italian public strawberry breeding program started 35 years ago. Since 1993 this breeding activity has been included in the National Project called "Frutticoltura", mainly founded by the Ministry of Agriculture and Forestry Policy (Mi.P.A.F.), but also receives financial support from Basilicata, Emilia Romagna and Piemonte regional authorities, Verona provincial authorities, and from some private strawberry growers' associations that participate in the final field evaluation of varieties before their release. Thirteen Italian public institutions cooperate in the "Frutticoltura" Project, where the major objective is to produce new and improved dessert cultivars that are well adapted to three wide-spread Italian areas (southern regions, the Po Valley, and northern mountain areas) characterised by different environmental conditions and management techniques. Breeding objectives reflect current strawberry industry trends and are specific for each growing area, but the improvement of the quality of the fruit is a common objective for all areas. A good quality fruit must have a good taste, high sweetness and acidity, high firmness, large size, with a long conical regular shape, a light red skin colour that remains uniform and steady until the eating time. In the last ten years, one major aim of the breeding programs has been to extend the season of production using both short-day and day-neutral types, expecially in relation to the fall culture in the northern areas i.e. a double (autumn-spring) cropping system from a single planting.

The recent advances in breeding for the three areas are reported.

Breeding Ornamental Strawberries

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Seed propagated strawberry varieties attract increasing attention from growers of ornamental crops. ABZ Seeds developed a special breeding program with focus on ornamental characteristics. Some of these characteristics are early flowering, compact plant habit and attractive flowers. The attraction of the flowers to consumers is stimulated by size, shape, number and color. Next to flower characteristics, an ornamental strawberry variety should have a fruit with optimal flavor. Shelf life of the fruit plays a minor role.
The emphasis on flower characteristics presents the possibility of selecting two generations of strawberry breeding material in one year.

Recent Progress in Strawberry Breeding in China

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Since 1990, the public strawberry breeding programs in China have merged in some province projects, mainly funded by the Ministry of Agriculture, Shanghai city, Beijing city, Liaoning province, and Jiangsu province. These projects aim to produce strawberry cultivars with large fruit, high yield, excellent flavor and firmer flesh, and that are adapted to the different environmental conditions of different regions of China. Some cultivars, No.1 XingDu, No.2 XingDu, ShuoXiang and ChunXing, released in 1996 and 1999, are described in detail.

USDA-ARS Strawberry Anthracnose Resistance Breeding Program

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The United States Department of Agriculture, Agricultural Research Service (USDA-ARS) initiated a breeding program in 1976 to develop anthracnose resistant strawberry cultivars adapted to the southeastern U.S., following an epidemic of anthracnose crown rot caused by the fungus, *Colletotrichum fragariae,* in North Carolina. Between 1976 and 1995, over 160,000 progeny from 448 crosses made at Beltsville, MD, primarily by Dr. Gene J. Galletta, were screened for anthracnose resistance in the greenhouse at the Small Fruit Research Station, Poplarville, MS. Fourteen-week-old seedlings were inoculated with a conidial suspension of *C. fragariae*, incubated in a dew chamber for 48 hours, and rated for anthracnose severity after 30 days in a warm greenhouse. Resistant seedlings were evaluated in the field in Florida, Louisiana, Mississippi, and North Carolina. Among the resistant seedlings field tested in Mississippi, 1515 selections were made, based on yield, fruit quality, plant habit, and resistance to leaf scorch, common leaf spot, powdery mildew, and two-spotted spider mites. Of these, 96 elite anthracnose resistant selections are currently maintained. Four anthracnose resistant breeding lines and one cultivar have been released from this program, and anthracnose resistance selections have been used as parents in other breeding programs in the U. S. Seedlings from state and private breeding programs continue to be evaluated for anthracnose resistance at the Small Fruit Research Station. The presence of an anthracnose disease complex became apparent early in the program, and isolates of *C. acutatum* are now routinely included in the screening protocol.

Breeding 2 - Genetic Diversity and Manipulation

The genetic basis of diversity in the genus *Fragaria*

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Plants of the genus *Fragaria* exist at four ploidy levels, display an impressive morphological diversity, and occupy a range of ecological niches from the temperate forests of Northern Europe, to alpine meadows at elevations exceeding 4000 m, to the sandy beaches of South America. Yet, despite this diversity and a large degree of geographical isolation, species within the genus remain relatively inter-fertile, and are all closely related.

The genome size of the diploid *Fragaria* species is comparatively small (approximately 1.5 times that of *Arabidopsis thaliana*), and this group represents an excellent model for the study of genomics of perennial Rosaceaous species.

In this study, a representative sample of diploid *Fragaria* species from Europe, Asia and North America were quantitatively and qualitatively characterised for a wide range of morphological traits, in order to identify the range of phenotypic differences. Two species accessions, *F. vesca* FDP815 and *F. nubicola* FDP601, were chosen as parents to produce an interspecific F_2 mapping population. These two accessions displayed significant morphological differentiation, and also differed for a number of morphological characters such as runnering and incompatibility, which are known to be under major gene control.

By employing primarily co-dominant micro-satellite and sequence tagged markers as well as ISSRs, a molecular linkage map was produced using this population, which defined the seven linkage groups associated with *Fragaria*. The mapping population was characterised quantitatively for a number of vegetative and reproductive traits under QTL control, in an attempt to elucidate the genetic basis of the heritable phenotypic diversity displayed by members of the genus.

Genetic Engineering of Strawberry cvs Firework and Selekta for Taste Improvement and Enhanced Disease Resistance by Introduction of the *thauII* Gene.

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Strawberry is an especially suitable target for improvement through direct gene manipulations because of the genetic limitations associated with high heterozygosity and polyploidy, which hampers conventional breeding programs. Thaumatin II, from *Thaumatococcus danielli*, seems to be a promising protein for biotechnological improvement of strawberry, due to its association with sweet taste and antifungal activity. Nineteen independent transgenic lines of cv. Firework, and 13 lines of cv. Selekta with thaumatin II gene, were obtained via *Agrobacterium*-mediated transformation using CBE21 *A. tumefaciens* stain harboring binary vector pBIThau35. Accumulation of thaumatin II was detected by Western blotting in 17 and 11 lines out of 19 and 13 respectively. The performance of 20 strawberry transgenic lines of cv. Firework, was evaluated in the field during 2000-2003. Ten out of 17 lines with a detectable thaumatin II expression, yielded as well as wild-type cv. Firework, and have the same phenotype. Seven lines exhibited some somaclonal variation. Organoleptic analysis of transgenic fruits demonstrated sweetness improvement in eight lines accumulating thaumatin II protein. Disease resistance evaluation also demonstrated a strong correlation between thaumatin II expression and enhanced resistance against *Botrytis cinerea*. All tested transgenic lines expressing thaumatin II protein showed a significantly smaller area of lesions and sporulation density, observed on the leaf disks. Four transgenic lines without somaclonal variations exhibited sweet phenotype and enhanced resistance against *Botrytis cinerea*. Field trials with 'Selekta' transgenic lines were commenced in 2003, and the evaluation of disease resistance enhancement and organoleptic analysis is in progress.

Shestibratov K.A., Dolgov S.V. (2002) Method of producing transgenic plants with increased pathogen resistance. / Patent application N 2002128414, 24 October 2002 (Russian).
Shestibratov K.A., Dolgov S.V. (2003) Method of transgenic plants producing by *Agrobacterium*-mediated transformation. / PCT Patent application PCT/RU03/00439, 23 October 2003

Pedigree Genotyping: A New Pedigree-based Approach to QTL Identification and Allele Mining

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Pedigree Genotyping is a new approach for the identification and exploitation of QTLs and their functional allelic diversity as present in ongoing breeding programs. This is achieved by including breeding material itself in QTL detection, covering multiple generations of crosses, cultivars, and breeding selections, which are linked by pedigrees to common ancestors. The principle of 'Identity by Descent' is utilized to express the identity of an allele of a modern selection in terms of alleles of founding cultivars. These founder alleles are used as factors in statistical analysis. Co-dominant, multi-allelic markers like SSR (microsatellite) markers are essential in this approach, since they are able to connect cultivars, selections, and progenies at the molecular marker level by monitoring specific chromosomal segments along family trees.

Additional advantages of the use of breeding material rather than special 'scientific' crosses are: (1) a major reduction in experimental costs since plant material is already available and phenotyped (2) continuity over generations within breeding programs with regard to marker research (3) the identification of a series of QTL-alleles as present in a breeding program, (4) the testing of these QTL alleles against a wide range of genetic backgrounds, making results more generally applicable.

For strawberry, Pedigree Genotyping provides new perspectives thanks to the increasing number of available SSR-markers and to new statistical software packages under development at, amongst others, Plant Research International: (FlexQTL™, Pedimap). Data on apple will be used to illustrate the principles of this powerful approach. First results on strawberry will be indicated.

Differential Expressed Genome Fractions and transcriptional factor isolation in *Fragaria spp.*

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Molecular and genetic analysis of fruit development, particularly ripening of fleshy fruits, has resulted in significant gains in knowledge over recent years, especially considering metabolic pathways characterizing commercial and nutritional fruit quality.

Ripening has an impact on fibre content and composition, lipid metabolism, and the levels of vitamins and various antioxidants in the fruit. The ability to understand and manipulate through breeding or biotechnology, key control points or regulatory points of specific ripening processes such as the production of carotenoid, flavonoid, vitamin, and flavour volatiles, will allow the control of nutrition and quality characteristics linked to ripening.

The present work aimed to isolate DNA fractions differentially expressed in *Fragaria spp.* during the ripening process, and the transcriptional factor involved in the processes.

To investigate this process, fruits of different genotypes were collected at three different ripening stages from green to ripe. RNA was isolated from fruit tissue, and cDNA was obtained in order to perform several experiments to isolate differential fractions. Specific and random primers were utilized in order to isolate sequences of gene involved in the ripening process.

All fragments differentially expressed among the ripening stages, and coming from the different genotypes utilized, were sequenced. The sequences obtained were compared against databases for similarity with genes already isolated. Sequences showed high homology with genes encoding protein with known activity as epimerase, carotene desaturase and zinc methabolism enzymes ecc. At the same time, several transcriptional factors were found, and in particular, those involved in sugar metabolism were isolated. All fragments isolated were used to produce a specific cDNA library.

Breeding 3 - Techniques

Characterisation of strawberry genotypes by Proton Transfer Reaction Mass Spectrometry

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Proton transfer reaction mass spectrometry (PTR-MS) is a recognised technique for fast and accurate detection of volatile compounds. In previous studies, the possibility of following shelf-life evolution of berries by non destructive head-space measurements has been investigated. In our recent activity we proposed the possibility of using PTR-MS spectral fingerprinting, both to classify agro-industrial products, and to calibrate it against other techniques, in particular, sensory analysis.

Here we suggest that this rapid fingerprint can indeed be used to unambiguously identify the cultivar from single, intact strawberry fruits. We describe the method on a nine cultivar experiment, using only three fruits per cultivar. We then show how the proposed model correctly predicts the cultivar of another 30 fruits collected independently in different fields and at different times. For two cultivars, 'Miss', and her daughter 'Queen Elisa' in particular, we have hundreds of measurements on single fruits harvested in different fields and in different seasons (2002 and 2003). Our data clearly indicate the possibility of correctly identifying every single fruit. Many statistical methods have been applied to the analysis of these data, and the different performances are shown, aiming at the development of a complete and automatic method for cultivar characterisation.

PTR-MS is a quantitative technique, and spectral line intensity gives an important indication of the concentration of aroma compounds. Here we show also how the high sensitivity and fast response of PTR-MS can be important, both in studying the response of strawberry fruits to mechanical stress, and in nose-space measurements during strawberry eating.

Usefulness of Some Strawberry Genotypes for Breeding of Late Ripening Cultivars

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Studies were carried out at the Research Institute of Pomology and Floriculture, Skierniewice, Central Poland. They were based on strawberry offspring (full-sib families) of a complete diallel-cross design (made according to the Griffing's method IV) among 10 common cultivars, and tested in the field. The following cultivars were used as the parents: midseason - 'Camarosa', 'Elkat' and 'Marmolada'; mid-late - clone K-1529, 'Filon' and 'Pegasus'; late - 'Vikat' and 'Vicoda', and very late – 'Pandora' and 'Sophie'. Observations on the following characters across two years (2001-2002) were made: time of fruit ripening, marketable yield, fruit weight, infection of fruit by grey mould, and susceptibility of plants to three main leaf diseases, *Mycosphaerella fragariae*, *Diplocarpon earliana* and *Sphaerotheca macularis*. Statistical analysis of data was conducted according to the fixed Griffing's model (for the method IV). Simultaneous comparisons of diallel-effect estimates were performed using Bonferroni's multiple test.

In both years of investigations, effects of general and specific combining abilities (GCA and SCA) were highly significant for most of the characters observed, indicating that both GCA and SCA are important in the expression of these characters in strawberry progenies. The highest positive GCA effects for late time of fruit ripening were found for 'Vikat' and 'Pandora', significantly higher than for 'Vicoda' and 'Sophie'. Then, 'Vikat' and 'Pandora' could be specially recommended as parents in breeding programs aimed at developing late ripening strawberry cultivars. The highest SCA effects for the same character were revealed for the crosses: 'Pandora' x 'Filon', 'Vicoda' x 'Sophie', 'Vikat' x 'Elkat', 'Vicoda' x 'Marmolada', 'Marmolada' x K-1529 and 'Filon' x 'Camarosa'.

Cross Breeding with accessions of *Fragaria chiloensis* resulting in clones with outstanding characteristics of Resistances and Fruit Quality

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One of the most dangerous diseases in strawberry cultivation in Europe is caused by the soil-borne pathogen, *Verticillium dahliae.* Susceptibility to *Verticillium* wilt occurs throughout the whole modern assortment of strawberry cultivars. Soil fumigants are increasingly restricted or forbidden by law in the European Union. Definitely, the best control lies in the development of wilt-resistant varieties by plant breeders.

Genetic sources of resistance to *Verticillium* are reported in the literature for some types of *Fragaria chiloensis*. In the presented work, several accessions of *Fragaria chiloensis* were used for cross breeding with *Fragaria x ananassa* cvs. 'Elsanta', 'Honeoye' and 'Surecrop'. Although the progeny of cross breeding with *Fragaria chiloensis*, 'Culture', showed high susceptibility of the seedlings in the *Verticillium* infected field, one specific accession of *Fragaria chiloensis* ssp. *lucida* resulted in selections with astonishing characteristics of plant health and fruit parameters in the field.

Results of *Verticillium* resistance evaluation are obtained by inoculation of Frigo plants under controlled greenhouse conditions (advanced inoculation procedure), and for plants in infected fields showing resistance for selected clones. Additionally, some are characterised by fruits that have an extraordinary aroma.

In addition to this cross breeding, the narrow genetic base of modern cultivars could broaden and provide the starting point for further breeding programs.

Poster abstracts

Transgene Environmental Relationship in Strawberry

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The increasing concern for safety in transgenic plantations, especially when wild relatives of transplants are present in the environment, needed special attention, study and assessment of the risk of gene escape by pollen spread, and of intraspecific and interspecific crossing.

In order to investigate the horizontal transmission of transgenes, strawberry has been chosen as a model plant among perennial species. The availability of *in vitro* regeneration systems by leaves, stipules and roots, has allowed a comparison of their potential efficiency in different strawberry genotypes, and the detection of suitable targets for genetic manipulation. GUS and GFP marker genes were used for the evaluation of the transgenes expression under *in vitro* and *in vivo* conditions, and to obtain some knowledge about gene inheritance in transgenic plant pollen, and pollination between transgenic plants and other strawberry genotypes.

Effect of high temperature stress on pollen of strawberry cvs 'Nyoho' and 'Toyonoka'

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Poor pollen quality in strawberry results in a reduction in fruit set, and the formation of malformed fruits, but there is scant evidence on the effect of heat stress on strawberry pollen. We studied the effect of heat stress on pollen viability and germinability on two short-day Japanese cultivars, 'Nyoho' and 'Toyonoka'. Plants were placed in growth chambers with day/night temperatures of either 23/18°C (control) or 30/25°C (high temperature) when the first inflorescence became visible. At anthesis, pollen was collected and tested for percentage pollen viability and percentage *in vitro* germinability. *In situ* pollen germination was also examined. Results showed that pollen viability in 'Nyoho' was not negatively affected at 30/25°C, when compared with pollen at 23/18°C (77-86% and 71-76% respectively). 'Toyonoka' pollen, however, had a significantly lower percentage viability at 30/25°C (30-55%) than at 23/18°C (70-79%). Percentage *in vitro* germination was significantly lower at 30/25°C than at 23/18°C in both cultivars, but 'Toyonoka' had a much lower percentage germination (~10%) than 'Nyoho' (~30%) at 30/25°C. Fluorescence microscopy of aniline blue-stained styles and ovules, revealed that in 'Nyoho', most of the pollen germinated on the stamen, elongated through the style and reached the ovule, regardless of temperature treatments. In 'Toyonoka', pollen germination and elongation was greatly inhibited at 30/25°C, but not at 23/18°C.

These results suggest that certain strawberry cultivars have pollen that is heat tolerant, which in turn could result in higher fruit set. Such cultivars can be used to develop heat-tolerant strawberry lines, enabling production under warmer temperatures.

Development of PCR-RFLP marker on strawberry and identification of cultivars and their progeny

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We developed 26 PCR-RFLP markers based on sequence information, for the purpose of strawberry (*Fragaria* × *ananassa* Duch.) cultivar identification. These are co-dominance-like markers. We successfully used them to distinguish 65 commercial cultivars. These markers were also capable of distinguishing closely related strains (48 strains of Sachinoka-selfed line). The results were highly reproducible among different extraction methods, different organs, and different researchers. The stability and simplicity of PCR-RFLP analysis makes it a good tool for the identification of strawberries. In addition, we investigated inheritance forms of these markers, using selfed lines of 'Sachinoka', 'Tochihime', 'Nyoho' and 'Cesena', and checked whether it was consistent with Mendel's law, and whether there was real co-dominance.

Aguedilla: A New Strawberry Cultivar from the Spanish Public Breeding Programme

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'Aguedilla' is the first strawberry cultivar released from the research project INIA CC01-0008 within the National Programme for Research and Development (I+D) that began in 2001. The main purpose of this project is to develop and release cultivars with increased adaptability to the environmental conditions of Huelva and other Spanish production areas. This new cultivar is a short-day type, characterized by excellent extra-early, early, mid and late season production with large fruit, a low percentage of second quality fruit, good adaptability to different environmental conditions and cultivation systems, and excellent post-harvest qualities. An agronomic and sensorial characterization of this new cultivar is presented.

Strawberry Germplasm Conservation: The Collection at IFAPA-CIFA (Málaga, Spain)

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Since 1990, one research group at CIFA (Centro de Investigación y Formación Agraria, Málaga, Spain) in collaboration with IVIA (Instituto Valenciano de Investigación Agraria), has developed the public strawberry breeding program in Spain, based on intraspecific hybridizations, followed by individual selections made on the crossing families. With that aim, a *Fragaria* germplasm collection was started at CIFA-Málaga in the late eighties. Thanks to several research projects, it has been broadened, evaluated and improved over the years. In addition, CIFA-Málaga supplies strawberry plants to several research projects and groups, and carries out trials for the Oficina Española de Variedades Vegetales (Spanish Plant Varieties Office).

The *Fragaria* germplasm collection at CIFA-Málaga includes more than 400 accessions of cultivars (260), wild genotypes (100), and selections from breeding programs (50). Its size continues to increase and therefore, it is necessary to improve procedures for the conservation of *Fragaria* genus germplasm.

Optimization of a Liquid Medium for Germination of Strawberry Pollen

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Misshapen fruit is an important problem in strawberry production in the Huelva area (south-western coast of Spain). Physiological and breeding studies on this topic require a deeper knowledge of factors affecting the fecundation process such as pollen germination. In order to attain a simple and suitable medium to improve *in vitro* pollen germination on specific cultivars, a total of 20 different liquid media, resulting from different combinations of boron (from 0 to 350 ppm) and sacarose (5 to 25%), were tested on four strawberry cultivars. Results showed that *in vitro* pollen germination requires boron. Percentages of pollen germination ranged from 16.8 to 55.9 %, and the higher values were obtained within the range of 10-20 % of sacarose, and 100-350 ppm of boric acid. However, maximum values for each cultivar were reached on different media. Within a medium, pollen germination percentages varied depending on the genotypes.

First Evaluation of Strawberry Genotypes Grown In Italian Mountain Areas.

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We report on the preliminary results of strawberry variety evaluation started in 2003 in Trentino, within a co-operation between the local growers, the Istituto Agrario di San Michele all'Adige and the Istituto Sperimentale per la Frutticoltura – Section of Forlì. In this area the major production system is annual, in plastic tunnels, conducted out of soil and the dominant cultivar grown is Elsanta.

Fifty-five genotypes were chosen among commercial strawberry varieties and advanced selections of *Fragaria x ananassa* Duch. to provide varietal information to the growers and to evaluate their performance in mountain Italian areas (Trentino region). A similar activity of evaluation was carried out on thirty-five genotypes of *Fragaria vesca.*

The plants were arranged in three-four plots of six plant each and analysed for horticultural traits, using a ranking scale for plant vigour, time of flowering, ripening, fruit size, weight, production per plant, soluble solids (°Brix), titratable acidity, firmness and colour. Susceptibility to grey mold caused by *Botrytis cinerea* Pers.: Fr., anthracnose and powdery mildew are also recorded.

Beside this agronomic evaluation of cultivars we started, following our studies on different berries of the species *Vaccinium* and *Rubus* in particular, to set-up and apply innovative approaches for the characterization of the cultivars. A comparative study of the nutritional properties in term of content of the main polyphenolic antioxidants and ascorbic acid in fruit extracts was carried on by HPLC-DAD and LC-DAD-ESI-MS.

This project, aimed to the identification of varieties and selections most suitable to this environment, is a joint venture between public institution and private companies, that should represent the basis for a competitive development of the strawberry production in Northern Italian mountain regions.

Isolation and Characterization of Genes Involved in the Biosynthesis and Signalling Pathway for Ethylene in Strawberry

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Strawberry is considered as a non-climacteric fruit where the role of ethylene in fruit ripening is not yet well understood. We were interested in elucidating some of the ethylene-dependent processes acting throughout the development of strawberry and during responses of this plant to environmental stimuli.
Our main interest is to characterize the multigene family encoding ACC-synthase in strawberry, in order to investigate the involvement of ethylene in the process of strawberry plant development, and especially in the process of fruit ripening. As an initial step towards this we have cloned several cDNAs for ACC synthase from different tissues.

Furthermore, using degenerate primers, we cloned the partial sequence of the genes coding ACC-oxidase, and two members of the ethylene signalling pathway, a strawberry homolog of the *Arabidopsis At-ETR1* and *At-CTR1*. Gene expression studies and sequencing of these genes are in progress.

Strawberry Breeding for the Central Plateau of Mexico

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Strawberry has been cultivated in Mexico since the 19th century. With an annual production of more than 100,000 t, México rates as one of the top 10 world strawberry producers since 1960. Seventy percent of that production comes from the Central Plateau, in Michoacan and Guanajuato States, from plantings at 1,500 to 2,000 m above sea level. The subtropical climate favours fructification during most of the year, with yields of 15 to 20 t/ha. The industry depends on US varieties. Despite the introduction of new genotypes, productivity has increased only slightly since 1965, due to the poor adaptability of the varieties, and to their susceptibility to root and crown disease caused by *Fusarium oxysporum*. Our breeding program, carried out by INIFAP and CINVESTAV public research institutions, commenced in 1997 to develop Mexican strawberry varieties free from disease. Varieties from California and Florida Universities were used as progenitors, due to their yield potential and fruit quality, and to their adaptability to short day photoperiod and cold requirements. Clones of *F. chiloensis* have been used for *F. oxysporum* resistance. This breeding program has two purposes. Firstly it aims to develop varieties with high yield potential and fruit quality for the fresh market and industry, and secondly, to breed cultivars that are tolerant or resistant to *F. oxysporum*. Forty-five advanced selections that have produced 25-100% higher yields than Camarosa, currently the most important variety in Mexico, have been bred. During 2003, the first two varieties, 'Cometa' and 'Buenavista', were released.

The strawberry breeding program of "fresas nuevos materiales s.a." (fnm): First cultivars developed

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Fresas Nuevos Materiales S.A. based in Huelva, Spain, has had a strawberry breeding program since 1999. The main goal of the breeding program of FNM is to develop short day varieties adapted to mild winter climates, especially for the Huelva area, that have high yields, good quality including firmness, flavour, and aroma, and increased disease resistance. Another goal is to obtain day neutral varieties to extend the harvest season.

During the last five years, 35,500 seedlings, 524 first year selections, and 56 second year and advanced selections were evaluated. The breeding program of FNM is releasing two new varieties, 'Cisco' and 'Pedrone'. 'Cisco' is a short day variety with good yield, mainly at the end of the season, and is firm, with good flavour . 'Pedrone' is a day neutral variety with good yield and very good flavour, recommended to extend the season beyond the normal production season of February to May. Several other cultivars are being considered for commercialisation within the next few years.

Advances of Strawberry Breeding in China

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China is one of the birthplaces of the strawberry genus, *Fragaria*. Strawberry improvement began in the early 1970s in China. In the 1980s, China carried out the collection and development of strawberry throughout the country, and utilized some better traditional varieties for local strawberry production. In the time, several foreign varieties were successfully introduced for research and production. The strawberry breeding program was initiated with the grant from the Department of Agriculture, in 1985. Shenyang Agricultural University, Jiangsu Academy of Agricultural Sciences, and Beijing Academy of Agricultural and Forestry Sciences, were the earliest units to commence strawberry breeding, followed by the Hebei Academy of Agricultural Sciences, Shandong Institute of Fruit Crops, Shanghai Academy of Agricultural Sciences etc., sooner or later. With the great efforts made by every strawberry breeder, 22 new strawberry varieties have been released, which has promoted the strawberry industry in China.

Selection of new strawberry varieties suitable for processing: Cultivar effects on the quality of strawberry sorbet

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Strawberry is an important commercial fruit with great processing potential. The lack of frozen strawberry in the supermarkets is mainly due to the delicacy of the fruit, which is easily damaged by handling and processing. The freezing effect is detrimental to the texture characteristics of the raw material. On thawing, loss of turgor and drip loss of frozen strawberry are the most evident defects, and they influence the quality of the product. Different factors can contribute to this quality problem: high water content of the fruit, the very large dimensions of parenchyma cells, and pectin composition, which are linked to cultivar variability. Cultivar selection is oriented towards the creation of varieties with specific physico-chemical characteristics, which can improve raw material quality for fruit processing.

In this paper, some strawberry selections suitable for the preparation of sorbets have been analysed. Samples coming from CIV fields were IQF frozen, and stored at -20°C until processing. After thawing, physical and chemical analyses were carried out, and the percentage of drip loss, and texture values, were measured. Furthermore, strawberry samples were processed and prepared in an artisan way for the production of sorbet, without any addition of additives. A sensory test was undertaken on the sorbet, and the panelists were asked to evaluate the acceptability of the final product. The results of the test confirmed the objective indices. Considering the good results of these first trials, further research should be directed into detecting new varieties that could enhance the quality of the final product, while maintaining the fresh fruit taste.

MTT Strawberry breeding programme

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Strawberry breeding at MTT was restarted and greatly expanded, during 1996. Between 1997 and 2003, about 47,000 new hybrid seedlings were produced for selection. The main goals for the breeding are resistance to mildew (*Sphaerotheca macularis* (Wallr. ex Fr.) Jacz. f. sp. *fragariae* Peries), and fruit firmness. A further fundamental criterion is good adaptation to the Finnish climate. The breeding programme is based on classical variety breeding, and in the early stages it involves hybridisations of hardy and well-adapted varieties with mildew resistance or firm fruit, or both. The selection for mildew resistance is done in the field under natural mildew infection.

The first selections from the new material have gone through the clone trial phase, and entered comparative trials. The most common parentages among the clones selected for clone trials were 'Polka', 'Hella', 'Kent', 'Emily', 'Marmolada', 'Bounty', 'Camarosa' and 'Jonsok'. Of the clones thus far selected for comparative trials, the most common parentages are 'Polka', 'Kent', 'Senga Sengana', 'Emily', 'Bounty', 'Camarosa' and 'Jewel'.

The new early strawberry variety, 'Kaunotar', produced in a previous strawberry breeding programme, was released for cultivation in 2003. 'Kaunotar' originates from a crossing between 'Hella' and 'Glima'. One of the positive features of the new variety is its earliness, which is comparable to that of 'Jonsok'. 'Kaunotar' also shares the tendency of 'Jonsok' for small fruit size, while clearly surpassing it in fruit quality, including taste.

Two new strawberry cultivars from East Malling Research

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Since 2000, two new strawberry cultivars have been released from the breeding programme at East Malling Research, one everbearing, and one June-bearing.

'FLAMENCO' (2002) is an everbearing type that crops from July to October in the UK, but is most productive in late summer and autumn. It has excellent fruit quality, and is suitable for all types of market outlets. The berries are large, firm, sweet and very attractive, with long shelf life. Plants are resistant to *Verticillium dahliae*, and moderately resistant to *Sphaerotheca macularis*. Runner production is prolific for an everbearing type, and the plants are moderately vigorous with intermediate habit.

'MAE' (2003) is an early June-bearer with a season approximately one week in advance of 'Elsanta'. Yield is similar to 'Elsanta', but average fruit size is larger. Both yield and fruit size is maintained well on second year plants. The berries are moderately firm with a regular conical shape, strong red colour, and pleasant flavour. The plants are compact and well suited for production under tunnels. Best performance has been achieved from planting a fresh runner or module plant in late July or early August.

The Application and Selection of New Strawberry Varieties –'Shimei series'

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The selection of new varieties started in 1980 in Shijiazhuang Pomology Institute of Hebei Academy of Agricultural and Forestry Sciences of China. Many germplasm resources from around the world were collected, reserved, evaluated and applied. From these resources, scores of excellent varieties were selected, which were fit to be planted in the central part of China. Similarly, many novel parent materials were identified. Now there are more than 400 germplasm resources. More than 100 good clones have been selected,from crossing, and many excellent varieties cultivated, such as 'Shimei 1'□ÿ†□ #.–□ 'Shimei 2'□ÿ.– #.–□ 'Shimei 3' and 'Shimei 4'. In addition, these varieties were distributed and grown in the main strawberry growing areas in China, achieving good economic performance.

Three Years of QTL Analyses for Developmental and General Fruit Traits in the Cultivated Strawberry

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Mapping of quantitative trait loci (QTL) controlling components of strawberry (*Fragaria* x *ananassa* Duch., 2n=8x=56) fruit quality, can be used to provide a better understanding of their genetic control, and to develop marker assisted selection (MAS) for breeders. For this purpose, a segregating population of 213 individuals of a cross between 'Capitola' and 'CF1116', two genotypes with many contrasting fruit quality traits, was used for genetic mapping. Nine developmental and fruit quality traits were evaluated during three years, including maturity, fresh and dry weight, fruit length and diameter, skin colour (L, a, b), and firmness. In addition to these characters, juice colour and ascorbate concentration were determined during two successive years. ANOVAs were performed to evaluate the variability of each trait. Putative QTLs for these developmental and fruit traits were identified using Composite Interval Mapping. Results are discussed in relation to year effect.

Flavour control in strawberry breeding by sensory and instrumental methods

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The consumer acceptance of strawberry cultivars is usually attributed to their dessert quality. Any newly released fruit which seeks to replace or compete with the cultivars now available in the market must be of superior eating quality. For this reason, flavour analysis by sensory and instrumental methods, as well as sugar and texture measurements were integrated into the breeding programmes of the BAZ.

After identification of 22 flavour impact compounds for the strawberry aroma by human sensory, gas chromatography/ mass spectrometry and /olfactometry, a reliable method was developed. Thus it is possible to prepare hundreds of samples by a simple procedure, carried out over long distances and analyzed in a specialized laboratory.

The analysis of variability of aroma patterns is demonstrated by an experimental crossing between cv. Elsanta, cv. Honeoye, cv. Surecrop and accessions of F. *chiloensis*. The high throughput method will be used in inheritance analysis of sensory traits and screening for interesting aroma types in crossings with wild strawberry types as well.

The New Infra-Short Day Strawberry Variety, 'Suzana'

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'Suzana', a new strawberry variety derived from the Israeli variety Ofra (Parker x Dorit) and breeding line No. 822 (Oso-Grande x Dorit), has been released as part of the Redeva strawberry breeding programme, and is presently under registration for Plant Variety Rights. 'Suzana' is an infra-short day type similar to other Israeli varieties, Dorit, Ofra, Tamar and Yael, which were bred at the Volcani Research Institute. With 'Suzana', flower induction can take place with up to 13.5 hours of daylength, and up to an average of 30°C day and 22°C night temperatures. This variety is therefore particularly suited to growing under sub-tropical conditions (latitude 30° - 35°) since it is more heat tolerant than day-neutral types.

The fruit are conic to oblate in shape, with a glossy red skin finish. The fruit is firm in both texture and skin finish, and is sweet and juicy when eaten. Typical brix levels in Israel in November/December are in the range of 12-14%. Although plant size tends to be smaller than most of the Californian and other Israeli varieties, yields of 70t/ha have been achieved with good sized fruit in the range of 30 - 40g.

Germination Characteristics of Pincette Harvested Seeds in Strawberry Cultivars

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In order to clarify germination characteristics of pincette harvested seeds in cultivated strawberries, three different experiments were carried out, using pincette harvested seeds and blender harvested seeds of 'Sachinoka', 'Nyoho' and 'Asuka-ruby' cultivars. In 'Sachinoka' and 'Nyoho', the germination rates of the pincette harvested seeds were much higher than those of blender harvested seeds. However, the seed germination rates of 'Asuka-ruby' were less than 10% in the case of both seed harvesting methods. The germination rate of the blender harvested seeds, which did not appear to be damaged, was much lower than that of the pincette harvested seeds in 'Sachinoka'.

Furthermore, the germination rates of out-crossed and selfed seeds in 'Sachinoka' were more than 90%, but those in 'Asuka-ruby' were only approximately 30%. From the results of these experiments, it could be considered that pincette harvested strawberry seeds exhibited germination characteristics closer to those in nature, compared with the blender harvested seeds.

Demographic history and linkage disequilibrium patterns in Chilean strawberry, *Fragaria chiloensis (L) Duch.*

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The native strawberry, *Fragaria chiloensis (L) Duch.*, is a species endemic to Chile. Its natural populations are widely distributed between 34°55□S and 47°33□S, through the Andes and coastal mountain range. This species is also found, on the Pacific Coast from Alaska to California, and in Hawaii. In Chile, two forms are distinguished, one being a wild, red-fruited species (*F. chiloensis ssp. chiloensis f. patagonica*), the other a light pink-fruited, cultivated species (*F. chiloensis* ssp. *chiloensis f. chiloensis*). The latter has a long and rich history because it was cultivated by the aboriginal people even before Spanish conquerors arrived in Chile in 1541. This species is considered to be the mother of the hybrid *Fragaria x ananassa*. The origin of the Chilean population of *F. chiloensis* is not clear, but it has been hypothesized that it could have been introduced from North America by migratory birds. If the current populations of strawberry originated from a few founder events of thousand of years ago, it should be possible to find a low genetic diversity with a scarceness of rare alleles and generalized high linkage disequilibrium. In order to test this hypothesis, we used 10 ISSR (Inter Simple Sequence Repeat) and 5 SSR (Simple Sequence Repeat) to analyze 63 accessions of *F. chiloensis*. Our results are in agreement with the hypothesis, because we found a low genetic diversity, high population identity, and high linkage disequilibrium. This would mean that an initial population of Chilean strawberry established from a few individuals, and the effect of genetic drift, would explain the results found in this investigation. We will discuss the role of the demographic history and the patterns of linkage disequilibrium for mapping genes in Chilean strawberry population.

Sustainability of Cold-climate Strawberry Production Systems

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An experiment is being conducted at Beltsville, Maryland, to compare the sustainability of 3 cold-climate strawberry production systems. Field plots of conventional matted row, advanced matted row, and cold-climate plasticulture, were established in 2002, and managed according to commercial standard practices for the region. Each system is replicated in 3 plots measuring 6 x 15 m. Data have been collected to measure the following components of sustainability: economic viability and efficiency, environmental impacts, and public acceptance. Marketable yields for Spring 2003, the first harvest season, were lower than normal due to above average rainfall and high disease incidence. The conventional matted row was the highest yielding at 17,381 kg/ha, followed by the advanced matted row and plasticulture with 13,219 and 11,786 kg/ha respectively, although fruit size and quality were higher in plasticulture. During the establishment year, soil loss from rain-induced surface runoff was 649 kg/ha for conventional matted row, compared to 224, and 153 kg/ha for plasticulture and advanced matted row, respectively. Nutrient leaching and runoff also varied among systems due to timing and method of fertilizer application. Volunteers harvested fruit from a small subplot in each system and were surveyed on their impressions of each system. Overall preferences were for the plasticulture system, however these may have been influenced by the differences in harvest season among systems. All plots were renovated following the 2003 harvest, and the project will continue through a second harvest in Spring 2004.

Adaptation and Agronomical Characterization of 'Medina' and 'Marina' Strawberry Cultivars

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'Medina' and 'Marina' are two short-day cultivars released from the Spanish National strawberry breeding programme (INIA Research Projects nº: SC94-033-C2 and SC98-035-C2-2). Since 2001, the performance of 'Medina' and 'Marina' in comparison with other standard cultivars, was evaluated at different locations within the area of Huelva (the main strawberry fruit production area of Spain) in order to assess their agronomical characteristics and adaptation. Both have shown to be vigorous, well-adapted short-day cultivars. 'Medina' is a highly productive cultivar with an interesting early production of large size fruits, and a small proportion of second quality fruit. 'Marina' has a production slightly lower than 'Medina'. Its fruit flavour is excellent and pleasantly aromatic, and it has a very good taste and very high colour intensity. These important qualitative traits make 'Marina' very appropriate for direct consumption as well as for processing. Results of the performance of these cultivars during the last cropping season (2003/2004) are shown in the present work.

Misshapen Fruit in Strawberry - An Agronomic Evaluation.

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Strawberry production in Spain has developed significantly since 1965. Strawberry is cultivated in all Spanish regions, but in Huelva, there is a great concentration and specialization of the crop. The cv. Camarosa was the predominant variety in the 1996/97 crop season, and now accounts for more than 90 % of the crop. The strawberry cultivated area in Huelva comprises 86% of the national crop and 94% of Spanish exports. The importance of the strawberry industry in Huelva is shown by the statistics, with strawberries grown on 6,700 ha producing 300,328 t, which is worth more than €400 million.

Although production can be considered to be good, there is restlessness in the industry due to the production of excessive volumes of misshapen fruit. Numerous factors may be involved in the development of misshapen fruit, all of them related to each other. No attempt to reduce the incidence of misshapen fruit in strawberry has been performed in Huelva. Nevertheless, work with this aim has been performed in France and England. Reports on this research note the importance of adequate pollination. To understand in detail the causes of misshapen fruit, it is also necessary to find ways to reduce the losses, which can reach 20-30 % of total production, that misshapen fruit cause.
Experiments were performed in two environments (both in Huelva), with three treatments: bumblebees, wind and control (without bumblebee or wind), over two years. The results showed that bumblebee can significantly reduce the incidence of misshapen fruit.

Antisense repression of AGPase in transgenic strawberry plants abolishes the leaf starch diurnal cycle, but has no effect on normal vegetative and reproductive development

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Sweetness is one of the most important traits determining strawberry fruit quality. Strawberry leaves show a diurnal pattern of starch accumulation. We hypothesized that preventing starch synthesis in source leaves would change the source-sink relationships in the fruiting plant, increasing sugar transport and availability to the developing strawberry fruit sink. The enzyme ADP-glucose pyrophosphorylase (AGPase) is a key enzyme in starch synthesis. In order to reduce AGPase activity in strawberry plants we generated transgenic strawberry plants with antisense repression of the AGPase small subunit under the control of the constitutive 35S promoter. Several transgenic plants showed a 90% reduction in AGPase activity and consequently had only traces of starch content in their leaves. The diurnal starch accumulation pattern in the leaves was abolished. During daytime the leaves of the transgenic plants accumulated soluble sugars, especially sucrose, thereby compensating for the starch, and the total diurnal carbohydrate level was not decreased.

Despite the dramatic reduction of starch level in the transgenic plant leaves and in other plant tissues, no obvious effect on vegetative or reproductive development was observed. Also, the reduction of the diurnal leaf starch accumulation did not affect fruit yield (fruit size and number) or fruit quality, as determined by total soluble solids (TSS). However, photosynthesis at elevated CO_2 was severely inhibited in the starchless transgenic plants. We conclude that the capability to synthesize starch in strawberry leaves during day time is not necessary for normal plant growth and development, but can contribute to photo-assimilation at high CO_2 concentrations.

Effects of Growth Substances on Out of Season Production of Strawberry

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The off-season for strawberry in Japan extends from July to October, because of high temperatures. Most demand during the period is met by imports, but consumer desire for domestic fresh strawberries, is high. Therefore, experiments on ways of extending the production season are being carried out in the regions where summer climates are cool. To harvest fruit in summer, flowers have to be initiated in spring. In northern Japan, natural conditions at that time are suitable for flowering of strawberry, but it is known that flower induction is inhibited during the post-chilling period. As endogenous gibberellins are suspected to be involved in the chilling response, it is likely that reducing the gibberellin content would restrict vegetative growth, and suppression of flowering. Runner plants of 'Nyoho' and 'Toyonoka' were potted in September, kept in a plastic house and then placed outdoors on 5 November. On 3 February they were transferred to a growth chamber set at 20/15°C (day/night) with a photoperiod of 8hr, for flower induction. Half of the plants were sprayed with prohexadione calcium, an inhibitor of gibberellin synthesis, four times at five day intervals. After 16, 20, or 25 days of induction treatments, plants were transferred to a growth chamber maintained at temperature 18°C under a 16hr photoperiod. Prohexadion calcium reduced petiole lengths and delayed the appearance of runners, but did not promote flower induction and the number of runners on both cultivars in this experiment. Results of other experiments with plant growth substances for out of season production will be also presented.

The Effect of Planting System on Strawberry Yield Grown Out of Season

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The system of strawberry production for summer harvest (out of season) was examined in the temperate climate conditions of the Republic of Croatia. The aim was to prolong the harvest season. Two new prospective short day cultivars ('Madeleine' and 'Raurica'), in combination with two plastic mulch systems (black and white), were grown in a one row bed system with a distance of 0.2m in-row, and 1.2m between rows (planting density 40000 plants per hectare), under drip irrigation. The highest yield was obtained from 'Raurica' in combination with white plastic mulch and tray plants (347.7 g/plant), while the lowest yield achieved was from 'Madeleine' on black plastic mulch with cold stored runner plants (61.1 g/plant). The quality of the fruit was good, with higher amounts of total solube solids in comparison with the same cultivars grown in season. By using new cultivars of higher yield potential, and excellent quality nursery plants, it will be possible to extend the strawberry production season.

Nitrogen Requirements of Drip Irrigated Strawberries Grown in Subtropical Environments

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A series of fertilization experiments was carried out in a subtropical environment of northwestern Argentina (province of Tucuman, 27°04'S-65°25'E). An optimum range of nitrogen (N) rates was determined for strawberries, which were grown in a winter-spring production system. One study was conducted in 1999 on varieties such as Camarosa, Cartuno, Chandler, Rosa Linda, Sweet Charlie and Tudla Milsei. Two studies were conducted in 2000 on Camarosa, Sweet Charlie and Tudla Milsei. A fourth trial was run in 2001 on Camarosa and Tudla Milsei. Fresh-dug strawberry transplants were used in all the experiments. Cropping beds consisted of drip-irrigated raised beds, covered with black polyethylene mulch. Data show that optimum N application rates for strawberries are within a range of 135 and 155 UF.ha^{-1}. These results have both practical and environmental implications.

Strawberry Fruit Quality in Two Production Types

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The short-day strawberry varieties 'Bounty', 'Honeoye' and 'Korona' were grown either under polythene or in the open, and the quality of their fruit was examined during the cropping season. Soluble solids content, pH, firmness, colour lightness, saturation and hue angle (L*C*h colour space) of the fruits were determined. The content of fruit soluble solids increased in both production types as the harvest season progressed. The content of soluble solids was significantly higher in the open field production than under the polythene. Fruits produced in the open field were also significantly firmer, and their colour was darker, than under the polythene cover. Fruits produced under the polythene were, however, redder than fruits in the open field production. Differences in colour saturation and pH were not significant between production types.

Performance of different Californian strawberry cultivars under warm semi-arid conditions of North India.

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A trial was conducted for the production of strawberries under North Indian conditions from 1998-99 to 2000-01. Plants in the high density winter planting were set at a distance of 25x25cm on raised beds in four rows, on loamy sand at the Kings Orchards, Sharawa (Hisar), situated 180 km west of New Delhi. Micro-sprinkler irrigation was applied for 40 days, after which a drip system was used. The average survival rate of the five cultivars tested, 'Camarosa', 'Chandler', 'Irvine', 'Oso Grande' and 'Selva', was more than 94%. 'Camarosa' had the highest survival rate of 97.48%, whereas it was 88.29% in Irvine. The maximum growth and spread in the plants was recorded in cv. Camarosa, followed by 'Oso Grande', whereas 'Irvine' had lesser spreading tendency. Fruiting commenced in January and continued up to 2nd week of April. The maximum yield was recorded in 'Camarosa', and the lowest in 'Irvine'.

The sensitivity of strawberry cultivars to major fungal diseases of leaves in Croatia, and the possibilities for their control

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In Croatia, the production of strawberries has been increasing steadily in recent years. The assortment has been changing from year to year, owing to the introduction of new cultivars. The most common cultivars in production are 'Elsanta', 'Marmolda', 'Maya', 'Madeleine', 'Miranda', 'Miss', and 'Raurica'. The aim of our research was to determine the sensitivity of these cultivars to major fungal diseases of leaves in Croatia, namely leaf spot (*Mycosphaerella fragariae*), leaf scorch (*Diplocarpon earliana*), leaf blotch (*Gnomonia comari*), and leaf blight (*Phomopsis obscurans*). In order to determine the possibilities for controlling these diseases, we conducted tests of fungicide efficacy on the most sensitive cultivars. The infection intensity of each disease was assessed according to the Townsend-Heuberg formula based on an analysis of 200 leaves and our own scale of 0-5, while fungicide efficacy was determined by Abbott's formula. Among the cultivars tested for leaf spot, the most sensitive cultivars were 'Madeleine' and 'Marmolada', while the other cultivars were relatively resistant to this disease. The cultivar most sensitive to leaf scorch was 'Raurica' and somewhat less, 'Marmolada'. All cultivars proved to have a low sensitivity to leaf blotches and leaf blight. Among the fungicides, Folicur M® and Euparen M® had the best efficacy for all the tested diseases. Kidan® had a good efficacy on leaf scorch, as did Quadris® on leaf spots. Based on the results obtained, we created a leaf protection plan, dependant on the cultivars grown.

Survival of *Colletotrichum acutatum* in dead plant material and soil in Finland

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Colletotrichum acutatum causes black spot disease on strawberry fruit, petioles, crowns and stolons. The pathogen is rapidly spreading on infected plant material, to new areas. The fungus was detected for the first time in Finland in the year 2000 in imported strawberry plants. *Colletotrichum acutatum* is a quarantine pest on strawberry in the European Union. In Finland, when a *C. acutatum* infection is detected, the infected plants are destroyed to avoid further spread of the pathogen.

The fungus had not been present in Finland before, and there was no knowledge of its overwintering capacity in Finnish conditions. The survival of *C. acutatum* in infected plant material was studied in 2002-2003 with artificially infected strawberry leaves, crowns and berries. The plant material was placed outdoors in small nylon-mesh bags, in buckets filled with sandy soil. The bags were placed both on the surface of the soil, and buried at two depths. Similar buckets were placed in a cold plastic greenhouse. The bags were removed in May, June and July, and the material was used as inoculum for young strawberry plants (cvs. Jonsok and Rita) in greenhouse trials. *Colletotrichum acutatum* was isolated from strawberry plant parts (stolons and petioles) on nutrient media, and the plant material was tested with PCR. *Colletotrichum acutatum* survived the winter both on the surface of the soil, and when covered with soil. The fungus was able to cause symptoms on strawberry plants in the first two trials, which commenced in May and June. PCR revealed several latent infections in the test plants.

The survival of *C. acutatum* infection in soil was studied using bait plants (cv. Jonsok) in a greenhouse, using soil from a naturally infected strawberry field. Soil samples were taken from the field a year after the infected plants were destroyed. Positive PCR results were achieved eight weeks after the bait plants were planted in the soil samples.

Strawberry powdery mildew: The effect of foliar nutrition on disease development in two strawberry cultivars

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Powdery mildew causes significant economic loss in strawberry crops in South Australia. Powdery mildew is difficult to manage using chemical fungicides, and the cultivars grown in South Australia are susceptible to the disease. The objective of this study is to investigate the effect of foliar nutrition on disease development as a possible means of biological control for powdery mildew disease. Calcium chloride (Stopit®, Phosyn) and potassium silicate (Kasil 2640®, PQ Corporation) will be applied as foliar sprays to 'Aromas' and 'Selva' cultivars during the 2003/2004 strawberry season. The mechanisms by which these nutrient applications improve disease tolerance will be investigated, using macroscopic and microscopic techniques, and genes associated with nutrient metabolism, and the host x pathogen interaction will be identified using a candidate gene approach.

Integrated Pest Management development in Strawberry cultivation and production in Israel

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Trials incorporating IPM practices wer conducted between 1992 and 2003, in strawberry production in Israel. This research has shown that beneficial insects can be used to control pests, reducing chemical use to produce high quality and safe fruit for export and local consumption.

This research examined the release of *Phytoseiulus persimilis* to control *Tetranychus urticae* and *T. cinnabarinus*; *Aphidius colemani* to control *Aphis gossypii*; and *Orius laevigatus* to control *Frankliniella occidentalis*. The experiments were based on releasing laboratory grown predators into nursery and fruiting fields, and monitoring their establishment, the biological conditions necessary for their multiplication, and the population dynamics of both pests and predators.

After a few years of trials it was recommended that commercial application and treatment be carried out on small scale fields supported by The Ministry of Agriculture, broad-acre vegetables, exporting companies, and farmer organizations. This support enabled the project to become practical and commercial within three years. The fruit packages and fields were marked and labeled as IPM production for export, and carried the trade mark of "Healthy Strawberry" for the local market. The project started with two hectares in 1997 (0.05% of total cultivated strawberry fields) to reach 200 hectares in 2003 (67% of strawberry fields).

This combined approach has helped Israel's strawberry farmers to reduce chemical use by 30%, and to increase the consumption and popularity of strawberry, increasing the income of farmers through exports and better local marketing. The next step is to investigate integrated disease management for powdery mildew, grey mould, and anthracnose, to provide a total biological basis as an alternative to the chemical control of pests and diseases.

Molecular view on susceptibility of strawberry cultivars to grey mould, *Botrytis cinerea*

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Since the end of the 1900s, breeding and cultivation of plants have been supported by molecular and *in vitro* technologies. Laboratory techniques assure, among others, more precise disease control, based on a wide range analysis of pest-host relations. The result is plants tat produce better quality fruits and more 'healthy' food. Grey mould, caused by *B. cinerea*, is one of the most economically significant diseases of strawberry plantings. At present, no cultivars are resistant to the pathogen. However, a large variation is observed in the reactions of infected cultivars. Additionally, the level of cultivars' susceptibility to fungal infection is correlated with fruit softness, a trait that is typical for each cultivar. Some genes, regulating cell-wall metabolism during the fruit maturation and softening, were isolated from strawberry plants. It has been suggested that these might be used to block the first, cell-wall connected step of pathogenesis. The genes were isolated from plants representing cultivars with strong, mild or no defence reactions. Comparison of sequences of expansin (Ex), cellulase (Cel) and polygalacturonase (Pg) genes originating from these plants showed high homology (99%). Meanwhile, connection of plant susceptibility with cell-wall metabolism was confirmed by the comparison of sequences of PGIP-gene (polygalacturonase inhibitor-protein) derived from strawberry, tomato and resistant pear and apple (homology from 50 to 70%). Based on apple PGIP-gene sequence, genetic construct was prepared and used for generation of resistant strawberry genotypes by *Agrobacterium tumefaciens*. Results suggest close correlation between different defence reactions, fruit softness level and kinetics of genes, regulating cell-wall metabolism expression.

Occurrence and Identification of Aster Yellows Related Phytoplasma in Strawberry in Poland

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Symptoms typical for phytoplasma diseases were observed on 'Mara des Bois', 'Selva', 'Evita', 'Senga Sengana', 'Venta' and 'Tango' strawberry plants growing in commercial and experimental plantations in Poland. PCR/RFLP analysis was carried out to identify the causal agents of the diseases. Nucleic acid was extracted from phloem tissue, and the target DNA was amplified by nested PCR with universal primers R16F2n/R2, followed by P1/P7. DNA extracted from healthy strawberry plants was used as a negative control. Fragments of 16S rDNA amplified with R16F2n/R2 were digested with *Rsa*I, *Mse*I, *Hha*I and *Alu*I restriction endonucleases. The purified PCR products were also sequenced. The sequences were assembled, nucleotide sequences compared, and multiple sequences aligned using the relevant programs of the Dnastar package.
All samples of DNA extracted from infected strawberry plants yielded a nested PCR product of the appropriate size. No PCR products were obtained from healthy plants. RFLP analysis of the R16F2n/R2 amplified fragments revealed that the phytoplasma isolated from the affected 'Mara des Bois', 'Selva', 'Evita', 'Venta' and 'Tango' strawberry plants was closely related to the aster yellows group (16SrI), subgroup I-B, whereas the phytoplasma that infected 'Senga Sengana', belonged to the aster yellows group, subgroup I-C. Sequencing of the purified PCR products amplified with R16F2n/R2 confirmed the PCR/RFLP results.

Effect of Preharvest Calcium Application on Grey Mould Development and Postharvest Quality in Strawberries

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Grey mould, or Botrytis fruit rot caused by *Botrytis cinerea*, is one of the most important postharvest diseases of strawberry. Appropriate plant nutrition appears to reduce susceptibility to the fungus by improving fruit firmness and maintaining plant growth. Calcium (Ca) is the nutrient most closely related to fruit firmness and hence quality, because of its role in strengthening cell wall and membrane structure. Addition of Ca to fruit has been reported to reduce susceptibility to postharvest diseases and disorders.

Strawberry (*Fragaria x ananassa* Duchesne) cvs 'Aromas' and 'Selva' were grown in sand in the glasshouse to investigate the effect of Ca on grey mould incidence and postharvest quality. Calcium sulfate ($CaSO_4$) was applied pre-planting as gypsum into the sand, at the rate of 400, 1200 and 2000 ppm Ca. Plants were inoculated at flowering by dropping 100 µl of conidial suspension of *B. cinerea* (10^6 conidia/ml) on each newly opened flower with a micropipette. Controls were untreated.

Harvested fruit were stored at 10°C for 10 days. During storage, grey mould development was monitored daily, while external appearance, fruit firmness, pH, soluble solids content and titratable acidity were monitored every second day. The effect of preharvest Ca application on grey mould development and postharvest quality in strawberries will be discussed.

Thirty Years of Advances in Arthropod Management Practices in Florida's Commercial Strawberries

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Over 2,800 ha of fresh market, winter-grown strawberries are produced annually in Florida. That production environment is conducive to development of arthropod pests of strawberry such as twopsotted spider mite, flower thrips, melon aphid, various noctuid moth larvae, *Drosophila* fruit flies, sap beetles, and others. Before 1978, these pests were controlled in most part, with broad-spectrum pesticides applied on a regular basis, with little regard for the ecological status of the arthropod community. About that time, scouting to assess the ecological condition of strawberry fields was introduced, and pesticide application decisions began to be made according to scouting information. By the late 1980s, *Phytoseiulus persimilis* predators were being introduced on some farms for control of spider mites, but much of the industry resisted this innovation. As more farmers adopted the practice over the next few years, a new awareness of ecological damage in the crop from broad-spectrum pesticides, emerged. New pesticides with better target pest specificity and other favorable environmental qualities replaced many of the harsher early pesticides. Today, many Florida strawberry farmers rely on biologically and ecologically based plans of arthropod pest management, and are seeking new biological controls for aphids, thrips and other pests in addition to spider mites. During this 30-year period of transition, the strawberry industry in Florida has expanded and has become an uncommon example of an annual, field-grown, horticultural crop produced with an applied biological component of pest management.

Distribution and significance of pathogens associated with Australian strawberry lethal yellows and green petal diseases

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Candidatus Phytoplasma australiense (Australian strain) was initially identified as the phytoplasma associated with SLY and SGP diseases. Recent studies have shown that the phytoplasmas, tomato big bud (TBB), Vigna little leaf, and the New Zealand strain of *Ca. P. australiense*, are also associated with SLY and SGP diseases. A phloem limited Rickettsia-like-organism (RLO) has also previously been reported as a causal agent of SLY disease. This relationship was recently confirmed by characterisation of the *sdhA* gene of the RLO associated with SLY. Strawberry samples exhibiting SLY and SGP symptoms were collected from south-east Queensland from 2000 to 2003, to investigate the relationship between strawberry disease, phytoplasma and RLO. Only 2 SGP disease samples were collected during the study, compared to 518 SLY disease samples. The two SGP diseased samples both tested positive for *Ca. P. australiense* (Australian strain). Of the 518 SLY samples, 147 tested positive for the RLO, 67 tested positive for *Ca. P. australiense* (Australian strain), and 11 samples collected at on the same date from the same location, tested positive for *Ca. P. australiense* (New Zealand strain). The tomato big bud phytoplasma was identified in only 2 SLY diseased samples. Eleven strawberry plants with both SLY and SGP symptoms were also collected, and all of these tested positive for *Ca. P. australiense* (Australian strain). These data indicate that the RLO was more commonly found in SLY diseased plants, and of the phytoplasmas detected, *Ca. P. australiense* was the most common.

Pathogenicity, Morphological and Molecular Characterization of *Rhizoctonia* spp. Isolates from Strawberry Plants in Israel.

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Rhizoctonia spp. isolates (total 76) were obtained from infected strawberry plants in Israel. Of the binucleate *Rhizoctonia* isolates - *R. fragariae* (Teleomorph: *Ceratobasidium cornigerum*), 28% of the isolates belonged to AG-A and 40% to AG-G, while the remaining 32% were multinucleate, and all belonged to AG 4 - *R. solani* (Teleomorph: *Thanatephorus praticola*). Of these isolates, 27% of the AG-A, 19% of the AG-G, and 31% of the AG 4, were highly virulent on strawberry seedlings. The phylogenetic analysis of the highly virulent isolates belonging to the three anastomosis groups corresponded to three defined clusters based on comparison of the of ITS 1-4 rDNA sequences of the isolates, as three defined clusters. Representative isolates of the binucleate AG-I, which are known to infect strawberry plants in relatively cold temperatures, appeared in a separate cluster, but no isolate belonging to AG-I was obtained from infected strawberry plants in Israel, in the present study.

The currently used pathogenicity test for *Rhizoctonia* spp. isolates is based on reduction of strawberry biomass, and is evaluated approximately one month after inoculation of daughter plants derived from runners. Since this method is not based on defined disease symptoms, it requires a long incubation period, and the results are highly variable. The present study was undertaken to develop a more effective and reliable pathogenicity test and three new methods were evaluated, namely, inoculation of 1. detached petioles 2. detached green strawberry fruit and 3. seedlings derived from strawberry seeds at the two true leaf stage. The latter method proved to be superior and more reliable for pathogenicity tests than the currently used method, and the alternatives for pathogenicity tests, having the following advantages 1. the pathogenic isolates incited typical disease symptoms 2. incubation time was only 6 days and 3. the variability of the assay was relatively low.

Alternative Means to Control Strawberry Powdery Mildew and Leaf Spot

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Foliar application of sulphur (Thiovit, 0.7%) and rapeseed oil (Rapsolje, Askim Frukt og Bærpresseri, 1%), and sulphur and a mixture of rapeseed oil (1%) and sodium bicarbonate (0.5%), were found to significantly reduce the severity of leaf spot (*Mycosphaerella fragariae*) and powdery mildew (*Sphaerotheca macularis* f. sp. *fragariae*) infections respectively, in 'Korona' strawberry (*Fragaria* x *ananassa*) plants.

This study examined the effect of sulphur, rapeseed oil, soft soap (Krystal, 2%), and rapeseed oil or soft soap in combination with sodium bicarbonate, applied weekly during the flowering period in an organically grown strawberry field over three years (2001 to 2003).

Leaf surfaces were rated for powdery mildew and leaf spot incidence at the beginning of harvest, and twice after harvest, and number and weight of infected berries were recorded. In the first year, no powdery mildew or leaf spot infections were recorded. In the second year, there was a small, but significant ($P = 0.04$) reduction of powdery mildew infection on the leaves with application of sulphur. In the third year, sulphur and a mixture of rapeseed oil and sodium bicarbonate reduced the severity of powdery mildew infections on leaves by 0.8 percent ($P = 0.01$), and on berries by 18.7 and 18.0 percent ($P = 0.1$) respectively, when compared to the control (water sprayed). The third year, plants treated with sulphur and rapeseed oil also showed a decrease in strawberry leaf spot (*Mycosphaerella fragariae*) infection ($P = 0.0005$) when compared to the water-sprayed control.

These results indicate that sulphur and rapeseed oil in combination with sodium bicarbonate may be effective for control of powdery mildew and leaf spot in strawberry.

Phytoplasma Detection in Insects Collected in Strawberry plants with virescence and phyllody symptoms

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Strawberry plants grown for fruit production in Caserta Province, showing 30% of first flowers with only sepals, no petals (virescence), and producing fruit with leaf-like tissues instead of seeds (phyllody), were analysed for phytoplasma infection. The leaf samples, collected from fifty-two plants showing the symptoms described above, and the insects collected on thirty-nine yellow sticky traps, were analysed using molecular tools.

Only four leaf samples resulted positive to 16SrI-C (clover phyllody) phytoplasmas.

The *Empoasca* spp. (Homoptera-Typhlocybinae) collected by the traps, were grouped into 18 batches, each of 2-5 insects, and the *Trialeurodes vaporariorum* (Westw.) collected either by traps or alive, were grouped into 21 batches, each of 10-20 insects.

Among the insects analysed, only one sample of *Trialeurodes vaporariorum* was rated positive for the phytoplasma group (16Sr I) associated with virescence and phyllody symptoms of strawberry plants.

Other phytoplasma groups such as the 16XII-A and the 16SrV, were found by RFLP analyses in leaves of damaged plants, and in the two species of insect analysed, but their role is unknown.

Main Diseases of the Cultivation of the Strawberry in Irapuato Guanajuato and Zamora Michoacán, México

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The National Institute of Agricultural and Cattle Forest Investigations has carried out investigations into the cultivation of strawberries in Zamora, Michoacán, and in Irapuato, Guanajuato, for about 30 years. Several investigators have participated in the plant pathology area, carrying out diagnosis work and integrated management of diseases. A technological package is now available for strawberry growers. The diseases affecting various strawberry plant parts, reported by different authors over 30 years, are listed in Table 1.

Table 1. Main Diseases Strawberry in Irapuato Guanajuato and Zamora Michoacán México

Part of Plant Damage	Cientific Name
Root and Crown (Fungal diseases of the root and crown)	*Fusarium oxysporum f.sp. fragariae*
	Alternaria spp
	Rhizoctonia spp
	Verticillium spp
	Phytophthora cactorum
Leaf diseases	*Mycospharella fragariae (Tul.)= Ramularia tulasnei*
	Diplocarpon earliana
	Xanthomonas fragariae
	Sphaeroteca macularis
	Colletotrichum spp
Fungal diseases of the fruit	*Botrytis cinerea*
	Phytophthora cactorum
	Sphaeroteca macularis
	Colletotrichum spp
Sistemic	Strawberry Crincle Virus (SCV)
	Strawberry Mottle Virus (SMV)
Fitoplasma	Aster yellow 16s ? rRNA
Diseases abiotic	Iron Zinc and Calcio deficiency
	Cat face
	Black arm
	Pistil sterility

Of the listed diseases, root and crown rots, induced by the pathogen group *Fusarium, Verticillium, Rhizoctonia, Alternaria* and *Phytophthora*, are very important, causing losses of 45% of plants in established commercial plantings. In the rainy season, the main problem is fruit rot, caused by *Botrytis*, *Colletotrichum* and *Phytophthora*, and resulting in 20% damaged fruit.

Chemicals used in integrated fruit rot management in subtropical strawberries in Australia.

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Fruit rot control in sub-tropical strawberry production in Queensland is directed towards black spot, *Colletotrichum acutatum*, grey mould, *Botrytis cinerea,* and powdery mildew, *Sphaerotheca macularis*. Depending on the nature of their farm enterprise, growers will favour a range of crop protectants and other integrated disease management options.

This paper gives a summary of fruit rot control with chemicals since the 1980s, and presents data that have resulted in recommendations that provide excellent control of these diseases for the commercial strawberry grower. We also offer data for products that may be used appropriately in the production of fruit for commercial organic or minimal chemical input systems. Such products still need to be submitted for registration before being used on farm.

Excellent control of black spot is provided by Euparen Multi® (tolylfluanid) and captan. Grey mould is adequately controlled by early applications of Euparen Multi, or with increased disease pressure, by Teldor® (fenhexamid), Scala® (pyrimethanil) or Rovral® (iprodione). The protectant fungicides, Euparen Multi® and Systhane ® (myclobutanil) together with Flint® (trifloxystrobin), which is soon to be registered, give excellent control of powdery mildew. Early application of these protectants is essential, especially when weather conditions favour the disease. They are compatible with current systems utilised for biological pest control.

Responses in strawberry cultivars to natural infection by *Fusarium oxysporum* f.sp. *fragariae*

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Fusarium wilt, *F. oxysporum* Schlecht. Ex Fr. F.sp.*fragariae* (Winks & Williams) (*Fof*,) was first recognised in Queensland when it was the cause of death of strawberry plants in 1962. Losses to this disease have been rare in the last fifteen years.

The phasing out of methyl bromide (MB), the lack of an equivalent replacement for MB, the cost of effective fumigants, and the common practice of replanting into old plastic mulch, have all contributed to the increase in the incidence of the disease in the last few years. Several sites that have experienced serious losses have been identified in the Sunshine Coast area of south-east Queensland.

A highly infected nursery site for this disease was developed at Maroochy Research Station, Nambour, A trial conducted in this nursery compared the highly susceptible cultivar, 'Maroochy Jewel', with nineteen other cultivars.

A wide range of responses to the disease were observed. Cvs. QHI Sugar Baby, CalGiant 3, Festival, Adina, QHI Earliblush, Cal Giant 2, QHI Harmony, and Gaviota, showed high levels of resistance. Cvs. Sweet Charlie, Redlands Joy, Maroochy Flame, and Pajaro were less resistant. Cvs. QHI Brighteyes, QHI Crimsonglow, Camarosa, and Diamante were intermediate between Pajaro and Malah in their reaction, while cv. Malah and cv. Selva were slightly susceptible. Cv. Kabarla and cv. Jewel were moderately and extremely susceptible respectively.

Resistance of Selected Strawberry Cultivars to root-knot nematode species (*Meloidogyne* spp.)

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Plant-parasitic nematodes have the potential to severely reduce strawberry production worldwide. To limit the impact that nematodes have on the strawberry production in Australia, the Queensland Approved Strawberry Runner Scheme (QASRS) was established. As part of the QASRS, soil samples are sent to AFFS Horticulture, laboratories in Indooroopilly to determine if *Pratylenchus vulnus,*
lesion nematode, or *Meloidogyne hapla,* root-knot nematode (RKN), are present. *M. hapla* is considered the most damaging RKN species on strawberry in temperate regions, but other RKN nematode species may be able to limit the production of strawberries in warmer regions. Because of the difficulty in distinguishing between RKN species using visual methods, it is necessary to determine how virulent the different species are on current strawberry varieties.

Three different strawberry varieties were inoculated with the eggs of four species of RKN. The reproduction of each species was determined by harvesting the nematode eggs from roots six and twelve weeks after inoculation. Additionally, the roots of eight plants of each cultivar were stained to determine the numbers of each nematode species that penetrated the roots four weeks after inoculation.

From this limited study it is established that RKN species other than *M. hapla* do reproduce on strawberries. The reproduction of *M. hapla* was not significantly greater than the reproduction of other species of RKN on strawberry roots. One cultivar, Joy, showed susceptibility to three of the four *Meloidogyne* spp. The testing for all species of RKN in the QASRS may be warranted given the damage potential of these nematodes on strawberries. Also, further evaluation of strawberry cultivars for resistance to *Meloidogyne* spp. needs to be undertaken as part of an integrated nematode management programme.

A Molecular Study Comparing *Colletotrichum* species from Strawberry and other Fruit and Vegetable Hosts

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Tray-Plant Quality in the Nursery throughout the Autumn Production Period

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Flower induction and formation and growth and development of the plant are dynamically linked in relation to forcing practices. Therefore, any index of plant quality from the nursery must be able to summarize the plant status and its potential use in different cultivation systems. The objective of the present work was to study flower formation and plant growth dynamics, through the architectural evolution in strawberry tray-plants, estimating their productive potential along the propagation phase.

In August, 250 homogeneous stolon plants of 'Gariguette' were rooted in plastic pots as for tray-plants, and grown under natural conditions. Vegetative growth and flower formation were checked in the period between September and December on seven dates. On each sampling date, one half of the plants was dissected and observed under a stereo microscope. The second group of plants on each date was placed in green house with long day and high temperature, to stimulate plant growth without further flower induction.

The inflorescence primordium was visible at the beginning of October, and it was developing to the stage of anther after the second week of November. Then axillary meristems produced new buds, which slowly grew and differentiated into flowers, reaching the stage of 'petal initiated' at the beginning of December. The inflorescence was strictly terminal, and when the tray-plants were forced, the vegetative growth was restored by the axillary bud immediately below the inflorescence, which was the origin of the extension crown, and rarely by other lateral basal buds. Finally, plant quality was strictly related to inflorescence status (number of flowers and flower stage), number of lateral vegetative buds, and satisfactory chilling.

Architecture of Strawberry Plants, cv. Camarosa, Propagated in a Nursery at High Altitude

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The strawberry plant shows high plasticity, and may fit a wide range of environmental and forcing conditions. In mild winter cultivation, the adapted varieties have a particularly low chilling requirement, and do not experience any prolonged vegetative stasis, such as dormancy. Their reproductive and vegetative behaviour confirms that new lateral shoots originate in stolon plants only late after the primary inflorescence is well differentiated. Therefore, the climatic conditions in the nursery are really effective in determining plant quality. In September, when the day-length is decreasing in the highlands of Central Italy (760 m a.s.l.), day temperature is still optimal, but during the night it is gradually dropping below 7°C. These conditions induce flower formation in the terminal apex, without determining lateral shoot growth.

The present work analysed the architecture of stolon plants, cv. Camarosa, produced in the Central Highlands, dug at the beginning of October, and bare-root planted at two sites in the south of Italy that are characterised by mild winters, to obtain out-of-season production. The autumn-winter growth of strawberries under plastic tunnels in the south was investigated by conducting destructive architectural analysis and compared that to growth in a controlled growth chamber with long days. The architectural analysis has allowed us to underline that flower differentiation continued in the new buds of increasing order, formed after planting. This type of growth may induce a scalar maturation that lasts for 3 months, because of the scalarity inside the primary inflorescence, and that among the inflorescences of new lateral buds formed after planting.

Fungicide screening for control of symptomless infections of Colletotrichum gloeosporioides in strawberry petioles

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Colletotrichum crown and stolon rot caused by *Colletotrichum gloeosporioides*, was first observed as a serious problem in Australian strawberries in 1989 and 1990 in the Queensland Approved Runner Scheme production area at Crows Nest. Losses also occurred in commercial strawberry fields during 1991-1993. Colletotrichum crown rot in fruit production areas was confused with a serious physiological problem during establishment. These were dry years and damage was limited to stolon and petiole rots in the nursery, which was then located at Stanthorpe. Regular fungicide application did not control the problem adequately.

Runner bed fungicide screening trials conducted at Maroochy Research Station in 1993 and 1994, showed that Octave ® [prochloraz (472g/kg)] at 200g/100L, substantially reduced the incidence and hence the recovery of *C. gloeosporioides* from symptomless infected petioles, giving excellent and highly reliable control. Subsequent *in vivo* tests using symptomless petioles with known high levels of *C.g.* infection supported the findings of the field trial. This method is a simple and reliable way of screening and identifying alternative fungicides for use in a resistant management strategy with prochloraz. This paper outlines the simple *in vivo* test and presents the results of the field and *in vivo* trials.

Influence of Micropropagated Material on the Production of Strawberry Runner Plants, Yield and Yield Quality

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Micropropagation methods have become a successful tool in propagation of pathogen-free strawberry mother plants all over the world. However, some problems still remain unsolved. While in many cases, no differences in total fruit production or fruit quality have been found between the progeny of the micropropagated plants and those obtained conventionally, in other cases, the latter performed better in the field. Therefore, there is a special need to study and optimise the number of subcultures in strawberry micropropagation, which would guarantee stable, high yielding offspring in the field.

Microshoots of three cultivars, Jonsok, Bounty, Senga Sengana, were introduced into tissue culture in four different years. Microshoots were cultivated either on high salt, or on low salt concentration medium for 6-28 subcultures. High salt concentration medium caused active proliferation, but the shoots remained too short for rooting, and the level of vitrification was high. At the low salt concentration, the proliferation rate was lower, but shoots elongated enough for successful rooting.

Micropropagated (MP) plants of a number of subcultures (tissue culture establishment year 1996, 1997, 1998 and 2000), and origin (EVIKA, Swedish and OÜ Mikrotaim), were evaluated in a field experiment conducted in south Estonia in 2001–2003. Younger mericlones where characterized by higher runner production rates than the older ones. The plants of cv. Jonsok produced numerous runner plants in all variants. The number of runner plants produced by the youngest mericlones in the experiment of cvs. Senga Sengana and Bounty was significantly higher than that of the older mericlones, MP plants of Swedish origin, or Senga Sengana MP plants of the OÜ Mikrotaim mericlone. Significantly higher yield compared to the control was obtained on Swedish mericlone of 'Senga Sengana'. The number of subcultures (age of mericlone) did not affect the yield production, the volume of berries, nor the amount of marketable berries from the total berry production.

Evaluation of strawberry nursery manage techniques to improve the quality of the plants

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Good quality plants is one of the most important aspects of strawberry production. In order to improve the quality of the plants to be harvested from a Gariguette nursery two treatments were performed. In one set of plants the mother plants were eliminated when the runners already covered all the inter row space.

When all the space between the rows was covered with runners, leaves from mother plants were cut , mother plants were eliminated and no treatment was done to mother plants. Crown diameter, root length, percent of commercial plants and starch concentration in the harvested plants was evaluated. Significant differences were observed between the witness treatment and the cut leaves treatment for the number of commercial plants produced, and also significant differences were obtained between the eliminated mother plant treatment and the witness treatment for the starch concentration of the plants produced. Better results were observed in the treatments that either cut leaves or eliminate the mother plants.

Strawberry Runner Suppression with Prohexadione-Ca

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Balancing vegetative growth with fruiting is a primary concern in strawberry fruit production. In many situations, vegetative growth control can be accomplished by cultural methods, including selection of nursery location, digging date, and duration of cold storage of the bare-root nursery plants. Where the use of these conditioned nursery plants is not an option, runnering can be excessive, and may require hand removal. The gibberellin inhibitor prohexadione-Ca (commercial formulation Apogee®) was tested over two seasons for suppression of autumn runnering of 'Chandler' plug plants in a cold-climate annual hill production system. Prohexadione-Ca was applied as a foliar spray at active ingredient concentrations ranging from 60 to 480 mg per liter, either as a single application, or repeated at 3-week intervals. The lowest rate resulted in inadequate runner control, with some runners producing malformed daughter plants. Higher rates resulted in 57 to 93% reductions in fall runner numbers, with a concomitant increase in branch crown formation. There were no affects of the prohexadione-Ca treatments on plant morphology the following spring, and no adverse effects on fruit characteristics or yield.

Nitrogen Requirements of Drip Irrigated Strawberries Grown in Subtropical Environments

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A series of fertilization experiments was carried out in a subtropical environment of northwestern Argentina (province of Tucuman, 27°04'S-65°25'E). An optimum range of nitrogen (N) rates was determined for strawberries, which were grown in a winter-spring production system. One study was conducted in 1999 on varieties such as Camarosa, Cartuno, Chandler, Rosa Linda, Sweet Charlie and Tudla Milsei. Two studies were conducted in 2000 on Camarosa, Sweet Charlie and Tudla Milsei. A fourth trial was run in 2001 on Camarosa and Tudla Milsei. Fresh-dug strawberry transplants were used in all the experiments. Cropping beds consisted of drip-irrigated raised beds, covered with black polyethylene mulch. Data show that optimum N application rates for strawberries are within a range of 135 and 155 $UF.ha^{-1}$. These results have both practical and environmental implications.

Strawberry lethal yellows in Australia: alternative hosts and vector studies

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Strawberry lethal yellows (SLY) consistently infects strawberry runners grown on the Granite Belt in Queensland. Although average annual incidence in fruit crops is less than 1%, individual growers have recorded higher levels in some years, especially in 2004. We have found that the phytoplasma, *Candidatus Phytoplasma australiense*, and a Rickettsia-like organism are associated alone or in combination with typical lethal yellows symptoms in strawberries. In 2004 an atypical symptom, which has not been attributed to either of these organisms, was expressed in cv. Rubygem. Both organisms have also been found in other plant species, but the identity of the insect vector has not yet been confirmed. Numerous leafhopper species including *Orosius argentatus*, a known vector of other plant diseases, have been collected from weed hosts growing near strawberry runner beds. Transmission experiments with *Orosius argentatus* have so far proved inconclusive, but recent experience has been that when the population of *Orosius argentatus* on weeds has been low, SLY incidence in strawberries has remained low. When the leafhopper population has been high as it was in 2004, SLY incidence was high.

Runner Certification and Virus Elimination in Commercial Strawberry Cultivars

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An extensive strawberry virus indexing program run by Crop Health Services (CHS) (Department of Primary Industries, Knoxfield) provides runner certification to the Australian strawberry runner industry on an annual basis. Biological indexing, by petiole grafting onto sensitive indicator species, is the basis of the certification program. The grafting assay reliably detects Strawberry mottle virus (SmoV), Strawberry crinkle virus (SCV), Strawberry mild yellow edge virus (SMYEV), Strawberry vein banding virus (SVBV), Tobacco streak virus (TSV), and Pallidosis. Confirmatory testing for Strawberry mild yellow edge potexvirus is also done, using enzyme linked immunosorbent assay (ELISA). The runners are indexed for the fungal diseases caused by *Phytophthora*, *Verticillium* and *Gnomonia comari* (leaf blotch), and are monitored for the presence of phytoplasma and bacteria.

Elimination of viruses from strawberries is achieved through thermotherapy in combination with regeneration of meristems, using tissue culture techniques. Tissue culture also provides a rapid clonal multiplication method, reducing the time to planting of large numbers of runners in the field. The CHS tissue culture laboratory is an AQIS (Australian Quarantine Inspection Service) accredited facility for the tissue culture multiplication of imported strawberry plants while under Post Entry Quarantine conditions.

The use of hot water treatment to eliminate *Colletotrichum acutatum* from strawberry runner cuttings.

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Runner cuttings were taken from three cultivars, Elsanta, Florence and Symphony, and subjected to hot water treatments. The cuttings were immersed in a pre-warming tank at 35°C for 3-7 minutes, followed by a hot water tank at 50°C for 2-5 minutes. The cuttings were then rooted into peat in modular cells under mist irrigation. Leaf appearance was recorded every four days, and after 32 days, fresh root weight was recorded. Survival and vigour was reduced with increasing immersion time at 50°C, and was also cultivar dependent. Some treatments involving immersion at 50°C for either 2 or 3 minutes gave good survival with acceptable vigour and root growth.

In separate experiments, runner cuttings were taken from mother plants that had been deliberately infected with *Colletotrichum acutatum*. These were immersed for 7 minutes at 35°C, followed by 2 or 3 minutes at 50°C. Both treatments were successful in reducing the proportion of cuttings infected with *C. acutatum* from above 80% in the controls, to between 6% and 17%.

Correlation of the Plant Harvest Index with morphological and physiological aspects of nutrition with NPK in strawberry (*Fragaria* x *ananassa* Duch.) plants, cv. Camarosa, in the highland nursery

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Correlation of Plant Harvest Index (PHI) with morphological and physiological aspects of the nutrition with NPK in strawberry fresh plants, cv. Camarosa, in the highland nursery between 2002/03, were studied. The nursery was fertilized with different levels of NPK: 1: Control 2:100 kg N/ha 3:100 kg N/ha and 90 kgP/ha 4:100 kg N/ha and 150 kg K/ha. 5:100 kg N/ha, 90 kg P/ha, 150 kg K/ha 6:54 kg N/ha and 190 kg P/ha 7:50 kg N/ha. The correlations of PHI of fresh daughter plants with bud, root length, crown size, petiole length, leaf number per plant, dry matter content of crown plus root, and leaf, bud blossom and crown number per plant, and Leaf Area Index (LAI), were evaluated. A descriptive correlations analysis was made of PHI with total N content (%) in petioles, and P and K content (%) in leaf at harvest. It was found that the PHI was positively correlated with bud leaf (0.807), root length (0.675), crown diameter (0.9659), petiol length (0.9), leaf number per plant (0.884), dry matter content of crown plus root (0.933), dry matter content of leaf (0.865), bud blossom (0.675) and crown number per plant (0.622), and was negatively correlated with the LAI (-0.4669). The PHI was correlated inversely with N (-0.27), P(-0.7) and a direct association with K (0.1) was found.

These results revealed that nutrition with NPK has an important role in morphological and physiological changes related to the quality of the fresh plant, measured through their correlations with the Plant Harvest Index. NPK nutrition has a decisive role in the increase of dry matter content in plants when they are dormant.

Evaluation of Phytosanitary Status of Cold-Stored Runner Plants of Strawberry in Basilicata (Southern Italy).

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The Basilicata region (Southern Italy) is one of major strawberry-growing areas of Europe. Over 600 ha of strawberry are cultivated under plastic tunnels using mainly cold-stored runner plants which are either produced in Italy or imported from other countries.

In order to assess the health status of cold-stored runner plants to be used for 2002 plantings a survey was carried out by extensive visual inspections and isolation of fungal pathogens by laboratory methods, *i.e*, isolation on suitable media and microscopic examinations, using thawed plant material. Particular emphasis was given to the presence of injuries due to by excessively low temperatures during storage and phytopathogenic fungi, including chromista, listed as quarantine pests. Furthermore, cold-stored runners were examined for *Phytophthora* infections employing polymerase chain reaction (PCR) assays.

A total of 3.000 cold-stored runner plants originating from several nurseryes and belonging to seven different cultivars were examined for injuries due to excess of low temperatures during storage. The injury severity was evaluated according to the Mac Kinney index which, varied from 0.09 to 1.53. Injuries observed appeared not variety-specific and varied considerably according to the plant nurseries that provided the plants. Detection and identification of fungal or chromista pathogens by classical and molecular methods revealed the presence of fungi belonging to ten different genus represented mainly by *Cadophora*, *Fusarium* and *Rhizoctonia*. The occurrence of *Phytophthora* infections was observed only with a high sensitive nested PCR assay. Using universal and specie-specific fungal primers and RFLP analysis with suitable restriction endonucleases, 30 out of 70 examined runner plants proved to be infected with *Phytophthora cactorum*. Among the 30 *phytophthora* positive plants, 10 plants showed no symptoms. Data obtained did not reveal phytopathogenic chromista fungi (e. g. *Phytophthora fragariae*) listed as quarantine in Europe.

Cryopreservation of in Vitro Cultured Shoot Tips of Strawberry

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The shoot tips of in vitro cultured strawberry were successfully cryopreserved. Excised shoot tips were pre-cultured for 12 days on solid MS medium with 2% DMSO. They were first treated at room temperature for 20 min, with a less toxic solution that contained 20% glycerol and 0.4M sucrose (pH 6.0), and pretreated in PVS, which contains 35% glycerol and 20% ethylene glycol, in the liquid MS medium containing 0.6M sucrose (pH 6.0) at 4°C for 50 min, before being immersed in liquid nitrogen. After
1 min warming at 40°C, shoot tips were rinsed for 30 min with liquid MS medium containing 1.2M sucrose, and transferred onto MS medium supplemented with BA 0.4mg/L, NAA 0.05mg/L, and GA 0.15 mg/L. The survival and regeneration rate of shoot tips was 82.4% and 77.8% respectively. This is the first report on the cryopreservation of strawberry using a one step vitrification procedure.

The Effect of Propagule on Yield of Day-Neutral Varieties in the UK: Bare Root Plants *versus* Misted tips

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The aim of this investigation was determine whether misted tip (MT) plants of day-neutral strawberries produce higher yields than either bare root (BR) or potted bare root (PBR) production types. Yields of the three propagule types of the varieties 'Everest', 'Diamante', 'Bolero' and 'Flamenco' were compared, but only 'Everest' and 'Diamante' were analysed over a two year period from 2002-2003. Plants were planted in a raised bed system with fertigation. It was shown that 'Everest' and 'Diamante' MT plants yielded significantly higher and earlier than when the PBR production system was used.

Effect of micro propagation on health status of strawberry planting material for commercial production of Strawberry runners for Queensland

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Plant tissue culture has been used for a number of years to produce micro-propagated strawberry plants for planting into the runner growing beds in the Stanthorpe (Queensland) and Bothwell (Tasmania) regions. This process has allowed for rapid release of new cultivars, from the LAWS (Late Autumn, Winter, Spring) breeding program, into the current runner production system. Micro-propagation *in vitro* allows plants to be produced during the autumn and winter months, when plants are normally in a fruit production phase in the field. The plants produced are of a high health status. The arrival and build up of various diseases in the runner field populations is then closely monitored. Using tissue culture for the first generation reduces the time the plants spend in the field by twelve months thus also reducing the potential for disease build up. To date, any disease out break has been successfully managed using early detection and rapid response methods.

The Effect of Irrigation Method on the Quality and Shelf-life of Strawberry Fruit in Organic Production

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Organic production of strawberry was investigated at MTT Agrifood Research, Finland, during 2000-2002. Research topics included irrigation method, and its effect on fruit quality. Organically produced cultivars 'Jonsok' and 'Bounty', were planted into black plastic mulch in double rows, and the field was divided into two areas: drip irrigation and no drip irrigation after the start of flowering. Half of the area without drip irrigation was irrigated with sprinklers, and the other half was left with natural rain only. Drip irrigation, and in 2002, sprinkler irrigation, was applied according to tensiometer measurements. No fungicides or organic products were used to control grey mould and other diseases. One plot of both 'Jonsok' and 'Bounty' was covered with a small open plastic tunnel from the beginning of flowering to the end of harvest, to investigate grey mould infection in a covered crop.

Fruit was harvested three times a week. To determine the shelf-life of the fruit, 40 berries of marketable quality were placed in plastic 'Jiffy pots' on trays, and covered with moist tissue paper. The trays were stored at room temperature, in black plastic bags. The amount of grey mould on fruit was quite low in 2001 on both cultivars. Drip irrigation did not reduce grey mould in the harvested fruit in 2001 in 'Jonsok', and in 2002, it seemed to increase the amount of infested fruit compared to sprinkler irrigation. 'Bounty' showed minor reduction of grey mould in 2001. The fruit from plots covered with plastic tunnels showed a very low grey mould infestation rate.

The shelf-life of strawberry fruit at room temperature was dependent on the weather conditions during harvest. In general, 'Jonsok' had a shorter shelf-life than 'Bounty', and the shelf-life was longest for the fruit from plastic tunnels. The irrigation method did not affect either the shelf-life or the quality of fruit. Strawberry varieties differ from each other in disease susceptibility, and the quality and shelf-life of the fruit is affected more by their properties and weather conditions, than by the irrigation method.

Evaluation of cold store strawberry plant quality, according to different postharvest treatments

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Chile has advantages for the establishment of good quality strawberry nurseries. A broad spectrum of latitudes and altitudes allows plants to accomplish cold temperature requirements, and geographical isolation facilitates the production of plants free of the main pest and diseases. Because of this, Chile has good prospects for the production of strawberry plants for export to the main producing countries.

The objective of the present study was to determine the effect of washing the plants, the optimization of the package, and the storage temperature related to the preservation of the starch content of cold stored strawberry plants. Strawberry plants of cv. Pajaro, grown in a nursery located in Los Angeles (Region VIII – Chile), were used.

Plants were subjected to the following postharvest treatments: Wash plus fungicide or a 'no wash' treatment, bagged with common bags or with gas proof bags, and with 2°C pre-storage treatment or without pre-storage treatment. Plants were stored at –2°C for 20, 40, 80, and 160 days.

After evaluating the treatments it was determined that a wash treatment prior to cold storage affected the starch content and establishment success, negatively. Plants maintained in common bags gave better results than those kept in gas proof bags, due to high levels of CO_2 that developed inside the bags. A 2°C pre-storage treatment showed no positive effect.

Post-harvest quality and shelf-life of fruits of strawberry varieties

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In the years 2001 and 2002, fruit of 18 strawberry varieties were picked commercially mature, and stored for 72 hours at 4.5°C, followed by 24 hours at 22°C. Fruit from the beginning of the harvest and that from the mid-crop were selected for quality measurements. Calyx freshness, predominant fruit colour, brightness, internal colour, uniformity of internal colour, and size of internal cavity were assessed before and after storage. Soluble solids (TSS) and acidity (TA) were also measured. Additionally, at harvest time, fruit firmness and taste were evaluated. Resistance to bruising and to fruit rot wase estimated. In the experiment, 'Senga Sengana' and 'Elsanta' were used as standards varieties.

Quality parameters (TSS, TA) depended on the vegetative season, variety and harvest date (beginning of harvest, and mid-crop). The highest TSS/TA ratio was found for 'Gaviota', 'Carisma' and 'Vima Zanta', and the lowest for 'Maya'. Fruits of 'Filon' rated the poorest in the taste test. Fruits of 'Onda', 'Paros', 'Elsanta' and 'Kimberly' were the most resistant to bruising and rotting. The freshness of the calyx and brightness of fruits depended on the vegetative season and harvest date. The majority of tested varieties exhibited better shelf-life than the standards.

The Estimation of Different Strawberry Cultivars for Chemical Composition and Processing

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Traditionally the assortment of strawberry cultivars grown in Latvia is quite wide. The aim of this study was to find out which strawberry cultivars grown in Latvia are the most appropriate for freezing and processing in jam and to estimate their chemical composition. 20 strawberry cultivars were tested during 2000-2002. Easiness of calyx removal, strawberry chemical content, including soluble solids, titrable acidity, ascorbic acid, pH, total sugars and sensory properties as flavour, attractiveness, odour, firmness and consistence, clarity and viscosity (only for jam) were determined. 'Senga Sengana', Eldorado', 'Korona' and 'Bounty' were the most suitable for freezing between tested cultivars. No one of tested cultivars showed better suitability for processing in jam as cultivar 'Senga Sengana', which is still dominant cultivar for processing industry in Europe. Rather good results were obtained also from cultivars 'Rubinovii Kulon', 'Jonsok' and 'Pandora'. The most inappropriate for processing were cultivars 'Prisvyata', 'Zefyr' and 'Tenira'.

The effect of chitosan coating and calcium chloride treatment on postharvest qualities of strawberry fruits (*Fragaria X ananassa*)

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The effect of chitosan coating and calcium chloride treatment on the postharvest qualities of strawberry fruit (*Fragaria X ananassa*) of the cultivars Prarajathan Nos. 50, 70 and 72, were studied. Strawberry fruits were dipped in the solution of high molecular weight chitosan (0.25% and 0.5%), low molecular weight chitosan extracted from crab (0.5% and 1%) and shrimp (0.5% and 1%), and calcium chloride (2% and 4%). Treated strawberry fruits were then dried at room temperature for 5 min., packed in a tray, wrapped with PVC, and stored at 0°C. The postharvest qualities were determined after a 4 day interval. Strawberry fruit treated with chitosan and calcium chloride before cold temperature storage showed no effect on physico-chemical properties i.e. there were no significant differences in respect of of firmness, titratable acidity, total soluble solids, ratio of soluble solids and titratable acidity, and peel colour, compared with the control after 16 days' storage. A reduction in vitamin C and phenolic content was detected in strawberry No. 70 after 4 days, whereas this occurred at 8 days in No. 50 and No.72. It can be concluded that treatment of strawberry with chitosan and calcium chloride can delay fruit decay of No. 70 for 4 days and No. 50 and No. 72 for 8 days, after cold storage. In addition, the extent of fungal infection was reduced for storage times of up to 16 days.

Effect of calcium chloride on the shelf life of strawberry cv. Oso Grande.

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The present studies were conducted at CCS Haryana Agricultural University, Hisar, situated 160Km. west of New Delhi (India). The fruits were harvested at 75 per cent colour development, and were dipped in $CaCl_2$@ 0.5%, 1.0% & 1.5%, for 15 min. at 45°C. The treated fruits were kept at 4°C for one day and were then stored at room temperature in 250g punnets. The $CaCl_2$ treatments reduced the physiological weight and decay loss. Better firmness was retained in $CaCl_2$ treated fruits during storage compared to the control. The decay losses were 7.78% in $CaCl_2$ treated fruits 25.26 % after 4 days of storage.

The shelf life of Californian strawberries under different storage conditions in north India.

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The present studies were conducted at CCS Haryana Agricultural University, Hisar, situated at 160Km. west of New Delhi (India). The fruits of four strawberry cultivars, 'Camarosa', 'Chandler', 'Oso Grande' and 'Selva' were harvested at 75 per cent colour development and stored at 4°C, as well as at room temperature. The physiological loss in weight was significantly lower in cv. Camarosa (9.59%), after 6 days of storage at room temperature, whereas similar weight loss was recorded after 9 days at 4°C. The decay losses were higher at room temperature, and cv. Camarosa could be stored for 12 days at low temperature. The highest TSS was recorded in 'Camarosa' after 2 days of storage at room temperature, and after 6 days at 4°C. The acidity was reduced with the increase in storage period; cvs. Camarosa and Chandler had higher acidity than the other two cultivars.

Analysis of Aromatic Volatile Compounds in 'Toyonoka' Strawberry Using the Porapak Q Column Extraction Method

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The simultaneous distillation extraction method (SDEM) is commonly used to extract large amounts of volatile compounds in fruits. Recently, we have reported the Porapak Q column extraction method (PQM) is useful for extracting the volatile compounds in melon fruit. So, to evaluate the effectiveness of PQM for analyzing the aroma compounds in 'Toyonoka' strawberry, we compared it with SDEM. Fifty-two aroma compounds were detected in the extract with PQM, but only 46 compounds with SDEM. The recovery rates of medium and high boiling-point compounds were higher with the PQM, especially 2,5-dimethyl-4-hydroxy-3(*2H*)furanone. The average coefficients of variation of the compounds were 11.3% and 19.6 % using PQM and SDEM, respectively. The odour of concentrates from PQM was similar to the natural aroma of strawberry, but the extract from SDEM was like a heated odour. Almost 100 % of the absorbed volatile compounds eluted in Porapok Q after two washes of 50 ml diethyl ether. Therefore, we concluded that PQM is an excellent method for extracting aroma compounds of strawberry because it is quick and easy to operate, capable of recovering a wide range of boiling-point volatile compounds without heating, and is highly reproducible.

Analytical and sensory evaluation of two strawberries cvs to improve the market acceptability

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Previous sensory evaluation in strawberries has shown that consumer preferences are most related (90%) to sweetness and aroma of fruits. A research on two strawberries cvs grown in two different areas of North Italy was carried out for three years. Fruits were evaluated with objective methods measuring colour, firmness, soluble solids, total acidity and ascorbic acid content at the harvest for each production areas. A storability evaluation was also made measuring % of weight loss, % of healty and decayed fruit and freshness after 3 days at 4°C plus 1 day at room temperature.

Sensory analyses were made both at the harvest and after storage by means of triangle test and by quantitative descriptive analysis to demonstrate the differences between the two cvs.
Results showed that cvs were different for firmness and sweetness and sensory profile confirmed those differences.

Furthermore volatile aroma substances, by means of dynamic headspace on cut fuits, were determined by GC-MS and by GC-olfactometry. The various odorous substances in the olfactometry analysis were judged on the basis of 20 smelling descriptors and on the basis of intensity scale (1-3). The most perceived odors substances were methyl butanoate, ethyl butanoate, ethyl hexanoate, linalool and y-decalacton.

Quality Postharvest Evaluation of Strawberry in Italy

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A National project of strawberry evaluation in experimental field is running since ten years. The aim of this program is to draw up a list of recommended cultivars suitable for different growing areas. National and foreign cultivars have been checked at least for two years both for agronomic characters and postharvest quality including the sensory characterization and, have undergone a short storability to simulate the trade channel.

Strawberry fruit quality: biochemical and molecular aspects

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"Qualifrape" is a project funded by the Italian Ministry of Agriculture and Ministry of Education and Scientific Research, with the aim of studying the molecular aspect of fruit quality. Genetic characterization and expression studies were carried out in the present work.

One hundred simple sequences repeat (SSR) markers were obtained from 270 DNA sequences containing AC-type SSRs. The cultivars 'Queen Elisa' and its maternal parent 'Miss', were chosen to detect more accurately the DNA marker length polymorphisms obtained from 20 pairs of primers, through the use of an Amersham Biosciences capillary sequencer. The SSR markers were developed with the aim of producing a linkage map, but were also tested for cultivar fingerprinting. In the second study, we analysed 3161 expressed sequences tags (ESTs) amplified from a fruit cDNA library from cv Queen Elisa. Over 1800 ESTs and candidate genes involved in fruit ripening, were used to produce cDNA microarrays to carry out comparative profiling experiments with genotypes having different fruit quality. Given its outstanding fruit quality, cv Queen Elisa was used as the control genotype in microarray experiments, and compared with each of its parents (cv Miss, sel. USB35). Differential expression of a limited number of genes involved in major fruit quality traits such as firmness and aroma biogenesis, was found. These results are in agreement with phenotypical differences among genotypes recorded in field trials.

Partnerships between Strawberry Industry, Market Development and Research Agencies

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Development of partnerships between strawberry growers, market development groups and research agencies is integral to industry development. Industry strategic planning involving these three groups working in association with an examination of all aspects affecting the supply chain, from plant selection to consumer attitudes, alerts the industry to existing and potential issues that will require resolution in forward planning. This enables the industry to become outcome focussed.

Such interaction determines the real issues and research priorities, and forms the basis for the setting of research priorities for the industry, with better funding.

Evaluation of strategies to commercialise new strawberry cultivars in Western Australia

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Strawberries underwent a transformation from a luxury fruit available seasonally, to a mainstream commodity available year-round, in the Australian market in the late 1980s. The transformation, which stimulated spectacular industry growth and consumer interest in strawberries, was largely the consequence of the introduction of a range of new cultivars bred in California, and sold in Australia under licence. Cultivars that proved to be well adapted to Western Australian conditions were Pajaro and Chandler, while the day neutral cultivar, Selva, performed well throughout the nation and revolutionised strawberry seasonal supply by making strawberries widely available in summer.

Despite the success of these cultivars, the principle of being totally dependent on imported germplasm made many leaders in the industry uneasy, and this led to the commencement of two breeding programmes in Australia in the early 1990s. Western Australia has collaborated with the temperate programme continuously since its inception, as a regional selection site.

Many new named cultivars from overseas, as well as Australian bred selections, have been evaluated since Chandler, in a formal way as part of the programme, and informally, by growers. Few cultivars of overseas origin have achieved enduring success in the market place, and none of those bred in Australia has done so. This paper examines our experiences in testing a range of strategies to commercialise a selection first identified in Western Australia in 1998 and later named Kiewa, compared to adoption of cultivars bred in California, which became available at the same time.

Seven-year work on alternatives to Methyl Bromide (MB) for strawberry production in Huelva (Spain)

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The National Project INIA has been carrying out seven-year experiments in the area of Huelva, to find short-term alternatives to MB for strawberry production. In 1997-2001, more than 25 soil fumigant treatments were tested in strawberry cv. 'Camarosa', under small plastic tunnels. The four-year results supported technically and economically feasible alternatives to MB in 1,3 dichloropropene+chloropicrin (1,3D+pic), chloropicrin alone (pic alone), Dazomet, soil solarization with shank-application of Metham Sodium (Sol.+MS), and biofumigation (Sol.+Biof.). In 2002-2004, the most promising MB alternatives have been used in field-scale demonstrations in several locations of Huelva, using the same cultivar under standard large plastic tunnels. The three-year results showed very similar yields to MB in the case of 1,3D+pic, and pic alone; but Dazomet, Sol.+MS and Sol.+Biof. gave poorer results. In 2003-2004, a series of experiments with new chemical alternatives to MB (DMDS, propylene oxide, calcium cyanamide) under LDPE and VIF films, has been initiated in two locations. Several of these MB alternatives could provide a short-term solution to the MB ban in strawberry cultivation. However, aspects concerning registration, environmental safety, EU policy on future agro-chemicals, utilization etc., remain unresolved. Applications for MB critical use exemption in 2005 are underway.

Solarization as an alternative method to soil disinfestation with methyl bromide for strawberry production

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The soil fumigant, methyl bromide, has been used for eliminating plant diseases, nematodes and weeds for many years. However, it has been demonstrated that methyl bromide is an ozone depletory, which can also cause severe damage to humans, and contaminate soil and water. The coming ban on methyl bromide use in 2005, has stimulated research to develop alternatives to this widely used compound. Solarization, by covering the soil with polyethylene films, is increasingly adopted as an effective method of soil disinfestation for horticultural crops. The aim of this work was to compare the effects of soil solarization and methyl bromide soil fumigation on strawberries grown under plastic tunnels in Sicily (Italy). The experiment was carried out for four years. Strawberry fresh plants obtained by rooting runner tips in polystyrene trays, were transplanted in September. Tunnels were covered in October with transparent PE. There was no difference in early yield between solarized and fumigated soil. Total yield for solarized soil was greater than fumigated soil and the control. Being an environmentally friendly technique, solarization will assume a predominant role as a soil disinfestation method in locations that have a hot summer.

Factors that Impact on the Ability of Biofumigants to Suppress Fungal Pathogens and Weeds of Strawberry

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Biofumigation refers to the suppression of soil-borne pathogens, weeds and pests, using volatile allelochemicals (isothiocyanates, ITCs) released from damaged *Brassica* tissues. Our research aimed at tailoring biofumigation to fit strawberry production systems, and examined the factors that influence their ability to suppress strawberry pathogens and weeds.

In vitro trials showed that macerated root tissues from a *B. napus* / *B. campestris* biofumigant mix were six times more effective at suppressing the strawberry pathogen, *Rhizoctonia fragariae*, than was shoot tissue. Further, the biofumigant mix was more toxic to *R. fragariae* at maturity than at emergence. These results agreed with those from a pot trial, which showed that roots from mature biofumigants released a greater quantity and diversity of ITCs into soils than did their shoots. Separate *in vitro* trials showed that the biofumigant mix suppressed a wide variety of soil-borne pathogens of strawberry, including *Alternaria alternata*, *Colletotrichum dematium*, *Cylindrocarpon destructans*, *Fusarium oxysporum*, *Phythophthora cactorum*, *Pythium ultimum*, and *R. fragariae*. Additionally, the biofumigant mix killed germinating *Trifolium* weeds and reduced the early vigour of surviving seedlings, although early competitiveness of these seedlings was unaffected. The degree that biofumigants suppressed *Trifolium* germination did not relate to seed size, but might relate to their hard-seededness.

In the field, the impact of biofumigants on strawberry pathogens and weeds was less than in the laboratory or glasshouse. Rotary incorporation of the biofumigant mix into field soils did not produce detectable levels of ITCs or reduce the survival of buried inoculum of *P. cactorum* or *C. destructans*. Yet it suppressed weed re-emergence by 30%, suggesting that allelochemicals other than ITCs might also play a role in biofumigation. The key to improving the efficacy of biofumigant crops in the field seems to lie in the development of application techniques that can macerate and incorporate plant material more evenly than is possible with rotary incorporation. Strawberry growers in Australia have begun to include biofumigants in their cropping rotations as cover crops ,despite their limitations, to increase soil organic matter in addition to the added benefit of possible biocidal effects.

Testing alternatives to methyl bromide in sub tropical strawberries

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Methyl bromide (MB) and its mixtures with chloropicrin (CP) have been used by the Queensland strawberry industry to fumigate runner nurseries and fruiting fields since 1981. The ongoing benefits in the control of soil-borne diseases and weeds, along with its plant growth promotion effect, established MB as an important management tool for up to seventy percent of the Queensland strawberry growing area. The impending MB phase-out in January 2005 required that alternative technologies including fumigants, soil ameliorants and alternative production systems, be tested. This paper reports on experiments that compared the efficacy of some alternative fumigants, soil ameliorants and soil solarisation options.

When compared to untreated controls, Telone C35 (TC35) was as effective as MB+CP mixtures in increasing yield or enhancing control of crown rot, *Macrophomina phaseoli*, and Fusarium wilt, *Fusarium oxysporum* f. sp. *fragariae*. Soil solarisation with plastic being laid in December or January was also effective. The use of metham sodium and metham potassium generally did not result in increased yields or enhanced disease control. Dazomet and calcium cyanamide had some yield benefits, but their use was not pursued further because of cost. Mustard meals were largely ineffective.

Issues associated with TC35 as a viable replacement for MB at this time are discussed.

Soil Diseases of Strawberry in Mexico: Their Control with Chemical Fumigants and Solarization

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In Michoacan and Guanajuato states of the central region of México, 4,500 ha of strawberry are harvested every year, under low technical management. Soil diseases are a major phytosanitary problem, causing the death or dwarfism of plants, and lowering yield and fruit quality. In both states, soil diseases are caused by a complex of fungi of which *Fusarium oxysporum* is the most important, with a minor incidence of *Rhizoctonia*, *Verticillium*, *Alternaria* and *Phytophthora*. The main reasons for the incidence of soil diseases are the use of (i) non-treated soils (ii) plots in which strawberry has been cultivated for several years (iii) infested plants and (iv) susceptible varieties. In seventy percent of the cultivated area no soil treatment is applied, and in the Zamora, Michoacan municipality, soils are over-flooded before planting (i.e. they are muddy). This method is not applicable to other growing areas because of the shortage of water.

This region of Mexico has predominantly clay soils and the methodology used in California, U.S.A., for disinfestations, is of no use. For this reason, alternatives have to be evaluated. Methyl bromide (MeB) 98% (250 kg/ha) and the mixture MeB with Chloropicrin 50/50, were effective in loam soils, and better than Basamid and Vorlex. Metham sodium was not effective in both kinds of soil. Solarization of both soil types was as effective as MeB for the control of soil diseases, with an optimum of three months of treatment during the hottest months (May-August), and is an option for minimizing the use of MeB.

Strawberry Production in Soil-less Systems with Slow Sand Filtration.

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Strawberry growers have been heavily dependent on using methyl bromide to control both insect pests and fungal diseases in the soil before planting. The potential loss of this major soil fumigant after 2005, has created a need to search for alternative fumigants, or new and modified production systems such as soil-less growing systems.

Soil-less growing systems are presented as an important alternative, to achieve a more sustainable, efficient and environmentally-friendly growing system for strawberry production. In this research, open and closed systems, with and without slow sand filtration for disinfection of the re-circulated nutrient solution, were evaluated, using coconut fibre as a substrate for two years. Open and closed systems, with or without filtration, were inoculated with *Phytophtora cactorum* and with *Verticillium dahliae* for testing the incidence of those soil diseases in these systems.

Using latent heat of water evaporation to cool culture medium for high-bench strawberry culture

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We designed a system that uses latent heat of water evaporation to cool culture medium in a high-bench culture system for out-of-season production of strawberries. The culture bench was constructed using metal frames and film bags. The film, which contained the culture medium, was composed of two layers; the inner layer was a silver-coloured plastic film, and the outer layer was cotton cloth, and was exposed to the air below the bench. A little water was splashed continuously onto the cotton layer to keep it wet. The water then evaporated because of the heat of the medium, thereby cooling the medium. The temperature of the medium measured at 5 cm below its surface (medium depth was 10 cm), was 5 to 6 °C less than that of the control, which had no cooling system. Moreover, when air circulation was supplied by a fan under the bench, the temperature at 5 cm depth was more than 10 °C less than that of the control. The water supply tube was contained in the frame of the bench to make it a simple structure. We expect that this technique will allow early transplanting around the end of summer.

Effects of K:Ca:Mg ratio on Performance of 'Elsanta' Strawberries Grown on Peat

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Strawberry plants cv. 'Elsanta' were grown in peat under glasshouse conditions. Six K:Ca:Mg ratios (8:1.5:1, 5:3:1, 2:4.5:1, 5:2:2, 5:1:3 and 5:0:4 mmol/l) were continuously applied in the nutrient solution, from planting until end of harvest.
During the first cropping cycle the K:Ca:Mg ratio did not affect fruit number, fruit weight nor total yield. However, during the second cropping, Ca application rates below 2 mmol/l significantly reduced fruit weight, fruit number and total yield (-15 %). Ca deficient plants showed severe burn of runner tips and bursting of stolons, which reduced runner formation by 35 %. With K:Ca:Mg ratios of 5:1:3 and 5:0:4 mmol/l, glossy curd formation with syrupy globs appeared on flower stalks (15 % and 25 % rspectively). Ca deficient fruits were smaller, had dense cover of achenes and a harder texture, and were acid.
There was a significantly higher acidity and sugar content in fruits with a higher K:Ca ratio.
Satisfactory yield and fruit size was obtained with a K:Ca:Mg ratio of 5:3:1.

Effect of Metosulam and Glyphosate on Flower Abnormalities of Strawberry

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The effect of the herbicide, metosulam, on flower phyllody was investigated. After short term cold storage in December, strawberry tray plants, cv. 'Elsanta' and 'Darselect', were established in January in peatbags, under glasshouse conditions. Foliar sprays of metosulam (25 mg/l) were applied 4 weeks after transplanting, when first flower buds emerged. Apparently, the treatment with metosulam at this stage interfered with flower differentiation, and resulted in a partial reversion from reproductive to vegetative development of the flowers. The most characteristic symptom was a pronounced foliaceous growth arising from the achenes, starting at the distal end of the receptacle and progressing towards the calyx. Symptoms were most pronounced in first flower trusses, then gradually disappeared in successive trusses. Metosulam treatment resulted in 32 % and 25% phylloid fruits in 'Elsanta' and 'Darselect' respectively.

In a second experiment, an aqueous solution of glyphosate containing 0.01, 0.1, and 1 mg/l of active constituent was applied to peat, 3 weeks prior to planting. Cold-stored strawberry plants cv. 'Elsanta' were transplanted in mid-July, in containers filled with the treated peat, and cultivated under glasshouse conditions.
At an application rate of 0.1 mg/l, toxicity symptoms became apparent, as plants had shorter petioles, and young leaves showed typical chlorosis. The strawberry plants grown on peat treated with 1 mg/l glyphosate developed needle shaped yellowing leafblades, and produced smaller flowers with short anthers and white pistils. Almost 48% of the flowers developed into abnormal, small globe-shaped berries, while the most severely stunted plants produced some phylloid fruits. The experiment proved that residues of the post-emergent herbicide, glyphosate, in the peat substrate, can readily be translocated from the roots upwards to meristematic tissue, and can adversely influence flower differentiation.

Effects of Sodium on Performance of 'Elsanta' Strawberries Grown on Peat

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In two successive trials, strawberry plants were grown in peat under glasshouse conditions to investigate the effect of Na on the cv. 'Elsanta'. Five concentrations (0.5, 1, 2, 3, 4 and 5 mmol/l) were continuously applied in the nutrient solution, from planting until the end of harvest.
During the first cropping cycle in autumn, Na application did not affect fruit number, fruit weight nor total yield, although above an application rate of 4 mmol Na/l, marginal necrosis was noted. However, during the second cropping cycle, typical marginal necrosis of mature leaves and calyces was already evident at Na application rates above 2 mmol/l, and peat concentrations exceeding 3 mmol/l. Total leaf area, length of petioles and inflorescences, fruit number, fruit size and total yield were reduced significantly with increasing Na application rates. Between-year differences were noted in Na tolerance due to varying climatic conditions. The critical Na value for yield, fruit number and fruit weight ranged between 2 and 3 mmol/l in the nutrient solution, which was correlated with Na concentrations exceeding 4 mmol/l in the peat substrate. Na application increased sugar and acid content, and improved fruit firmness and shelf life.

Critical Level of Potassium for Fruit Development and Yield Response of Substrate Cultured Strawberry

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Balanced nutrient solutions, based on Hoagland solution and modified for plant species or cultural conditions, are usually supplied for substrate cultured crops, including strawberry. Most of such solutions are optimized for hydroponics to keep the composition of major nutrients and pH in the solutions. However, when strawberries were grown on peat-based substrate and with a solution in which the concentration of Ca and Mg was reduced to 50% of a standard solution, no negative effect was observed. Except for N, it may not be necessary to supply nutrients as balanced solutions for strawberries grown on substrates. As K is a nutrient often absorbed luxuriously, it's concentration in the solution may be reduced without negative effects on strawberry production. 'Nyoho' and some other cultivars were planted on peat bags, and modified Hoagland solution (NO_3 8, NH_4 1, P 1, K 4, Ca 2, Mg 1; mM) was supplied after planting in September 2001. K concentration was reduced to 4 (Control), 2, 1, and 0mM, by replacing to Ca on 14 November. Three weeks later, no K was detectable in the drainage except in the control. K concentration in fruits decreased with decreasing concentration of the solutions, but there was little difference in leaf K concentration between 2 and 4mM. No difference was observed in the content and composition of sugars and acids in fruits on the primary inflorescence. However, sugar content in the 5th fruit on the second inflorescence, decreased significantly only in 0mM. When yield response was examined with 4 to 0.5mM of K, total yield and average fruit weight were largest in 2mM of K. The K concentration in Hoagland solution may be supra-optimal, and half of it is sufficient for substrate-grown strawberries.

Strawberry Quality Cultivated in Soil-less Systems.

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Sensorial quality of the fruit defined in terms of visual appearance (form, colour, size), texture, flavour and aroma, is the much appreciated by consumers. However, the nutritional quality and food safety are also of great importance.

The main characteristics related to nutritional quality were investigated in strawberry fruit cultivated in soil-less systems using peat, composted cork and coconut fibre as organic substrates, and disinfecting the leachate by means of a system of slow sand filtration. The concentration of compounds such as organic acids (citric, malic) and soluble sugars (fructose, glucose and sucrose), minerals (calcium, potassium, sodium, magnesium, copper, iron, zinc and manganese) and anions (nitrate, sulphate, phosphate) was obtained using different techniques: HPLC with diode array spectroscopic detection and refractive index detection, atomic spectroscopy, and ionic chromatography. Protein, ash, humidity, acidity, pH, starch and reducing and total sugars, were also determined. The results for all parameters were compared statistically with those from traditional cultivation.

Multivariate statistical techniques will allow an evaluation of whether the chemical composition differed under the different systems or substrates used, as well as to identify the analytical parameters that contribute to the differences among the samples.

Polyethylene bed mulch and yield performance of strawberry in high tunnels in Southern California

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California produces over 20% of the world's strawberry crop, based entirely on the use of outdoor production systems. In 2002 and 2003, we compared strawberry yield performance for plants grown outdoors or in tunnels in southern California. Individual tunnels measured 4.9m wide, 25m long and 3.7m high, and covered three planting beds. Half the plots in each bed received clear polyethylene mulch, while the other half received black polyethylene. Bare-root transplants were planted in early October. Tunnels were covered with 0.015-cm thick polyethylene on November 16, 2001 and December 2, 2002, and tunnel sides were left open to a height of 1.2 m. In both years, fruit were harvested 1-2 times weekly from mid-December through April 1.

Use of tunnels resulted in higher air and soil temperatures compared to outdoor plots. For both years and both mulch treatments, tunnels resulted in enhanced yield compared to outdoor plots. Regardless of tunnel treatment, use of clear mulch resulted in greater soil temperature and greater yield compared to black mulch. For tunnels, yields to 1 March ranged from 167% to 217%, and from 127% to 175% of that of outdoor treatments, in 2002 and 2003, respectively. Total yields in tunnels ranged from 155% to 195%, and from 111% to 136% of that of outdoor treatments, in 2002 and 2003, respectively. Use of tunnels generally resulted in enhanced fruit appearance and size compared to outdoor culture. These trials were conducted in years characterized by very low rainfall, thus yield enhancements in tunnels appear to have resulted mainly from temperature modification.

Malformation of strawberry fruits during glasshouse production in spring

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Strawberry production under heated conditions in glasshouses in spring leads to bent fruits. Depending on the circumstances 5 – 15 % of the fruits are bent. The first fruit of the truss especially, is often malformed. The cause of malformation is subject to speculation. Insufficient pollination, reduced development of stamens, shortage of cold, and forced growth by heating, have all been suggested.

It was shown in an earlier study that conditions during autumn production of strawberry fruits, and partly at the start of the spring production, are responsible for the development of bent fruits. Applied Plant Research, and Plant Research International, conducted glasshouse experiments in 2002/2003 and 2003/2004 to explore the cause of malformation of strawberry fruits, cv. Elsanta. Different cultivation systems were employed, with or without assimilation light in autumn and/or spring, limitation of nitrogen supply during production in autumn, removal of the second truss in autumn, and absence of cyclic lighting in spring. At different intervals, plant samples were taken and analysed microscopically. Morphological flower development was rated according the classification defined by Taylor et al (1997).

Limitation of nitrogen supply in autumn resulted in fewer malformed fruits in spring, but overall production was limited. Application of assimilation light in autumn and/or spring decreased the percentage of malformed fruits to some extent. Removal of the second truss, and absence of cyclic lighting in spring, increased the percentage of bent fruits. The relation between formation of domes, which developed grooves, and malformation of fruits, is still unclear, and the subject of further studies.

The Effect of Different Organic Mulches on Strawberries

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[2]Department of Plant Biology & Protection, Latvia University of Agriculture, Jelgava, Latvia

Studies concerning evaluation of different organic mulches were carried out in the Pk□re Horticultural Research Station during 2000-2002. Three organic mulch types: straw, shavings and living grass mulch, were compared with standard system - without any mulching in two cultivars: 'Induka' and 'Festivalnaya Romascha'. The influence of mulch types on the phenological stages, runner development, flower frost resistance, winterhardiness, productivity, yield quality, fruit size, spreading of strawberry blossom weevil and diseases were studied. Flowering and production time did not differ significantly between treatments. Better runnering, flowering and productivity were observed in production system without any mulching, followed by living grass mulch. Though in the treatment without any mulching rotted berries were more than with using of any mulch. Living grass mulch succeeded spreading of blossom weevil, higher developing of misshaped berries and reducing of fruit size. Spreading of leaf and root diseases were mostly influenced by growing season and cultivar and was not affected by treatment. In total, cultivar 'Induka' showed better results than 'Festivalnaya Romascha'.

Testing of strawberry varieties for organic production

Andreas Spornberger[1], Robert Steffek[2], Sylvia Blümel[2], Ursula Barth[1] and Barbara Meltsch[1]

[1]Department of Applied Plant Sciences and Plant-Biotechnology, University of Natural Resources and Applied Life Sciences Vienna, Austria
[2]Institute for Plant Health, Austrian Agency for Health an Food Safety, Vienna, Austria

In two field trials, some new strawberry varieties were compared to standard varieties and tested for their suitability in organic production. In the first trial, the strawberries were planted on an organic farm north of Vienna in spring 2000, and tested during the season of 2001. A second set of strawberry varieties was planted on three organic farms in the northeast of Austria in 2002, and evaluated in 2003 and 2004. The following characters were evaluated: vigor of growth, total and marketable yield, susceptibility to grey mould, anthracnose, powdery mildew, and other pests and diseases. In addition, different parameters of fruit quality were analyzed, and fruits were tasted. On the basis of these results recommendations for variety choice in organic strawberry production in Austria can be made.

Development of a Commercially Viable System for Organic Strawberry-Runner Production

Monika Walter[1*], Cath Snelling[1], Kirsty S.H. Boyd-Wilson[1], Graeme Williams[2], Geoff I. Langford[1]

[1] Future Horticulture, HortResearch, Lincoln, New Zealand
[2] Department of Corrections, Rolleston Prison, Rolleston, New Zealand
*Corresponding author: Monika Walter, Future Horticulture, HortResearch, Lincoln, New Zealand

System requirements for organic runner production were determined during the 2001-02 and 2002-03 season. Production costs (per plant) were determined. In both seasons, the organically produced runners were then evaluated in the field in comparison with conventionally produced runners for yield and fruit quality under organic, BioGroä certified production conditions. Several cultivars were studied with the main emphasis on cv 'Sunset' and cv 'Aromas'. The curtain system, where mother plants grew on benches in the glasshouse and the first two runners were potted into growth substrate produced approximately 200 plug plants/m^2 and was the best system. Diseases and pests were mostly controlled by sanitation. The least preferred system was the bin production, where mothers were let to runner into a bin in the glasshouse containing the growth substrate. Approximately 100 bare rooted plants were produced per m^2. *Botrytis* infections occurred due to the dense strawberry canopy. The cost per runner is NZ$ 0.50 and 0.86/plant for the curtain and bin systems, respectively. Production of organic runners under glass allowed earlier (March vs May) planting which produced yield increases of approximately 200 g/plant. This more than compensates for the additional cost of organic runners compared to conventional bare rooted runners.

The International Society for Horticultural Science and the Queensland Strawberry Growers Association.

GROWERS DAY BOOKLET

5th International Strawberry Symposium

5-10 SEPT 2004
COOLUM AUSTRALIA

Sunday 5th to Friday 10th September 2004

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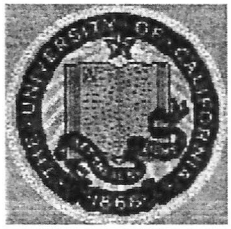


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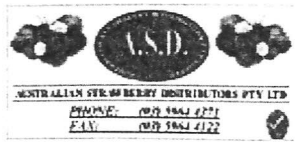
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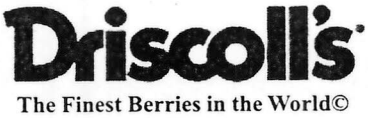

Welcome to Australia and to the ISHS 5th International Strawberry Symposium hosted by the Queensland Strawberry Growers Association. Oz Fresh and Driscoll are proud to be the Premier sponsors for this important event.

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Oz Fresh has in 2004 joined with Driscolls to bring the finest tasting berries in the world to the Australian consumer. While the Joint Venture is still in its infancy, initial trials have shown that the public is prepared to pay a premium price for superior tasting berry fruit.

Research and development by competent and committed scientists is the corner stone on which delighting the consumer is based. Growers, marketers, retailers and consumers have greatly benefited from the effort of dedicated R&D teams and eagerly await new developments.

We know that everyone attending this symposium will have an informative and enjoyable experience. We are glad to be able to share it with you.

Joe Pignataro
Managing Director
Oz Fresh

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Essential Information

Registration Desk
The registration desk will be open from 8.00 am each morning.

For Sunday 5 September, it will be located in the Lower Lobby close by the Hyatt's check-in and guest reception area. From Monday 6 to Friday 9 September, the registration desk will be located in The Pavilion foyer in front of the poster and trade display area.

Name Badges
Please wear you name badge throughout the symposium program. Your badge identifies you for venue staff, the organising team and fellow delegates. It will provide admission to the symposium sessions, lunches and morning and afternoon teas and any other social activities for which you are registered.

Assistance for Delegates
Should you require assistance of any kind, please ask a member of the organising team. They will be wearing MAROON shirts and YELLOW badges for easy identification.

Messages
A message board will be located at the registration desk. Please check it regularly.

Catering
Your registration fee covers morning and afternoon teas and lunches, for each day you are registered. Arrangements have been made for those who have indicated special dietary needs on their registration form. This will be discussed with you when your register. If you have not already indicated you have a special dietary requirement, please do so as soon as possible after registering.

Symposium Banquet
We have arranged a gourmet banquet for Thursday evening to celebrate the symposium. Only those who have registered for the banquet can attend. We can not accept more banquet registrations after Monday evening. Please dress smart-casual.

Program

THURSDAY 9 SEPTEMBER

8.20 **Introduction – Growers Days Program**

8.30 *Advances in strawberry breeding and strawberry production technology at the University of California Davis.* K. Larson (California USA)

8.50 *The LAWS breeding program.* M Herrington (Queensland)

9.10 *Strawberry breeding in Southern Australia.* B. Morrison (Victoria)

9.30 *Status of the Florida strawberry industry and the University of Florida strawberry research programs.* C. Chandler (Florida USA)

9.50 *Managing climate variability and climate change – relevance for the strawberry industry?* R. Stone (Queensland)

10.10 **Morning Tea**

10.30 *Getting a grip on thrips.* M. Steiner (New South Wales, Australia)

10.50 *Chemicals used in integrated fruit rot management in subtropical strawberries in Australia.* D. Hutton (Queensland)

11.10 *Substrates as an alternative to methyl bromide for strawberry fruit production in Northern Europe in both protected and field production.* P. Lieten (Belgium)

11.30 *Assessing the information needs of subtropical strawberry growers in Australia.* N. Vock (Queensland)

12.00 **LUNCH**

12.50 *Visy 'One Touch' packaging solutions.* P. Fenwick, Visyboard (Queensland)

13.10 *A new retail direction in strawberry packaging.* G. Ganzenmuller, Amcor (Queensland)

13.30 *Strategies for the management of sustainable strawberry production through the effective monitoring of nutrition and irrigation.* J. Moisander (Queensland)

13.50 *Irrigation management in strawberry fields: Is it more than just turning the pump on and off?* P. Broomhall (The World)

14.10 *A California perspective on organic strawberry production.* T.Sjulin, Driscoll's California (USA)

14.30 *Sustainability - A farm gate view.* M. McGinnis (Queensland)

14.50 **Afternoon Tea**

15.10 *5th Element – A natural fertiliser for horticulture.* G Nunn, 5th Element (Queensland)

15.30 *Double your yield!* J. Dick, Hydrogarden (UK)

15.50 *Optimising strawberry production.* Ilan Kanety, Azrom Greenhouses (NSW)

16.10 *Methyl bromide research summary.* S. Mattner, A. Shanks and D. Hutton (Australia)

17.00 **Summary – Growers Day Program**

17.10 Strawberries Australia Levy Payers Meeting

19.30 **SYMPOSIUM BANQUET**

Abstracts

Advances in strawberry breeding and strawberry production technology at the University of California Davis

Kirk D. Larson, Douglas V. Shaw and Christina Smith

Department of Pomology, University of California Davis

The University of California (U.C.) strawberry improvement program conducts research in California and worldwide to develop cultivars with broad adaptation and strong environmental tolerance, meeting growers' needs while satisfying the demands of an increasingly sophisticated market. Currently, U.C. strawberry cultivars are the most widely-grown cultivars in the world. For the U.C. program, nearly 100 traits are quantified during the development of a new cultivar, including important characteristics such as: fruit quality (flavor, shape, appearance, color), fruit size and firmness, postharvest quality, harvest efficiency, percentage of cull fruit, production pattern, plant architecture, environmental and pest/disease tolerance, rain and heat tolerance, climatic adaptation, and nursery runner productivity. In view of the potential loss of methyl bromide and other soil fumigants, during the past eight years the U.C. program has used genetic screens to identify advanced U.C. genotypes that are tolerant of major lethal pathogens such as *Verticillium dahliae*, *Phytophthora cactorum*, and *Colletotrichum acutatum* Here, the program's objective is to use recurrent breeding and selection to develop cultivars that possess the many requisite horticultural traits while also possessing tolerance or resistance to these important pathogens. Obviously, this is a long-term objective, and the development of improved cultivars with the many requisite horticultural traits *and* multiple disease resistances will be very difficult indeed. This report provides an overview of breeding program objectives, a summary of progress made in cultivar development during the past decade, and program developments that we anticipate in the future. The report also provides information on performance and production management guidelines for the day-neutral cultivars Diamante, Aromas and Albion, as well as the short-day cultivars Camarosa, Ventana, Camino Real and Gaviota. Importantly, the U.C. strawberry research program is not limited to breeding activities, but rather integrates cultivar improvement with improvements in cultural practices and production management. In recent years, production research at the University of California has included investigations of methyl bromide alternatives in nurseries and fruit production fields, pest and disease control methods and strategies, influence of polyethylene mulches on cultivar performance, irrigation, mineral nutrition, protected culture, hydroponic production, runner plant nursery management, plant propagation systems, and nursery plant maturity. This report presents highlights of this research.

The LAWS breeding program

Mark Herrington[1], and Jennifer Moisander[2]

[1]Maroochy Research Station, Department of Primary Industries and Fisheries, Nambour, Queensland, Australia
[2]Redlands Park, Department of Primary Industries and Fisheries, Cleveland, Queensland, Australia

The breeding objectives, which include maximising consumer satisfaction and profitability of production, the general procedure and progress of the Australian LAWS (late autumn winter spring market) program are described. The cultivars developed include Kabarla, Redlands Joy, DPI Sugarbaby and DPI Rubygem. Increased product differentiation as a method of satisfying both consumers and producers is proposed.

Strawberry breeding in Southern Australia

Bruce Morrison, Karen Spencer, Adam Shaw and Fiona Thomson

Primary Industry Research Victoria, Victoria, Australia

The Strawberry Breeding Program for temperate areas of Australia aims to commercialise new short day and day neutral varieties with wide adaptation to the southern and western production areas. These varieties will have high consumer appeal, be efficient to produce while cropping for extended periods and have a reduced dependence on expensive soil fumigants and other crop protectants. To achieve this, seedling selection and early generation trials are conducted at a number of sites across Australia, and no fungicides, miticides or soil fumigants are used during the selection and trialing process. Varieties commercialised include Tallara and Alinta (1999), Lowanna (2000), Adina (2001), Kiewa (2003) and Millewa (2004).

TALLARA is a short day variety producing excellent yields of very large, uniform, very attractive, conic fruit. Plants are robust and if planted by mid April in southern Australia, will crop until late summer.
ALINTA is a strong day neutral variety producing very heavy yields of high flavoured fruit. Due to its pest and disease resistance and dense plant structure, it has been licensed for home garden production.
LOWANNA is a day neutral variety producing high yields of uniform, conic, very attractive fruit. Fruit develops its colour from the shoulder producing fully coloured, glossy fruit from late spring through to mid winter.
ADINA is a short day variety producing exceptionally large attractive fruit on plants with a very open structure. In years with a cooler summer, Adina will behave as a day neutral and crop continuously. Research has shown that the flavour and texture of Adina is very close to the consumers' perception of an ideal strawberry.
KIEWA is a short day variety producing high yields of large, low acid, high flavoured conic fruit, which does not darken in the heat of summer. Plants are robust, resistant to powdery mildew, and should be planted by mid April in southern Australia.
MILLEWA is a non-classic short day variety producing very good yields of very large, attractive fruit during the spring-early summer and heavy crops again during the autumn-early winter, thus providing an alternative to day neutrals in areas with hot summers. Millewa, which is highly resistant to powdery mildew, should be planted by mid April in southern Australia.

Status of the Florida strawberry industry and the University of Florida strawberry research programs

Craig K. Chandler

Gulf Coast Research & Education Center, University of Florida, Dover, Florida

The Florida strawberry industry is an important source of fruit for North America during the late fall and winter. The industry has expanded in recent years, and currently occupies about 3,000 hectares. Total sales for the 2003-04 season were nearly $200,000,000. Despite a generally strong demand for their product, Florida growers are finding it increasingly difficult to make a profit, which is due primarily to a rising cost of production. Most Florida strawberry growers are members of the Florida Strawberry Growers Association (FSGA), a voluntary commodity organization that assists its members with regulatory issues, public relations, and marketing. In addition, FSGA works closely with the state government and the University of Florida to determine and support research priorities. The University of Florida currently has research programs dedicated to developing improved strawberry cultivars, cultural practices, and pest and disease control methods.

Managing climate variability and climate change – relevance for the strawberry industry?

Dr Roger C Stone

Department of Primary Industries and Fisheries, Toowoomba, Queensland, Australia

Australia has the highest level of year-to-year climate variability on earth. Much of the cause of this high level of variability is associated with the El Nino/Southern Oscillation phenomenon. One practical way of measuring the status of the El Nino/Southern Oscillation is through use of the Southern Oscillation Index (SOI). The SOI is simply a measure of the difference in air pressure between the central tropical Pacific Ocean (normally Tahiti is used) and the western Pacific Basin (usually Darwin). (More precisely, it is the difference between air pressure anomalies).

Patterns of the SOI, or SOI 'phases' can be used to provide forecasts of rainfall or temperature for any location world-wide, including locations on the Queensland coast. The highest levels of reliability and accuracy in climate forecasting are generally available for winter, spring, and early summer, critical periods for strawberry farm management. The value of seasonal climate forecasting is increased when it is more targeted to specific needs (such as irrigation systems), provision of frost forecasts, forecasts of cooling degree days, or when integrated into crop simulation models to provide forecasts of potential yield.

Additionally, the knowledge of the more likely timing of rainfall events can be aided through the use of the Madden-Julian Oscillation or 'MJO'. The MJO is a pulse of air pressure that moves from west to east from the Indian Ocean across northern Australia with a mean return period of 40 days (with a standard deviation of 10 days). We have found that cloud bands and rain can form in southern regions over Queensland in association with the MJO. (A recent passage of the MJO was in the last days of August, 2004). Knowledge of the MJO may aid growers in decisions associated with planting and harvesting.

Getting a grip on thrips

Marilyn Steiner and Stephen Goodwin

Gosford Horticultural Institute, Gosford, New South Wales, Australia

Strawberry fruit is damaged by a variety of insects and diseases, and by vagaries of weather and nutrition. Matching symptoms with causes is not always easy. This paper outlines results from a three-year study in a hydroponic strawberry crop near Sydney, which began with management of western flower thrips, *Frankliniella occidentalis* (Pergande) as its goal, and ended with a better appreciation of the nature of thrips damage, thresholds for action, the interaction of the environment and damage severity, and tools for managing populations below economic threshold levels.

Two distinct periods of damage to fruit with different symptoms, were recognised. The most severe damage was manifest as a network of surface russeting on young green fruit about two weeks post-flowering, with secondary damage caused to late green and red fruit in the form of browning around the seeds. Action thresholds and monitoring methods that are based primarily on flower counts, were developed, though yellow sticky trap counts can provide supporting information. An action threshold of 45% of flowers with 5 or more adult western flower thrips, or 40% with 10 or more plague thrips, *Thrips imaginis* Bagnall, was established, with a greater tolerance during cool wet periods. For western flower thrips, the action threshold also corresponded with a sex ratio of thrips caught on sticky traps of 60-65% females (20-30 females per trap).

Overhead misting during hot dry periods was found to reduce damage severity and thrips population density. Familiarity with local thrips species and natural enemies and their seasonal occurrence is important, as management approaches will need to be adapted to them.

Chemicals used in integrated fruit rot management in subtropical strawberries in Australia

Don Hutton, Roger Smart and Grant Bignell

Department of Primary Industries and Fisheries, Maroochy Research Station, Nambour, Queensland, Australia.

Fruit rot control in sub-tropical strawberry production in Queensland is directed towards black spot, *Colletotrichum acutatum*, grey mould, *Botrytis cinerea,* and powdery mildew, *Sphaerotheca macularis*. Depending on the nature of their farm enterprise, growers will favour a range of crop protectants and other integrated disease management options.

This paper gives a summary of fruit rot control with chemicals since the 1980s, and presents data that have resulted in recommendations that provide excellent control of these diseases for the commercial strawberry grower. We also offer data for products that may be used appropriately in the production of fruit for commercial organic or minimal chemical input systems. Such products still need to be submitted for registration before being used on farm.

Excellent control of black spot is provided by Euparen Multi® (tolylfluanid) and captan. Grey mould is adequately controlled by early applications of Euparen Multi, or with increased disease pressure, by Teldor® (fenhexamid), Scala® (pyrimethanil) or Rovral® (iprodione). The protectant fungicides, Euparen Multi® and Systhane ® (myclobutanil) together with Flint® (trifloxystrobin), which is soon to be registered, give excellent control of powdery mildew. Early application of these protectants is essential, especially when weather conditions favour the disease. They are compatible with current systems utilised for biological pest control.

Substrates as an alternative to methyl bromide for strawberry fruit production in Northern Europe in both protected and field production

F Lieten

National Research Station for Strawberries, Proefbedrijf der Noorderkempen, Meerle, Belgium

In the mid-eighties substrate culture of strawberries developed mainly in The Netherlands and Belgium where strawberries are grown now intensively year round on small farms. Due to the limited available surface and knowledge on growing of soil less vegetables and flowers, substrate culture of strawberries gained much interest and has become a common cultivation method. In the nineties the technique has spread in central Europe, mainly UK and the north of France and Italy. More recently substrate culture has known a strong development in the southern regions of Spain, France and Italy due to the phase out of methyl bromide. On the other hand the interest in northern Europe (Germany and the Scandinavian countries) is rather limited. Currently the production area of strawberry soil less culture in Western Europe can be estimated around 1270 ha or 2.7 % of the total production area which is estimated to be around 47.000 ha.

Assessing the information needs of subtropical strawberry growers in Australia

Noel Vock and Neil Greer

Department of Primary Industries and Fisheries, Maroochy Research Station, Nambour, Queensland, Australia

The timely access to effective technical information is a key ingredient of profitable strawberry production. Through the Better Berries Program, a joint RD&E initiative of government and industry, DPI&F is a major provider of technical information to Australia's subtropical strawberry industry. Products and services have included the Agrilink Strawberry Information Kit, the Agrilink Strawberry Information Online CD and the Better Berries annual grower field day/seminar and information booklet. However, there is a lack of knowledge of how well these are meeting the information needs of growers, both in content and delivery. This is being researched through a current project.

The project involves detailed face-to-face on-farm interviews with a random sample of approximately 10% of the industry (40 growers). The sample has been stratified to ensure that all sectors of the industry are represented, including large and small, and novice and experienced growers.

Results so far indicate that information sought by growers and the style in which it is best presented varies significantly with grower experience but much less so with farm size. New growers have a wide range of needs while the needs of experienced growers are focussed mainly on problem identification and new production developments. Interestingly, the overwhelming majority, across all sectors, still prefers paper-based information products despite their extensive use of computers for business purposes. The findings are being used to develop an improved range of technical information products and services which are more accessible, easier to use, more timely and more relevant to the needs of growers.

Visy 'One Touch' packaging solutions

Peter Fenwick

VISYBOARD, Brisbane, Queensland, Australia

A new retail direction in strawberry packaging

George Ganzenmuller

Amcor Fibre Packaging Australasia, Rocklea, Queensland, Australia

Traditionally, packaging technologists have focused on developing the overall most cost effective packaging solutions for the given market, taking into consideration materials, marketing, protection and distribution aspects. Specifically, the largest driver for secondary packaging and produce packaging has been for optimisation based on distribution constraints and customer requirements.
A paradigm shift is currently taking place with the design focus for nearly all packaging for retail products as the "One Touch" trend is now moving towards optimisation for the retail environment, sometimes at the expense of the customer or packer and distribution chain. Through attendance of the presentation, delegates will gain an overview of the package development systems, identify the latest packaging trends for key products into the retailers and identify some of the compromise solutions being developed by the packaging industry.
Specific developments for strawberry packaging will be discussed with a number of new modular packaging initiatives being presented as a result of recent changes to the traditional retail supply chain systems.

Strategies for the management of sustainable strawberry production through the effective monitoring of nutrition and irrigation

J.A. Moisander[1] and D. Lyons[2]

[1]Department of Primary Industries and Fisheries, Redlands Research Station, Cleveland 4163 Queensland, Australia
[2]Natural Resource Sciences Chemistry Centre,Department of Natural Resources, Mines and Energy, 80 Meiers Rd., Indooroopilly 4068 Queensland, Australia

The application of excess nitrate fertiliser and the excessive use of water have been shown to result in losses of over 80% of the nitrate fertiliser applied to strawberry (*Fragaria spp.*) plants through a trickle irrigation system. The fine-tuning of recommendations for commercial soil test interpretation data, and the greatly improved adoption of soil testing services by growers over the last 10 years, has lead to a much greater understanding of the requirements of strawberry plants throughout the season. The adoption of the practice of monitoring leaf sap nitrate levels in plants throughout the different growth stages in the season has greatly reduced the amount of nitrate fertiliser applied during the season. This has been achieved over the last 10 years through the establishment of desirable sap nitrate levels for more than 15 commercial strawberry varieties, and these predetermined levels provide added guidance to growers in their monitoring program. After demonstrating to growers the potential water savings to be had by using trickle irrigation systems in preference to overhead systems, the further step of instructing them in the use of various soil moisture technologies such as tensiometers, Enviroscan®, has greatly reduced water consumption on farms and reduced the leaching effect on their applied fertilisers. The adoption of these technologies has resulted in growers attaining optimal yields, reduced fertiliser and water use, and reduced environmental impact from their strawberry enterprises.

Irrigation management in strawberry fields: Is it more than just turning the pump on and off?

Peter Broomhall

Hortech Services Pty Ltd, Kallangur, Queensland, Australia

Irrigation scheduling is an important element in improving water use efficiency in irrigation systems (Howell, 1996). The moisture content of a soil matrix is a major determining factor in plant growth (Allison et al, 1983). The management of soil moisture content by irrigation may be used as a tool to manipulate the fundamental biological processes of photosynthesis, cell elongation and cell reproduction, with the objective to optimize yield and quality of a plant product (Cull, 1992). The application of this approach for strawberry production must be developed on both variety and site-specific circumstances linked to the relative effectiveness in conserving water whilst maintaining acceptable yield and fruit quality.

Continuous logging, multi-depth capacitance soil moisture sensors offer an opportunity for improved precision in irrigation scheduling (Buss, 1996). The monitoring of fine changes daily changes in soil water content has been effective in identification of the critical soil water content at which plant growth is affected for a number of crops (e.g. Peach trees (Goldhammer et al, 1999) and Sugar Cane (Inman-Bamber and Spillman, 2003)). The monitoring of soil water dynamics within and below the rootzone leads to improved accuracy of soil water bass calculations, and therefore, an accurate estimate of drainage and crop evapo-transpiration (Fares and Alva, 1999).

This presentation outlines examples from either continuous soil moisture data or field observations which provide an insight into irrigation systems performance and crop water use in Strawberry fields.

A California perspective on organic strawberry production

Thomas M. Sjulin, Director of Strawberry Production and Research

Driscoll Strawberry Associates, Inc., Watsonville, Calif., U.S.A.

The cultivated area of organic strawberries in California has doubled in the past five years to approximately 250 hectares. This area is still very small (approx. 2 %) relative to the total area of cultivated strawberries. The majority of the production is located along the central coast in the Watsonville-Salinas district. Despite higher costs and lower yields, returns, as a percent of capital costs, have been higher for organic than conventional production for Driscoll's contract growers in the past two years. Consumer demand for organic strawberries has been strong, and our growers have received significant price premiums relative to conventional strawberries during this period. Despite this success, Driscoll's and its organic growers face numerous challenges and threats. A major challenge is the development of cultivars that are adapted to organic production but still meet our customers' expectations for fruit quality. Other challenges include finding suitable land; developing a supply of organic fruit that parallels the year-round supply of conventional strawberries; producing pest- and pathogen-free planting stock; and controlling pests and diseases. Threats to the future of organic strawberry production in California include the lack of cultivars with resistance to soilborne fungi; increasing salinity of irrigated croplands; encroachment of urban areas on suitable land; and the emergence of pests and/or diseases that have previously been controlled by soil fumigation.

Sustainability - A farm gate view

Mick McGinnis

Woombye, Queensland, Australia

There are community wide concerns about the condition of our natural resources. This has triggered action at policy, guideline and project level to create producing systems which stabilise or reverse symptoms of natural resource degradation.

Most of these endeavours require change by farmers. At the same time, the community expects no reduction in the quantity, quality or affordability of farm products. This is reinforced by global trading access to low cost producers and use of competition policy, not true total cost to determine prices.

There are six critical and interdependent elements in Australian farm sustainability. These are weather, soil, water, biodiversity, energy and social and economic viability. Each has a limit of use past which whole -of-system degradation occurs. Because our concerns are limited to human time scales, time! itself is a complicating factor.

Our society is dependent on non-production outputs from our farms. It is the quality supplies of water, biodiversity, fresh air, etc. and threats to these, that are a source of concern, not just the distant possibility we may go hungry.

Pragmatically, our current and possible farming Best Management Practices, economic and social conditions will not produce systems of sustainable resource use. The irony for farmers is that we have to plan for changes not possible to achieve under current conditions.

A lot of private and government funded work continues to be done on sustainable systems. The time has come to make it all work on a range of farms. The most valuable outcome for the whole community would be demonstration sites at a commercial level of truly sustainable systems. Initially, sustainable natural resource utilisation for production should be achieved, regardless of cost! Then the distribution, economic and social aspects required should be considered. Finally, an understanding by our society of the facts, not the wishful thinking, would contribute to a debate on best national outcome for natural resource use and product security.

We need to know where we are planning to go. Will it be sustainability, or continuing comfort now at the cost of reducing asset values and future prospects?

5th Element - A natural fertiliser for horticulture

Garry Nunn

Fifth Element, "Wyoming", Eumundi, Queensland, Australia

What is it? - A patented liquid compound fertiliser with a unique balance of plant available nutrients a result of intense microbe digestion.

What is it made from? - Poultry litter, carbon, bacteria in a specialist formula.

How do plants respond? - Higher yields, quality of production and market prices. Longer shelf life and harvest periods, plant pest and disease resistance, great tasting food.

Why does it work? - A nutrient composition like no other. Amino acid based which re-writes the text books on plant nutrient forms and uptake mechanisms. This is the frontline in horticultural nutrient development and research.

What is the availability? - An emerging industry which offers 2 options. Concentrated liquid product purchase or on-site fertiliser production. The sustainable option.

- Food safety and environmental issues addressed
- Disadvantages and advantages in relation to supplementing/replacing existing fertilising styles.
- Cost comparisons

Double your yield!

James Dick

Hydrogarden, West Midlands, UK

Economic pressure in the soft-fruit sector has forced us to look at means of increasing production. The Fruitwise System can effectively double or triple conventional plant densities per unit area and therefore increase overall crop yields. This proven system has been trialed in South Africa with excellent results. Hydrogarden Wholesale Supplies Ltd is a leading hydroponics company distributing world wide. Hydrogarden are marketing the Fruitwise Growing System.

Optimising strawberry production

Ilan Kanety

Azrom Greenhouses, Azrom Australia Pty Ltd, Binya, New South Wales, Australia

This presentation identifies the key problems that play a large part in effecting successful Strawberry production in the open field. These issues are discussed in detail and solved through Greenhouse production. a brief insight into the research and development of strawberry greenhouse production over the last 15 years concludes the presentation.

Methyl bromide research summary

S. Mattner[1], A. Shanks[1] and D. Hutton[2]

[1]Primary Industries Research Victoria, Knoxfiled Centre, Victoria, Australia
[2]Department of Primary Industries and Fisheries, Maroochy Research Station, Nambour, Queensland, Australia

S. Mattner - Reporting on methyl bromide replacement in runner beds

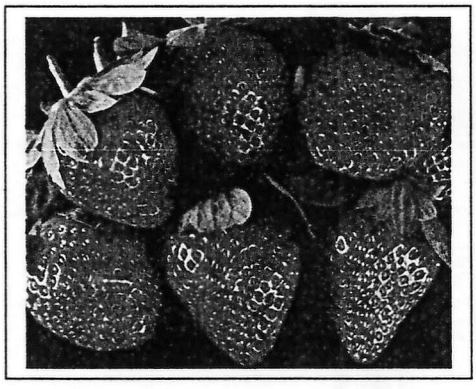
A. Shanks - Reporting on national methyl bromide program report

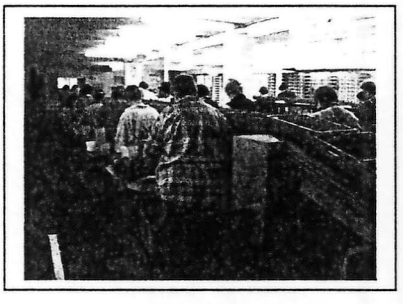
D. Hutton - Reporting on methly bromide alternatives in commercial fruit production

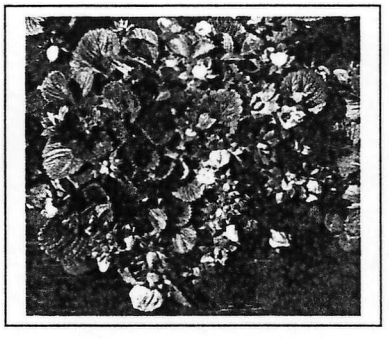
Technical Tour Guide

September 8 2004

ISHS 5th International Strawberry Symposium – 2004







Tour Managers:

- **Better Berries Team**

Queensland Government
Department of Primary Industries and Fisheries

Welcome

To all technical tour participants, a very warm welcome to the Sunshine Coast region of Queensland. We hope that you are enjoying your stay here and look forward to showing you some of the strawberry industry today.

As general background The Sunshine Coast and Cooloola region extends from Caboolture to Maryborough and includes a number of major coastal towns such as Bribie Island, Caloundra, Maroochydore, Noosa and Rainbow Beach, and a number of rural hinterland communities such as Glasshouse Mountains-Beerwah, Maleny, Palmwoods-Woombye, Nambour, Cooroy-Pomona and Gympie. The region is part of the fastest growing region in Australia, with up to 1,000 new residents per week, mostly from interstate migration.

The major industries are tourism, horticulture, forestry and fishing. With regard to horticulture, the region is one of Queensland's major horticultural production areas, producing the majority of Queensland's pineapples, ginger, macadamias, strawberries, custard apples, sweet persimmons, passionfruit and subtropical bananas. Other significant horticultural industries include low chill stonefruit, lychee, mango, citrus, vegetables (predominantly beans, cucurbits and sweet potato) and amenity horticulture (cut flowers, nurseries and turf).

The tour today features four aspects of the strawberry or associated industry including the research facility at Maroochy Research Station.

The tour will examine some of the key production, processing, marketing, tourism and research issues within the strawberry industry, as well as providing a glimpse of some of the scenery of the Sunshine Coast region.

We hope you enjoy the technical tour and the remainder of conference.

Itinerary

Bus 1&2		Bus 3&4	
Time	**Activity**	**Time**	**Activity**
0800	Depart Hyatt Coolum to travel to Twists Chevallum	0800	Depart Hyatt Coolum to travel to Twists Chevallum
0845	**Stop1**: Twists Chevallum	0845	**Stop1**: Twists Chevallum
0950	Travel to Maroochy Research Station	0950	Travel to Carmichaels 'Strawberrry Fields' Palmview
1020	**Stop 2**: Maroochy Research Station (morning tea, station tour, lunch)	1020	**Stop 2:** Carmichaels 'Strawberrry Fields' Palmview (morning tea)
1230	Travel to McGruddy's Palmwoods	1140	Travel to Maroochy Research Station(station tour, then lunch)
1300	**Stop 3**: McGruddy's Palmwoods	1210	**Stop 3**: Maroochy Research Station (morning tea, station tour, lunch)
1415	Travel to Carmichaels 'Strawberrry Fields' Palmview	1355	Travel to McGinnis's Woombye
1445	**Stop 4:** Carmichaels 'Strawberrry Fields' Palmview (afternoon tea)	1425	**Stop 4**: McGinnis's Woombye
		1535	Travel to Maroochy Research Station (for short afternoon tea)
1615	Travel to Moffats Beach via Bruce Highway	1600	Maroochy Research Station (for short afternoon tea
1645	**Stop 5**: Moffats Beach, dinner	1615	Travel to Moffats Beach via Bruce Highway
		1700	**Stop 5**: Moffats Beach, dinner
2100	Travel to Hyatt Coolum	2100	Travel to Hyatt Coolum

Sites Visited

1.

Name of enterprise. Twist Brothers (Rick, Jeff and David).

Location. 447 Chevallum Road, Chevallum.

Size of operation. More than one million plants.

Crop grown. Strawberries.

History of enterprise. A family business, with the brothers moving from Burpengary near Caboolture to Chevallum 33 years ago.

Background of owners. Family commenced growing strawberries because of desire to work with a winter producing crop rather than a summer producing crop.

Main focus of enterprise (pick your own, sustainable growing techniques, etc). Commercial production with preference to work with owner-operators in associated businesses, based on strong loyalties to merchants, etc.

Number of employees (full time and casual). 160.

Main cultivars grown. We are growing Selva, Camarosa and Kabarla this season, and observing a range of the newer varieties in smaller plantings.

Source of planting material. Toolangi (Victoria) and Stanthorpe (Queensland).

Soil type. Sandy loam, with small areas of red loam.

Soil preparation (fumigation, etc.) used. Cover crops are grown between seasons, using the same blocks each year because of limited availability of land. Historically we have fumigated with methyl bromide and were the contractors for MB fumigation in the early 1980s.

Type of irrigation system used, and method of scheduling irrigation. We use overhead irrigation on some blocks, although we are gradually moving the entire farm onto trickle. However, there will still be a need for overhead irrigation for frost protection. Irrigation scheduling is based on experience.

Fertilizer program used (application before planting, fertigation, foliar fertilizers). Pre-plant fertilization is based on soil analyses. Plant nutrition is then maintained by regular foliar applications with a boom spray, with two tractors dedicated to this operation.

Method for determining fertilizer applications. We use soil tests at the end of the harvest to assess what has been taken from the soil, and prior to hilling up the beds to assess what is required for crop. Crop status is regularly monitored (one block in a three week rotation) using sap testing, with the fertilizer program modified each time.

Are there problems with birds and other vertebrate pests? Ducks and parrots are major problems. Ducks are a problem on one half of the farm and not on the other.

We have encouraged eagles to visit and they seem to reduce the duck problem.

Main pests and their control. Mites and caterpillars are the major pests, with control based on experience and strategic pesticide applications applied with a 'Hardi-mister'. We spray regular 'hot' spots to reduce the amount of chemicals used. These decisions are based on a sound knowledge of the farm, and continual monitoring.

Main diseases and their control. 'Grey mould' and 'black spot' are the main diseases, and are controlled with recommended chemicals.

Summary of operations in the packing shed (grading of fruit, cooling, type of punnets used). The fruit are either packed in the shed immediately after picking or held for a time in the cold room if the supply of fruit from field exceeds the capacity of the packing line. Once packed, the fruit are cooled with forced air coolers and packed into lidded punnets.

Destination of crop (local, major urban markets). The fruit are sent Australia wide, but mostly to Brisbane, Sydney, Melbourne and Adelaide. There are occasional special orders to other locations such as Townsville.

Details of involvement with local tourism industry and other businesses on the Sunshine Coast. Fifty percent of our workers are 'backpackers'. Some of the fruit are sold to locals straight from the packing shed. We are a major contributor to the local Chevallum State School's 'Strawberry Festival' in September each year, and to other local charities.

Provide details of attempts to reduce the impacts of your farming operation on the environment. All fields are equipped with 'silt traps', which capture soil and solid fertilisers from the runoff. The trapped silt is returned to the farm once a year.

What are major issues facing the local strawberry industry. Overproduction. The market is limited to the domestic scene because export markets have not been able to guarantee adequate returns. Prices on the domestic market have been strong this year because the drought has reduced overall production.

Provide details of your involvement in industry research, extension and development. Rick has been on the Strawberry Industry Executive for 33 years through Local Produce Associations and the Queensland Strawberry Growers' Association. We also provide a 'behind the scenes' contact point for growers and are willing to share information for the benefit of other producers, believing it is important to look after the industry. We were instrumental in having methyl bromide adopted by the industry and were contractors for MB in the early days. We have been co-operators for many DPI&F trials including variety evaluation, MB replacement and disease management.

2.

Name of enterprise. STRAWBERRY FIELDS (Maurie and Von Carmichael).

Location. Laxton Road, Palmview.

Size of operation. 400,000 to 450,000 plants.

Crop grown. Strawberry.

History of enterprise. The farm was previously a dairy and virgin land. We bought the property and began growing crops in 1977 (27 years ago), initially sowing beans and zucchini (summer squash) and the following year planted 900 (nine hundred) strawberry runners. Ten to twelve years ago, buses began arriving with tourists. Since then, we have evolved, responding to the needs of tourists, including the development of a shop, pick-your-own (PYO) strawberries and meals.

Background of owners. Maurie was born in Bundaberg, and qualified and worked as 'Fitter and Turner' in north Queensland, before coming to the Sunshine Coast in 1970. Von was born Maryborough (arch rival of Bundaberg), is mother of six and has always been interested in farming and gardening (look at her beautiful gardens!).

Main focus of enterprise (pick your own, sustainable growing techniques, etc). Commercial strawberry production for southern markets, with about 10% for PYO and the local tourist trade.

Number of employees (full time and casual). 65 to 70.

Main cultivars grown. We grow mainly Kabarla (early) and Camarosa (late). We also have a range of others varieties, including Festival, Redlands Joy (for PYO only) and Chandler. Chandler and Joy are not likely to be planted next season, with the latter being replaced by Rubygem.

Source of planting material. Toolangi (Victoria) and Stanthorpe (Queensland).

Soil type. Sandy loam.

Soil preparation (fumigation, etc.) used. We fumigate the whole farm, previously with methyl bromide, but now use Telone.

Type of irrigation system used, and method of scheduling irrigation. We use both trickle and overhead irrigation. Overhead is used during establishment, and when necessary during the growing season for frost protection and to wash dust off the berries. Irrigation is scheduled using 'Phytech' soil water and plant meters.

Fertilizer program used (application before planting, fertigation, foliar fertilizers). We employ cover crops, preplant fertilizers, fertigation and foliar fertilizers. We previously used 'mill-mud' as a soil amendment, but now use a by-product from the Golden Circle Cannery in Brisbane.

Method for determining fertilizer applications. We use preplant soil analysis after the cover crop is ploughed in at the end of January, and monitor the petiole sap of the strawberries every three weeks.

Are there problems with birds and other vertebrate pests? Birds are occasional pests. The strawberry field is surrounded by a 2 km, 1.8 m (6 ft) wire fence, which keeps out dogs, foxes, wallabies and hares. Dogs and foxes are a problem earlier in the season after the beds have been formed but before the runners are planted. These animals severely damage the mulch and irrigation infrastructure.

Main pests and their control. Mites are a severe problem in hot, dry weather, with IPM employed, with the assistance of pest consultants.

Main diseases and their control. The main disease is black spot, which is effectively managed with regular Euparen sprays.

Summary of operations in the packing shed (grading of fruit, cooling, type of punnets used). Fruit come in from the field, are forced-air cooled to 4° to 8°C, taken from cold room, graded and packed, returned to the cold room and then despatched.

Destination of crop (local, major urban markets). The main markets are Melbourne, Sydney, Adelaide, with a small proportion of the crop sent to Brisbane. The on-farm shop provides an outlet for our 'seconds'.

Details of involvement with local tourism industry and other businesses on the Sunshine Coast. We have developed a PYO operation, with numerous tourist buses coming to the farm.

Provide details of attempts to reduce the impacts of your farming operation on the environment. We use IPM, barrier fences, trickle irrigation and 'Phytech' soil water monitoring.

What are major issues facing the local strawberry industry. Over-production.

Provide details of your involvement in industry research, extension and development. We have conducted trials on mites and disease control, replacements for methyl bromide (MB), fertilisers and varieties in collaboration with DPI&F, although we have no trials at the moment. Contributions to the strawberry industry include Past President of the Queensland Strawberry Growers' Association (QSGA) and Strawberries Australia Representative.

3.

Name of enterprise. Peter and Pam McGruddy.

Location. 180 Landershute Road, Palmwoods.

Size of operation. 150,000 plants.

Crop grown. Strawberries.

History of enterprise. We commenced farming in 1980.

Background of owners. Peter was a Maths/Science Teacher, and Pam a Nurse.

Main focus of enterprise (pick your own, sustainable growing techniques, etc). Commercial strawberry production for national markets.

Number of employees (full time and casual). 20.

Main cultivars grown. We grow mainly Camarosa (66%) and Queensland varieties such as Kabarla and Rubygem (33%).

Source of planting material. Toolangi (Victoria) and Stanthorpe (Queensland).

Soil type. Sandy loam.

Soil preparation (fumigation, etc.) used. We use potassium metham.

Type of irrigation system used, and method of scheduling irrigation. We use drip (trickle) during the growing season, and overhead irrigation for frost protection and plant establishment. Irrigation is scheduled with the help of tensiometers.

Fertilizer program used (application before planting, fertigation, foliar fertilizers). We fertilize the cover crop, based on soil test prior to sowing. After the cover crop is ploughed in, we apply a six-month controlled-release fertilizer into the rows at hilling, and adjust this with fertigation and foliar sprays, depending on the results of monthly sap tests.

Method for determining fertilizer applications. We take a soil test prior to sowing the cover crop, and follow up with a monthly sap test for the strawberries.

Are there problems with birds and other vertebrate pests? The main pests are ducks.

Main pests and their control. The main pests are caterpillars, which are controlled by BT, Gemstar and Vivus, and mites that are controlled by predatory mites.

Main diseases and their control. The main disease affecting the strawberries is grey mould, which is controlled by Euparen and Teldor Scala. We also have fairly stringent field hygiene.

Summary of operations in the packing shed (grading of fruit, cooling, type of punnets used). Contractors pick and weigh the fruit, which are then pre-cooled to 2° to 8°C, packed into lidded punnets, labelled with date code, etc., palletised, and then

stored in a cool room. We are very meticulous in our grading, and operate under the SQF and HACCP quality assurance programs.

Destination of crop (local, major urban markets). Our main market is the national Coles Supermarket operation.

Details of involvement with local tourism industry and other businesses on the Sunshine Coast. We support our local community through donations to retirement villages, schools, girl-guides, etc.

Provide details of attempts to reduce the impacts of your farming operation on the environment. We mulch the inter-rows, adjust fertiliser and water applications to make sure that no water or nutrients move off-site. We also maintain wildlife corridors, and tolerate the local scrub turkeys, parrots, blue jays, etc.

What are major issues facing the local strawberry industry. Over-production of strawberries by inexperienced producers who saturate the market with poor quality fruit.

Provide details of your involvement in industry research, extension and development. We have been involved in cultivar and irrigation trials. We represent the strawberry industry at local, state and national levels.

4.

Name of enterprise. Rivendell (Mick McGinnis).

Location. 128 Simba Road, Woombye.

Size of operation. Seven hectares, fully netted.

Crops grown. Low chill stonefruit (peach and nectarine) – 4,000 trees. Non-astringent persimmon – 1,100 trees. Beef cattle – integrated into management plan. 10,000 strawberry plants to maintain picking crew.

History of enterprise. The vacant and undeveloped pastureland was purchased in 1983. This allowed for a strategic design and layout of future activities. Initially planted Lady Finger banana and papaw (papaya), but changed the orchard in 1994 when I realised that the competition from North Queensland would be too high. The enterprise has been at the mature orchard phase for the past two years, and is now into the replacement phase.

Background of owners. Banana and papaw (papaya) in a nearby orchard from 1978 to 1983.

Main focus of enterprise (pick your own, sustainable growing techniques, etc). Survival in a competitive market! We aim to supply a commercial niche market with very early (early August) harvest, high quality, high priced stonefruit. We are part of a tightly focused group of three farms, with selected outside growers providing some product with close contact between participants, agents and buyers. I am a Member and Director of the Australian Persimmon Export Company with suppliers in four states exporting to South-East Asia.

Number of employees (full time and casual). One permanent and four casuals for nine months of the year. We want a stable, highly skilled workforce and stagger our farm production, with stonefruit in spring, persimmon in autumn and strawberry in winter.

Main cultivars grown. We grow mainly 'Sunwright' nectarine, 'Flordaprince' peach, 'Fuyu' and 'Jiro' persimmon and 'Festival' strawberry.

Source of planting material. Commercial nurseries. Festival strawberry runners from Stanthorpe Queensland.

Soil type. Weathered, heavy, shallow, stony, volcanic clay that is naturally high in magnesium (Mg).

Soil preparation (fumigation, etc.) used. We build up row mounds and apply large quantities of organic matter.

Type of irrigation system used, and method of scheduling irrigation. We use only drip irrigation.

Fertilizer program used (application before planting, fertigation, foliar fertilizers). Essentially, we use "soil conditioners" rather than standard chemical fertilizers. When adding N, P and K, we use naturally-derived products whenever possible (eg. P from colloidal clay and Ca that is earth based). We use micronised Ca

through the irrigation water. We avoid soluble chemical fertilisers as far as practical, using potassium sulphate and nitrate when necessary, along with potassium humate. We apply micronutrients such as Zn, Mo and B whenever necessary.

Method for determining fertilizer applications. We use soil and leaf tests, along with previous experience.

Are there problems with birds and other vertebrate pests? No. Most flock birds, eg. crows, lorikeets and fruit bats are excluded by the netting. Some eg pale-headed rosella parrots and grass parrots have over time, found entry into the netted area, but are not a significant problem.

Main pests and their control. Netting has altered the microenvironment around the crops. Queensland fruit fly (QFF) is significant. We use male baits and cover-sprays at appropriate times (FF has a low damage threshold). Peach white scale is difficult to see, but can be a major problem. We spray strategically. For clearwing moth (CWM), we physical remove the girdling grubs early in season and spray CWM 'mating-disruptive' pheromones later in season. Sooty mould is related to scale and mealy bugs. Controlling ants often reduces the scales. We monitor the crop as part of IPM and only spray when necessary. We have introduced predatory mites for the stonefruit and strawberries.

Main diseases and their control. We use commercial fungicides, pre- and post-harvest, with an ozone generator in the cold room.

Destination of crop (local, major urban markets). The persimmons are sent to South-East Asia, and the stonefruit and strawberries to niche markets in Brisbane and Sydney.

Provide details of attempts to reduce the impacts of your farming operation on the environment. The operations on the farm are based on reducing the effect of agriculture on the environment. The SQF2000 Management System provides details of the activities that can affect the environment, soil, water biodiversity and ways to monitor and minimise these. We regularly monitor water quality in the local Petri Creek above and below our enterprise. We aim to minimise soil erosion and want to keep all the soil, chemicals and nutrients on the farm. We implemented significant earth works when we purchased the farm to meet this objective. The crops grown have high light requirements and therefore, the rows run NS irrespective of slope, and require 60 cm mounds along rows. The ends of rows have contour drains. The gentle gradient is designed to slow the run-off to allow settling, filtering and sedimentation of soil particles. The run-off accumulates in a dedicated settling tank and then into the creek. The water leaving the farm is invariably clear. This system also allows pondage for water storage.

Provide details of your involvement in industry research, extension and development. Commercial involvement – staying in business. I have been a representative on QFVG Committees for 24 years, and a representative on community environment issues, eg. Chairman on Catchment, National Heritage Trust (NHT) and Land Care Committees.

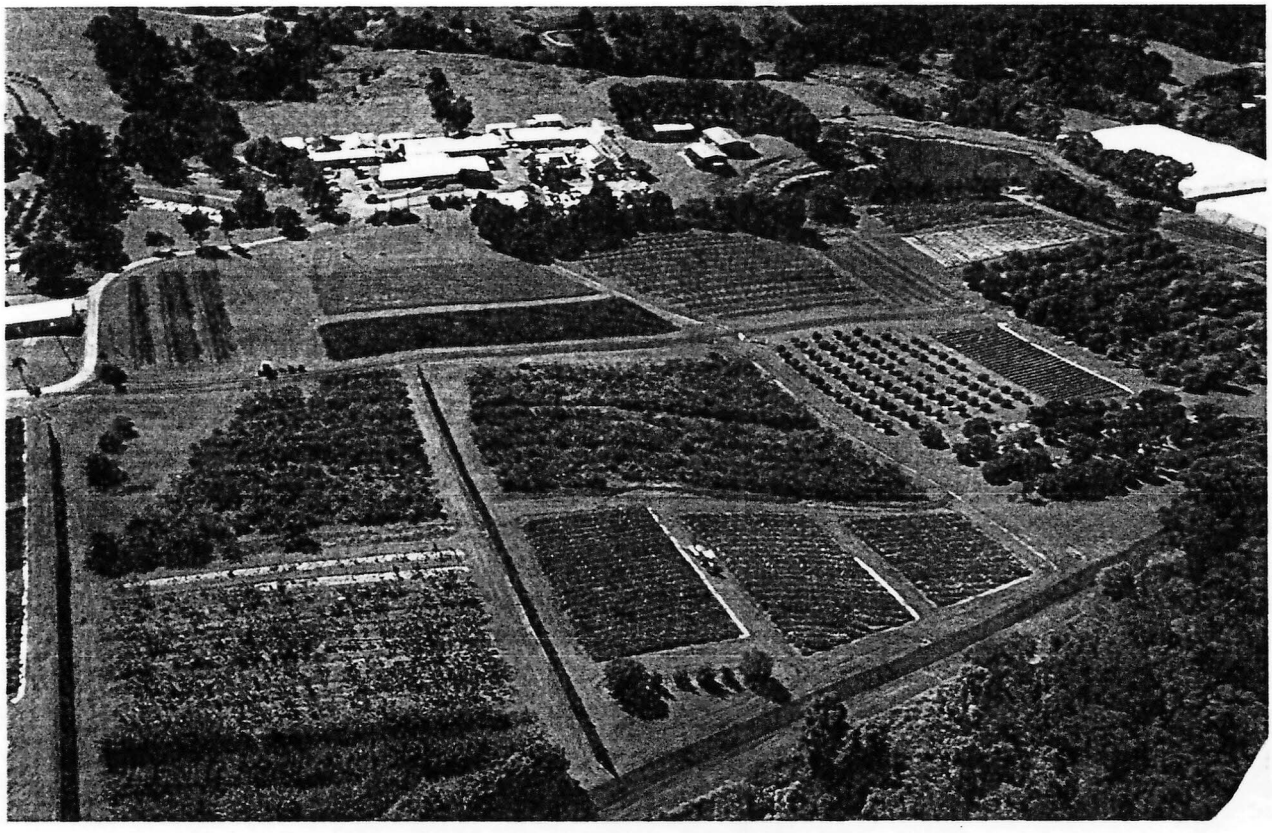
5.

MAROOCHY RESEARCH STATION, MAYERS ROAD, NAMBOUR

The Maroochy Research Station is owned and operated by the Queensland Government's Department of Primary Industries and Fisheries, and specialises in research and extension services for subtropical fruit industries. The station consists of 60 hectares, of which less than half is used for research purposes, the remainder being native bushland and open space. The farm was originally used almost solely for pineapple research, with the focus shifting to tree crops and strawberries in the 1970s and 1980s. Major programs and projects currently in place cover pineapple, avocado, strawberry, macadamia, citrus, low chill stonefruit, sweet persimmon, passionfruit, ginger and subtropical banana. The station has strong bonds and links with many other research centres nationally and internationally, and regularly hosts visiting scientists and visiting groups. Staff are also involved in a number of international projects, primarily in south east Asia through the Australian Centre for International Agricultural Research (ACIAR).

The station employs about 40 permanent and 15 casual or part-time staff across research, information, extension, biotechnology, regulatory and administrative disciplines.

The visit will feature strawberry research activities and provide a brief description of major research activities in other crops currently under investigation and development.



Location

Nambour is located about 100 km north of Brisbane, with regular bus and electric rail services connecting to the Domestic and International Airports. The local Maroochy airport with services connecting to Sydney and Melbourne is only 15 km away. Maroochy Research Station is located at 26° 38' 40" S; 152° 56' 23" E AMG (Australian Map Grid reference) at elevation of 33 m. Maroochy Research Station is 4 km SSW of the Nambour town centre while the eastern shore line of Australia and the South pacific Ocean is 16 km E.

Geography and land use

The research station is undulating, with moderate to steep slopes up to 30%. The site is drained by two major watercourses that are tributaries of Coes Creek. The area has a wet subtropical climate with an annual rainfall of 1700 mm. Sixty-five percent of the rain falls from December to March, with occasional tropical cyclones bringing torrential rain and gale-force winds. Frosts can occur in low-lying areas from June to August. Mean monthly total rainfall, mean number of rainy days, and mean monthly maximum and minimum temperatures are given in Table 1.

Table 1. Mean monthly rainfall, number of rainy days, and mean monthly maximum and minimum temperatures for Nambour.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	238	261	236	148	143	90	90	53	47	107	141	176
Number of rain days	16	17	18	13	13	9	8	8	9	12	12	13
Mean max. temp. (°C)	29.1	28.5	27.9	26.1	23.6	21.6	21.0	22.4	24.7	26.5	28.0	29.0
Mean min. temp. (°C)	19.1	19.6	18.2	15.3	12.0	9.2	7.6	7.8	10.4	13.6	16.2	18.0

All original vegetation with the exception of 6 ha was cleared for dairy and pineapple production prior to purchase by DPI&F. Clearing of this eucalypt forest is likely to have occurred 70 to 100 years ago. Original and regenerated forests are present on the site as well as a small area of rainforest. There is also one ha of replanted forest, and tree belts forming a natural buffer between the site and neighbouring properties. Currently, fruit tree, berry crops, and grass (non-arable areas) are the predominant vegetation. The three soils on the research station are easily identified by surface soil colour and by their position in the landscape (Table 2).

Table 2. Description of the major soil types at Maroochy.

Soil	Great soil group	Comments	Proportion of site
Ninderry	Earthy podzolic	Soils occur on hill crests and slopes often in complex with lithosols	50%
Woombye	Sandy podzolics	Soils are moderately deep, with a sandy texture and good drainage	10%
Perwillowen	Prairie soil to minimal prairie	The geology is dominantly tertiary basalts	40%

Maroochy has 61.2 ha in total, originally purchased as three blocks the first 46.1 ha, the second 11.0 ha and the third 4.0 ha. The current land use is as follows: citrus IPM (1 ha), in-ground lysimeters (1 ha), macadamia cultivars (2 ha), strawberry breeding (2 ha), strawberry entomology and pathology (3 ha), avocado cultivars (1 ha), fruit fly exclusion netting (2 ha), stonefruit breeding (3 ha), subtropical tree research (6 ha), pineapple breeding (3 ha), custard apple breeding (6 ha), office, buildings and surrounds (6 ha), roadways and internal access (5 ha), creeks, drainage and forests (8 ha), with a non-arable area of 12 ha.

Water supply

Maroochy has on site water storage of 75 megalitres for irrigation that is stored in three earth wall dams. A reliable rainfall and a good catchment recharge the dams on a regular basis. Storage adequately meets irrigation demand. An array of irrigation infrastructure is utilised to service the requirements of research crops, plant and glasshouses.

Breeding Better Strawberries

The strawberry breeding program at Maroochy aims to produce varieties for production from late autumn to spring. Sections of the program are conducted at Cleveland, Bundaberg and Applethorpe. The main drivers are ensuring that the berries are easily harvested, attractive, delicious, and travel well, and that the plants are productive early in the season and for the whole season, up to the end of August. Cultivars developed recently include: 'Redlands Joy' released in 1992 (attractive, large, firm, sweet berries); 'Kabarla' released in 1995 and 'Maroochy Flame' released in 1997 (early cropping, firm berries); 'Earliblush' released in 2000 (very early and high yielding); 'Harmony' released in 2003 (large, deep red, juicy berries); 'Brighteyes' released in 2003 (large, orange red, firm berries); 'Sugarbaby' released in 2003 (early season, medium sized, red, juicy berries); and 'Rubygem' released in 2003 (early season, large, deep red, juicy berries).

The breeding procedure involves:

- Choosing the most important characteristics that a successful cultivar needs, and looking to see what is available in the current genepool, here and overseas.
- Making crosses between suitable parents (approximately 30) and growing on the 5,000 to 15,000 seedlings.
- Evaluating the seedlings over three years to select the top two or three lines.
- Evaluating the new lines in on-farm trials under a range of commercial conditions.
- Conducting "time of planting" trials, and if appropriate, some formal/professional taste panels.
- Assessing whether the new lines need different pest, disease or fertilizer management.

It usually takes four to five year years before the new lines are available commercially. Fresh material planted in late March begins cropping in early May and continues fruiting until mid-September. Double rows of plants on black polythene in non-fumigated beds (30 cm inter-row, 40 cm intra-row and 140 cm between bed centres) are employed, along with trickle irrigation, fertigation, and standard pest and disease management. Data on fruit weight and fruit number are collected weekly from one to three blocks, with six plants per plot.

Containerised Plants

Plugs or containerised plants offer potential advantages over traditional runner plants. Some of these benefits include easier planting, better establishment, fewer pests and diseases, lower water use after planting and therefore less leaching of applied fertilizers. Plugs also offer the potential for mechanical planting. In some areas of Europe and northern America, plugs provide earlier production, greater productivity and larger fruit over runners. Research has also shown that the plants can be grown under controlled conditions (short days and low temperatures) to manipulate flower initiation and fruiting. Plugs are more expensive compared with runner plants, and will only be adopted by industry if the extra costs are matched by increased returns to producers.

Chris Menzel and Geoff Waite investigated the productivity of 'Festival' and 'Sugarbaby' propagated by plugs (33 cm^3 containers) and runners from Stanthorpe in southern Queensland (elevation of 872 m), and grown at Nambour on the Sunshine Coast (elevation of 29 m). The harvest season commenced after 60 days, with the plug plants yielding only 60% of the yields of the runner plants. The lower yields of the plug plants probably reflect their small size at planting. Future research will determine whether plugs grown in larger cells (75 to 300 cm^3 as in the USA and Europe) are more productive. The tips grown in larger containers would need to be harvested earlier than those in small cells to maximize root growth before planting. This will probably extend the time required to harvest the tips and pot them from the current four to five weeks, to eight to ten weeks.

Sustainable Pest Management

Geoff Waite, Principal Entomologist, has worked at Maroochy for 24 years. During that time he has been involved in developing IPM systems for tropical and subtropical tree crops such as avocado, macadamia and lychee, but more especially for strawberry.

When the predatory mite, *Phytoseiulus persimilis*, became available in Australia in the early 1980s, Geoff initiated experiments to investigate its ability to control spider mite, *Tetranychus urticae*, in the strawberry crop grown in the field. Results on protected crops in Europe had looked promising, and early work in California showed that the predator could suppress spider mites in the field, but in those trials, enormous numbers were required. By 1983, the first field experiments had indicated that when the predators were released early, control was possible with random *P.* persimilis release rates as low as two individuals per plant. However, only a few growers were prepared to adopt this strategy, with the bulk of producers preferring to use chemicals, which were phytotoxic, and to which the spider mite was becoming resistant. The 'pest in first' (PIF) strategy was suggested as far back as 1984, but it was not until disaster hit one of the larger orchards in 1993, that it really took off. Today, biological control of the mite operates on about 70% of Queensland's strawberries, with management of the other pests tuned to the preservation of this valuable predator. Because of the system used for the mass rearing of the predators, the pest in first system has evolved into the 'simultaneous release' (SR) system.

Current research is centred on accumulating data for the efficacy of predator-friendly insecticides for controlling caterpillars, and attempting to demonstrate to interstate quarantine groups that bait sprays are suitable for the control of fruit flies, and are effective substitutes for cover sprays of dimethoate, which disrupt the predatory mite.

Integrated Disease Management

Don Hutton has been working as a Plant Pathologist in strawberries since 1988, and continues to be a part of the Better Berries Program Team with a focus on developing integrated disease management (IDM) programs to support the Queensland industry.

The current work seeks to address issues in both fruit and runner production. Activities include developing alternatives to methyl bromide, integrated disease management of fruit rots, management and monitoring of *Colletotrichum* crown rot in the runner beds and management of strawberry lethal yellows with Entomologist Geoff Waite. Work with methyl bromide has concentrated on alternative fumigants, along with the effects of solarisation, biofumigation and biological agents. This work has also sought to monitor the occurrence of diseases occurring in the absence of methyl bromide.

The disease work with fruit rots has contributed to the registration of key fungicides for black spot (*C acutatum*), grey mould (*Botrytis cinerea*) and powdery mildew (*Sphaerotheca macularis*). We have also sought to provide information about the relative susceptibility of new cultivars and advanced breeding lines to these diseases. We have established a nursery where we are able to screen the new gene pool for resistance to *Fusarium*. The lethal yellows work, in collaboration with the Charles Darwin University has shown that a phytoplasma and a rickettsia both cause symptoms. We are now studying potential methods for controlling these diseases in the field.

Control of *Colletotrichum* crown rot has been a major achievement. We regularly monitor runner production from the tissue culture stage to the harvest of the runners in the field, with the runner growers applying prochloraz at fortnightly intervals.

OTHER CROPS STUDIED AT MAROOCHY

A wide range of subtropical tree crops have been studied over the past 25 years. Much of this research has contributed to the successful development of new industries for Australia including lychee (litchi), avocado, low chill stonefruit and non astringent persimmons and the revitalisation of more traditional industries including custard apple, mango and macadamia. Industries under threat such as banana and pineapple have also been supported by innovative programs.

Appendix 1 provides a brief outline of the Maroochy R&D program. Appendix 2 lists significant achievements by the Maroochy R&D Team.

Appendix 1

A BRIEF OVERVIEW OF THE RD&E PROGRAM

Facilities

- Research farm of 60 ha including a range of soil types, aspects and elevations
- Lysimeter complex
- Office and laboratory complex
- Special tissue culture and biotechnology research laboratory
- Special postharvest research laboratory
- Complex of glasshouses including a controlled environment facility and insectary

Staff

- 26 research staff including assistants (crop improvement, crop physiology and agronomy, entomology, plant pathology, biotechnology, postharvest)
- 9 extension and information staff (including assistants)
- 6 plant and animal health regulatory staff
- 6 farm staff
- 7 administration and IT support staff

Main research and extension programs and projects

Crop improvement program

- Breeding and selection of new subtropical strawberry varieties for early production and better flavour
- Breeding and selection of new better eating hybrid pineapple varieties for the fresh fruit market, particularly in winter
- Breeding and selection of new low chill stonefruit varieties (peach, nectarine, plum) for better subtropical adaptation and market performance
- Breeding and selection of new more productive and better eating custard apples
- Field performance assessment of new macadamia varieties

Crop physiology and agronomy program

- Improved canopy management systems for avocado and lychee
- Use of growth regulators for improving avocado fruit set, size and shape
- Macadamia root and nutrition studies

Entomology

- Improvement of the citrus IPM system
- Improvement of the macadamia IPM system
- Improvement of the strawberry IPM system including refinement of the 'pest in first' system for mite control
- Spotting bug management systems

Plant pathology

- Improved management of diseases in the strawberry runner scheme
- Methyl bromide fumigation replacement technologies
- Integrated fruit rot management in strawberries
- Passionfruit disease resistant rootstock investigations

Biotechnology

- In vitro collection of banana germplasm
- Chromosome doubling to improve ginger rhizome size
- Use of tissue culture to obtain disease and nematode free ginger planting material
- Development of blackheart resistant pineapples

Postharvest

- Disinfestation protocols for interstate and international export of fruit
- Extending storage and transport times for mangoes and avocados
- Postharvest testing of new varieties from the crop improvement program
- Postharvest testing of new field management practices on fruit quality and shelf life

Extension/industry development

- Better Berries Program for strawberry industry development
- Custard apple industry development project
- MacMan project (recording and comparative analysis software; grower discussion groups; benchmarking)
- AVOMAN project (orchard management software, grower discussion groups)
- AVOINFO avocado reference database
- Agrilink project (series of 25 information kits for major fruit and vegetable industries)
- Landcare in horticulture
- Study of peri-urban horticultural farming
- Pineapple study groups and production of a best practice manual

International projects funded by Australian Centre for International Agricultural Research (ACIAR)

- Evaluation of new temperate fruit crops in Thailand, Laos and Vietnam
- Development and evaluation of landcare in the Philippines
- Development of blackheart resistant pineapples (Malaysian partners)
- Supply chain issues for bananas (Indonesian partners)

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Appendix 2

ACHIEVEMENTS

- Macadamia long-term regional cultivar trials have lead to a revolution in industry variety selection and the industry becoming internationally competitive.
- Macadamia varieties rated for tolerance to the major disease, huskspot to aid variety selection. A highly effective IPM system for huskspot disease management developed.
- An introduced parasitic wasp successfully controlling macadamia nutborer.
- Plant nutritional element standards defined for macadamias
- Integrated Pest Management System developed for the subtropical citrus, featuring imported exotic parasitic wasps.
- Systems approach to the control of the serious citrus disease, blackspot that is definitive and allows worldwide trade.
- Control of *Phytophthora* root disease in citrus, using phosphonates.
- Identification of the major plant vascular disease Bacterial Wilt in tree crops for the first time
- Development of tree injection with phosphonate saved the avocado industry from devastation caused by the *Phytophthora* root disease.
- Rootstocks, canopy management and growth regulators increased the productivity and quality of avocado.
- Agrilink information kits produced for a range of fruit and vegetable crops.
- Computer based decision support and orchard management systems providing major improvements to the avocado, pineapple and macadamia industries.
- A series of early season quality strawberry varieties produced for the Queensland industry.
- Climatic limitations established for a range of tropical and tropical fruit species.
- Integrated nutrition, and pest and disease management developed for strawberry enterprises.
- Maroochy staff have been on the frontline with disease diagnosis, describing new pathogens and helping industry to respond quickly to disease outbreaks.
- An effective IPM system is available to strawberry growers based on control of two-spotted mite. A recent innovation is the "simultaneous release" technique.
- We have the only pineapple breeding program in Australia and have produced new cultivars for the fresh market with higher sugars, lower acid, higher vitamin A & C contents and that are free of blackheart.
- Maroochy maintains one of the world's largest *in vitro* collections of banana germplasm that is being utilised to control major diseases.
- Produced a new ginger variety with larger rhizome, through chromosome doubling, to improve industry profitability.
- Established Australia's first genetically engineered pineapples. Initial targets for improvement are blackheart resistance and control of natural flowering.
- Reduced impediments to exports by reducing the negative impacts of disinfestation procedures on fruit quality.
- Have identified significant constraints in the supply chain that are affecting industry profitability.