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Sub group “Pome Fruit Diseases”**

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**Cesare Gessler, Vittorio Rossi
and Simona Giosuè**

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Meeting at Lindau (Germany), 2002

Control of apple scab (*Venturia inaequalis*) in organic apple growing. StopScab: A Danish research programme for screening substitutes to copper fungicides

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Abstract: The Danish research project StopScab (2002-2004) has recently been initiated to identify and begin to develop some new approaches and materials for the control of apple scab in organic growing. Four linked objectives are included: 1) screening of materials for scab control 2), histopathological investigation of host-pathogen interactions 3) orchard testing of selected control compounds and 4) characterisation of metabolite profiles in apples.

Apple scab IPM: preliminary report on the application of a new sampling technique to determine “scab-risk”

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Abstract: To facilitate grower adoption of apple scab management thresholds, a simplified, autumn sequential sampling technique to determine the ‘scab-risk’ of an orchard was proposed in the scientific literature. However, this technique had not been field validated. This research determined that: (i) the sequential sampling technique provided ‘scab-risk’ orchard ratings consistent with the original, non-sequential procedure, at potentially a significant time savings; (ii) similar ‘scab-risk’ ratings were obtained by using different combinations of trees and shoots within an orchard; (iii) following the ‘delayed-spray’ strategy in ‘low-risk’ orchards did not result in significant differences in fruit scab at harvest compared to spraying from the green-tip bud stage.

Spatial distribution of ascospores of *Venturia inaequalis* within the tree canopy

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Abstract: The amount of airborne *Venturia inaequalis* ascospores present during an infection period is rarely considered. Airborne ascospore concentration (AAC) can be measured, in real time with spore traps. However, the level of heterogeneity of the AAC within an orchard block makes it unreliable. Moreover, when the spore traps are located near the ground (height of 40 cm), the correlation between AAC and scab development is poor. To optimize the use of AAC as a decision tool, the spatial distribution of *V. inaequalis* ascospores within tree canopy was studied.

The airborne (AAC) and rainborne (RAC) ascospore concentration were measured in 31 locations within tree canopies (cv McIntosh) and at 6 heights (20 to 275 cm) from the ground with volumetric air samplers, passive traps and funnels devices during 6 major rain events of the spring 2001 to 2002. Scab severity was measured on leaves surrounding the trapping devices. The AAC measured with the volumetric spore traps decreased with increasing height from 20 to 275 cm and the RAC increased with increasing heights. Higher correlations were obtained between scab severity and AAC when the volumetric samplers were located at the tree level (80 to 120 cm) than at the ground level (20 to 40 cm). The experiment was conducted in an orchard block with high inoculum potential. In commercial orchards with lower inoculum, it would be more difficult to measure ascospores at this height due to the reliability of the trap. Nevertheless, the results of this experiment showed that it was possible to measure rainborne ascospore concentration and the AAC are not uniformly distributed within tree canopy.

Sanitation practices to reduce apple scab inoculum in orchards *

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Abstract: Economical and pomological factors have increased the sensitivity of modern orchards for fungal diseases. Different strategies must be integrated in the control measures to achieve a sustainable production system. The disposal of modern fungicides with a high performance is only one pillar in disease management. Sanitation, optimal timing of spray treatments, adequate application techniques and resistance risk modifiers are the main tools to obtain an integrated durable fruit production structure. Besides this agricultural approach, the consumer attaches more importance to the side effects of pesticides on the environment and eventually the residues left on the fruits.

Scab (*Venturia inaequalis* on apple and *Venturia pirina* on pear) is the key parasite on pipfruits. On the most commercial varieties, more than 60 % of treatments are related with scab control. The evolution to monocultures of one variety, and the ban of plant growth regulators to shorten the growth period and in this manner the infection period, has increased the infection pressure to a level that one mistake in the spray program can lead to an economic disaster. In the scab risk assessment, biological factors as inoculum, varietal susceptibility, ascospore release and leaf growth are incorporated in Mills infection periods to improve scab-warning services. The determination of biotic parameters is enormously labour consuming and here software image analysing systems and simulation models can contribute to better estimate the infection risk.

Several practices can be used to reduce the amount of inoculum in the orchard and to enhance the efficacy of the fungicide program. Spray coverage and distribution are improved by pruning the tree in an open canopy. Moreover this improves penetration of air and light, which shorten wetness periods on leaves and fruits. Reducing or eliminating apple scab inoculum on overwintering leaves reduces disease pressure in spring. In our research program we have carried out different trials to limit the overwintering population.

Effect of apple cultivar mixtures on the epidemic of *Venturia inaequalis* in a treated orchard

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Abstract: In an experimental orchard comprising 2 different cultivar mixtures, a fungicide applications protocol with a treatment threshold was applied. However, difficult climatic condition caused a decrease of the efficiency of 3 treatments. In this situation of fungicide treatments failure, the within-row mixture efficiently reduced the apple scab epidemic on fruits and leaves of the Smoothee cultivar compared to monoculture, but was not efficient to reduce significantly scab on fruits at harvest. The scab epidemic in the between-row mixture was not so high than in the monoculture, but the differences observed were not significant. This work showed that within-row mixtures can reduce the scab epidemics when the fungicides action does not control completely the disease.

Phytotoxic effect of lime sulphur on apple and pear

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Abstract: The total area of cluster leaves and the general leaf condition were reduced by the preventive lime sulphur schedules on apple, but not for the curative lime sulphur schedule. Russetting of fruits increased by the preventive lime sulphur schedule on apple in 2000 and to a minor extent in 2001. The curative lime sulphur schedule promoted russetting in apple in 2000, but not significantly in 2001. Consequently, the percentages of first class apples were reduced by the lime sulphur schedules. There was no effect on total production.

On pear, the total area of cluster leaves tended to be smaller in the preventive lime sulphur schedule in 2000. This effect was significant in 2001. There was no effect of the lime sulphur schedule applied at high spray volume (1000 l/ha) on pear leaf condition in 2000, but the leaf condition was affected in 2001. However, lime sulphur schedules did not affect the leaf condition when applied at a spray volume of 200 l/ha or at half the standard dosage. Lime sulphur schedules produced more russetting of pear fruits. The production decreased in the lime sulphur schedule in 2000, but not significantly in 2001.

It was concluded that lime sulphur could be phytotoxic on both apple and pear under the Dutch climate conditions.

Pome fruit storage diseases

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Abstract: Pome fruits are one of the main Portuguese cultures with great economical importance. They can be stored for very long periods, sometimes reaching nine or ten months. Several fungi often cause diseases in fruits during this period, although they can be originated in the orchard or in the store. The aim of this work is to quantify and describe the mycological pathologies in apples and pears stored in refrigerated chambers and under several conditions related with different atmosphere contents and post-harvest fungicide treatments. Samples of different kinds of fruits ("Rocha" pear, Golden, Gala Must, Royal Gala, "Reineta" and Starking apple) were taken and, after being accounted, the pathogenic fungi were isolated from them. *Alternaria*, *Aspergillus* and *Penicillium* were the most common identified fungi but several other fungi were isolated, mostly saprophytic ones. To store fruits for a long time, the use of controlled atmospheres and the treatment with fungicides are profitable. Under such conditions, rotting decreases and fruit quality remains better. Controlling post-harvest diseases is an integrated system which involves the hygiene of the orchard and the store chamber, the handling and the storage programme, all carefully planned in accordance with the storage period.

Durable disease resistance and high fruit quality, a challenge for apple breeding

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Abstract: High fruit quality and durable disease resistance are crucial aspects in apple breeding directed towards sustainable production systems. Results of consumer tests with new disease resistant apple cultivars confirm that progress has been achieved in improving fruit quality and, as a consequence, in consumer acceptance. Fruit firmness, juiciness and aroma are among the most important criteria. The challenge of breeding durable disease resistant varieties is approached by developing efficient molecular techniques that allow to detect the combined presence of the target resistance genes in a seedling. First examples for molecular selection towards genotypes with pyramided genetic resistance against scab (*Venturia inaequalis*) and powdery mildew (*Podosphaera leucotricha*) are promising.

Geographical distribution of *Venturia inaequalis* strains virulent to the *Vf* gene in Europe

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Abstract: The results obtained in the frame of the DARE project, added to the previous published data, allow the distribution of the *V. inaequalis* strains virulent to the *Vf* gene to be mapped in Europe. Nine years after the first report of the presence of race 6 in Germany, and 8 years after the first report of the presence of race 7 in England, the results showed that races 6 and 7 were present in 7 European countries, situated mainly in the Northern part of Europe. Strains combining the virulences of races 6 and 7 were detected in the Netherlands. In this country, as in France and Denmark, the presence of virulent strains was reported in commercial orchards. These data question the stability of the *Vf* gene resistance in Europe and the management of the *Vf* resistant cultivars.

Factors influencing deposition of *Venturia inaequalis* ascospores on apple trees

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Abstract: A model simulating the deposition of *Venturia inaequalis* ascospores on apple leaves was used to determine the effect of rainfall, wind, distance from the inoculum source, and tree canopy density (as LAI, leaf area index) on the number of ascospores deposited per leaf area unit. LAI and rainfall had a significant effect on ascospore deposition. The effect of wind is closely related to the distance from inoculum source, and can be considered of little importance at an orchard scale. Using data from model simulations, the proportion of airborne ascospores deposited on apple leaves in relation to LAI and rainfall was estimated by a combination of two regression equations. The first equation accounts for the proportion of spores released into the orchard air from pseudothecia that remain in the air layer between the ground and the lowest leaves; since these spores do not reach the apple canopy, they are removed from the airborne ascospore dose. The second equation determines the proportion of ascospores deposited onto the apple leaf surface. Deposition of all the ascospores which are airborne within the canopy is possible only when LAI is equal to or greater than 1, and there is rain. Since the primary inoculum season usually advances when there is little foliage on the trees, and ascospore ejection, though initiated by rain, continues with no rain, the findings from this work have a practical importance and should be used to improve estimation of the risk level for scab infection.

A Chorus tolerant population of *Venturia inaequalis* found in a South African apple orchard

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Abstract: At the farm, Ouplaas, in the Agter Witzenberg area, South Africa, Chorus 50 WG was used for the control of apple scab from the 1996/97 to the 2000/01 growing seasons. During the 1996/97 season it was applied six times at pre-blossom stage as well as at the early post-blossom stage, while during the other seasons application was only at the pre-blossom stage and never more than three times per season. In the 2000/01 growing season severe fruit scab was experienced in an Early Red orchard at Ouplaas. The first symptoms were observed a fortnight to three weeks after the last Chorus application. In order to determine whether Chorus tolerance of the scab fungus was the reason for the severe scab incidence, the following investigation was conducted. Scab infected leaves and fruit were collected in the problem orchard and the scab fungus was multiplied on fungicide free potted MM109 rootstock trees. Three groups of potted MM109 trees each were sprayed with Chorus 50 WG at 30g/hl (1X), at $\frac{1}{2}$ X and at $\frac{1}{4}$ X respectively. Unsprayed control trees were kept as well. One day later half of the trees of each group were inoculated with a conidial suspension of the Ouplaas scab fungus line, while the second half was inoculated with a conidial suspension of a reference fungus line. The latter was known to be sensitive to all fungicides used for the control of scab in South Africa. All rates of Chorus gave more than 90% scab control on trees inoculated with the reference fungus line, while on trees inoculated with the Ouplaas fungus line, scab control varied between 71 and 37% on trees sprayed with the 1X, $\frac{1}{2}$ X and $\frac{1}{4}$ X of Chorus. After withholding Chorus applications for two seasons from orchards at Ouplaas, scab infected leaves and fruit were collected again in the problem orchard in January 2002, the second part of the 2001/02 growing season. Then scab control by Chorus was compared on three scab fungus lines, i.e. the reference fungus line, the 2000/01 collection and the 2001/02 collection. Control of the sensitive reference fungus line was more than 97% on trees sprayed with any of the three rates of Chorus, while control varied between 26% and 43% on trees inoculated with the two fungus lines from the Ouplaas orchard. There was virtually no difference between control of the 2000/01 and the 2001/02 collections from the Ouplaas orchard except that at the highest rate of Chorus control of the 2001/02 collection was significantly better. Excessive use of Chorus has to be avoided for the control of scab. It should not be applied more than twice per season. Once Chorus tolerance has been demonstrated in an orchard, Chorus or any other anilino-pyrimidine fungicide should not be used for the time being.

Evaluation of *in-vitro* grown apple shoot sensitivity to *Venturia inaequalis* using a detached leaf assay

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Abstract: Assessment of scab susceptibility or resistance of apple plantlets, grown *in-vitro*, is important for early assessment of individuals transformed with putative scab resistance genes. Useful clones can be selected and only these plants need be grown further and acclimatised to the greenhouse. Here we describe a detached leaf assay carried out using *in-vitro* grown shoots of the cultivars Florina, Enterprise and Gala. We define resistance reaction classes observed on a microscopical level that enable us to distinguish resistant (*Vf*) cultivars from susceptible ones. Under the conditions described statistically significant differences are seen between Florina (*Vf*) and Gala. Also tested are Florina shoots that have been re-generated from calli, as transformed plantlets would be. No significant variation was observed between the results from these plants and those of Florina shoot tip cultures.

An adaptation of the New Hampshire degree-day model to predict ascospore release of *Venturia inaequalis* in Norway

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Abstract: Volumetric spore traps were used to monitor ascospore release of the apple scab fungus, *Venturia inaequalis*, at four locations in southern Norway. Forecasts of a model of ascospore maturity, previously developed in New Hampshire (Gadoury & MacHardy, 1982), were compared to observed release. The model predicts 50, 95, and 99% spore maturation to occur at 250, 420, and 490 degree-days (DD), respectively. In the current investigation, the mean DD accumulation (base temperature 0°C from the green tip phenological stage of the apple flower bud) at the time when the seasonal spore trapping had accumulated to 50, 95, and 99% was 334, 621, and 694, respectively. In locations and years with frequent rain events throughout the season for ascospore release, the actual spore release followed the predicted maturation closely. Long periods without rain not only delayed spore release, but also spore maturation and consequently extended the season for ascospore release. The most extreme year was 1992, when DD accumulation at the time 95% of the season's spores were trapped reached 1305 and 1092, respectively, at two sites. By halting DD accumulation during dry days, it was possible to improve the accuracy of the model. The best estimate of the spore maturation was made by halting DD accumulation after more than 4 days without rain.

Meteorological data for warning systems: some views concerning sensors

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Abstract: Weather data, as a basis for estimating various biological developments, has become an important resource in our efforts to produce food with more environmental-friendly methods.

Mainly three different types of weather stations are used in Sweden; Metos, Adcon and Campbell. Some discriminating features are presented. They are used either as stand-alone instruments or in smaller networks. Whether the sensors should be placed in or near the crop, or according to the rules for “normal” stations used by public weather institutes, is another important issue.

Main items discussed in this lecture are weak points in the field part, especially leaf wetness sensors and relative air humidity sensors. Some systems calculate the leaf wetness periods and there are two types of sensors used, with two different ways of presenting the leaf wetness status. The importance of high quality system maintenance and a validation system for the database is also emphasized.

The simulation of ascospore release from apple scab: do we use suitable climatic data?

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Abstract: Simulation of ascospore release with RIMpro shows a good accuracy in timing and quantity of released ascospore compared to trap records, however the peak release period may be delayed compared to trap counts. Also ascospore releases under special climatic situations like cold periods, snow cover and after extended dry periods are not properly calculated by the programme under all circumstances. Using climatic data like temperature and wetness driving ascospore maturation and release from leaf litter instead from the tree canopy as usual, the overall accuracy of the simulation has been improved significantly as well as the above mentioned releases under special climatic conditions. The high value of the programme can be increased by feeding the developmental stages of the fungus taking place on the orchard floor with temperature and wetness data from the leaf litter and the infection process itself with traditional climatic data from tree canopy.

Chemical control of apple powdery mildew (*Podosphaera leucotricha*): mode of actions

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Abstract: Eight fungicides (dinocap, kresoxim-methyl, myclobutanil, bupirimate, fenarimol, triadimefon, penconazole and pyrifenoX) were tested for their epidemiological mode of action (e.g. protectant, anti-sporulant, curative activity) against *Podosphaera leucotricha* at two rates (25% and 100% of the label recommended rate) in comparison with untreated or water-treated plants. All the fungicides were effective in controlling powdery mildew when applied as a protective, anti-sporulant and curative treatment. Fungicides differed significantly in their efficacies. However, these differences were generally small compared to the differences with the controls. Protective activities (or persistence) decreased more or less linearly with the interval between fungicide application and inoculation. Fungicides had little effect on disease when leaves were inoculated 10 days after application. The curative activity varied little between applications applied 48 and 96 h after inoculation. In general, application at quarter rates significantly reduced the fungicidal activity, especially for triadimefon, penconazole and kresoxim-methyl. PyrifenoX, myclobutanil, dinocap and bupirimate were shown to be the most effective fungicides, whether applied as a protective or curative, anti-sporulant treatment.

Meeting at Piacenza (Italy), 2005

Biological characteristics of dicarboximide-resistant isolates of *Stemphylium vesicarium* from Italian pear orchards

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Abstract: Dicarboximide-resistant isolates of *Stemphylium vesicarium* have been detected in Italian pear orchards since the early 1990s. Two different resistant phenotypes were observed during a 9 year monitoring study. R1 phenotypes showed Resistance Factor (RF) > 100 towards procymidone and between 3 and 100 to the other dicarboximides (iprodione, vinclozolin and chlozolinate) whereas R2 phenotypes showed RF > 100 towards all fungicides of this group. Various morphological and physiological characteristics of the different resistant isolates, such as mycelial colour, mycelial growth rates, sporulation, germination rates and pathogenicity on detached leaves, were compared to those of sensitive isolates. No significant differences could be noted among the phenotypes. Competitive abilities of sensitive and R1 resistant isolates were then evaluated *in vitro* on unamended medium through mixed inoculations of R/S conidia in 75:25, 50:50 and 25:75 ratios. R1 resistant isolates did not seem to be less competitive *in vitro* than sensitive ones in the absence of dicarboximide fungicides.

Control of brown spot of pear in organic pear orchard

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Abstract: Due to the Reg. CEE n. 473/2002 it is necessary nowadays for farmers to reduce the amount of copper applied in the orchard. Following the Regulation, copper applied in the orchard must not exceed 38 kg/ha over the years 2002-2006 and progressively be reduced to 30 kg/ha from 2006 to 2010 and on.

Therefore the efficacy of some copper-based formulations applied at different rates and calcium polysulphate were tested against pear brown spot in an organic pear orchard.

Trial was carried out over the years 2001-2004 in Emilia-Romagna region on cv. Conference particularly susceptible to *Stemphylium vesicarium*.

Bordeaux mixture, copper hydroxide and copper sulphate were compared. In 2001 and 2002, bordeaux mixture applied at 50 and 25 g (cu ions)/lt of and ca polysulphate were compared. In 2003, bordeaux mixture applied at the same rates of the previous years were compared with copper hydroxide at 52,2 and 26,25 g (cu ions)/lt and tri-basic copper sulphate at the rate of 29,25 g (cu ions)/lt. In 2004 the same products were tested but only at lower rates.

Treatment started in may when a volumetric spore-trap recorded the first peak of *S. vesicarium* conidia and continue with a weekly interval until pre-harvest. On the whole 12, 12, 8 and 11 chemical applications were carried out in 2004, 2003, 2002 and 2001 respectively. At harvest disease incidence on fruits were evaluated.

In 2001 and 2002 disease incidence on fruits was relatively low (5,4 and 5,6 respectively on untreated plots), while in 2003 and 2004 the disease caused severe damages (21,6 and 29,5 respectively). Results show that calcium polysulphate was not statistically different from the check. All the copper-based formulations proved to be effective (except the bordeaux mixture at 25 g/hl in 2001) but were not statistically different from each other. The highest efficacy (65%) was obtained applying bordeaux mixture at 50 g/lt but lower rates of copper (25-26 g/lt) provided at most 50% efficacy.

An average of 10-12 copper applications per season against brown spot, at the higher dose as used in the trial would deliver in the orchard from 6-7.2 hg copper. If we consider further copper applications needed to control fire blight and scab, the amount of copper distributed in the orchard will easily overcome the threshold imposed by the CEE Regulation.

Screening of organically based fungicides for apple scab (*Venturia inaequalis*) control and a histopathological study of the mode of action of a resistance inducer

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Abstract: A range of possible substitutes for copper-based fungicides for control of apple scab (*Venturia inaequalis*) in organic growing were tested in laboratory and growth chamber experiments in the Danish project StopScab (2002-2004). Eighteen crude plant extracts, 19 commercial plant-based products and 6 miscellaneous compounds were tested for their ability to reduce scab symptoms on apple seedlings. Most of the compounds were also tested for their effect on conidium germination on glass slides. Fourteen of the crude plant extracts, 13 of the commercial plant products and 5 of the miscellaneous compounds showed promising control efficacies when used either preventively or curatively in the plant assay. A histopathological study was carried out on the mode of action of the resistance inducer, acibenzolar-S-methyl (ASM), which reduced scab severity and sporulation on apple seedlings in several plant assays when applied as preventive treatment. The effect of the inducer on key pre- and post-penetration events of *V. inaequalis* was studied and compared to these events in water-treated control leaves. The histopathological study showed that the inducer had its strongest effect on post-penetration events indicated by delayed infection and reduced stroma development. In addition, a small but significant inhibition of conidial germination and a stimulation of germ tube length were observed. This investigation provides new histopathological evidence for the mode of action of ASM against *V. inaequalis* and serves as a model for evaluation of the mechanisms by which the organically based fungicides reduce infection of *V. inaequalis*.

Development of an integrated pest and disease management system for apples to produce fruit free from pesticide residues – Aspects of disease control

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Abstract: In experiments aimed at improving dormant season disease control in apple orchards, observations on time of leaf fall showed that in Cox this was generally complete by end of November compared to Bramley and Jonagold where leaves could still be present on trees at the end of December. Leaves dipped in captan degraded slowly compared to untreated leaves. Copper oxychloride and pyrifenoxy also delayed leaf rotting. Other trials showed that powdery mildew overwintering in buds could be reduced or eliminated by spraying a surfactant when the trees were fully dormant. In a large plot replicated orchard experiment, over four seasons, the pest and disease control achieved in managed plots, based on a zero pesticide residue management system was compared with that in plots sprayed conventionally or left untreated. The zero pesticide residue management system (MS/MR) is based on the use of conventional pesticides (excluding organophosphorus insecticides) up to petal fall and after harvest, but using biocontrol for dealing with pests and sulphur or cultural methods to control powdery mildew and storage rots between petal fall and harvest. Dormant season control of scab and powdery mildew is a key component of the system. Over the four seasons the control of scab, powdery mildew and storage rots achieved by the MS /MR system was as good as or better than that in the conventionally treated plots and at lower cost. No residues of pesticides applied to the MS /MR plots were detected in harvested fruit.

Evaluation of alternative treatments to urea to eliminate leaf litter in organic apple production

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Abstract: Elimination of overwintering inoculum is one of the key factors in the integrated approach to scab control. In conventional production a spray of 5% urea is applied post harvest before leaf fall to reduce or eliminate the overwintering inoculum. The urea acts in two ways (1) directly on the scab fungus by interfering with the formation of the sexual state and (2) by encouraging colonisation of the fallen leaves by micro-organisms, which initiate rotting and make the leaves more palatable to earthworms. Unfortunately use of urea is not permitted in organic production. The purpose of this work was therefore to identify alternatives to urea which could be used in organic production.

Five separate experiments, the latter two at each of two sites, were conducted to test alternatives to urea for post harvest treatment to encourage rotting of apple leaves on the surface of the ground in the orchard post harvest. Apple leaves cv Fiesta collected from an organic apple orchard before leaf fall were dipped in solutions of the test treatments in December, then held on the surface of the ground in batches of 30 in the test orchard. The numbers of leaves that disappeared subsequently due to degradation and earthworm activity was assessed at intervals during the dormant period following treatment. Treatments tested included compost tea, Nugro, Maxicrop, Digester, Sea Vigour (fish oil) and Liquid Vinasse with urea as the standard and an untreated control.

None of the treatments evaluated at standard rates were as consistent or as effective in encouraging leaf decay as urea. Sea Vigour (Fish oil) and Nugro (4000 ppm N = ten times normal rate) encouraged leaf rotting compared to the untreated in some seasons and may be worth including as post harvest pre leaf fall treatments. Compost tea (bacterial or fungal) was completely ineffective and may have delayed leaf rotting.

Heterogeneity in apple scab: implication for management

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Abstract: Scab is an important disease of apple and its control depends almost exclusively on frequent use of fungicides. In north-eastern North America, the strategy to manage apple scab is mainly based on a good control of primary infections, in order to avoid epidemic build-up caused by secondary infections and subsequent fungicide applications during the summer months. During the primary infection period, fungicides are applied on a calendar basis, or based on risk of scab development. In the latter case, the risk for primary infections is estimated mainly from the stage of ascospore maturation and climatic conditions associated with risk of infection.

Disease measurement is essential in every epidemiological study and can be used to evaluate various management tactics. "Without quantification of disease no studies in epidemiology, no assessment of crop losses and no plant disease surveys and their applications would be possible" (Kranz, 1988). To accurately measure disease (incidence or severity, and inoculum level) knowledge on spatial and temporal distribution is crucial. Most of the discussion has focused on temporal distribution and spatial distribution has received far less attention. The objective of this work was to study spatial heterogeneity in apple scab epidemiological components, including primary inoculum, disease expression and host growth.

Heterogeneity in ascospore production was studied at various scales (leaf, tree, and orchard). Regardless of the scale used, high level of heterogeneity was observed among leaves, within tree canopy and among trees within an orchard. This high level of heterogeneity makes ascospore inoculum difficult to measure. Spatial heterogeneity in disease expression (primary lesions) was studied at the orchard level. Overall, spatial distribution of primary lesions was homogeneous. Consequently, primary lesions could be measure accurately using proper sampling plan. Finally, heterogeneity in host growth (leaf emergence and growth) was studied at the orchard level. At the beginning of the season, leaf emergence was homogenous among trees and between various cultivars. From the information on apple scab heterogeneity, it was concluded that primary inoculum is highly heterogeneous and primary lesion as well as growth were homogenous. From these results a different approach of scab management was designed based on detecting first ascospore ejection, rate of leaf emergence and scab development at the end of the primary infection period.

Field and *in vitro* sensitivity of *Valsa ceratosperma* (*Cytospora vitis*) to fungicides

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Abstract: The occurrence of *Valsa ceratosperma* (Tode ex Fr.) Maire, causal agent of Valsa canker, was reported for the first time as a pathogen on pear in the Emilia Romagna region (Italy) in 2001 and since then the disease incidence has greatly increased. Valsa canker is one of the most important diseases of apple orchards in China, Japan and Korea where preventative good farming and chemical treatments (especially with SBIs and benzimidazoles) are the best way to try to control the disease on pear. In order to investigate the possibility of chemical disease control, tests *in vitro* (mycelial growth on PDA) and a field trial were carried out. SBIs, benzimidazoles, strobilurins, dicarboximides, tolylfluanid, fluazinam, fludioxonil, cyprodinil, dithianon, mancozeb and captan were tested *in vitro* assays. Some of the formulated compounds used in *in vitro* assays were applied in the field trial. All fungicides tested *in vitro* were more or less active; SBIs, benzimidazoles, fludioxonil, fluazinam and iprodione showed the best effectiveness. No activity was shown by any of the products in the field trial, probably because they are not able to penetrate through the bark and reach the pathogen in the cortical tissues and phloem.

Sensitivity *in vitro* of *Stemphylium vesicarium* to fungicides

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Abstract: Brown spot, caused by *Stemphylium vesicarium*, is the most important pear fungal disease in Northern Italy and its management relies on frequent preventative applications of fungicides. Dicarboximides (mainly procymidone) are the fungicides most effective against this pathogen but the occurrence of field resistant isolates in the early 1990s led to a reconsideration of other products. *S. vesicarium* sensitivity to SBIs, dithiocarbamates, anilinopyrimidines, strobilurins, phenylpyrroles and sulphamides was evaluated through inhibition tests of conidial germination, mycelial growth and hyphal elongation. Fenbuconazole, penconazole, ziram and strobilurins showed good efficacy on conidial germination also in isolates resistant to dicarboximides, while the best activity on mycelial growth was obtained with anilinopyrimidines, tebuconazole, flutriafol, difenoconazole and propiconazole. The best hyphal growth inhibition was observed with ziram and fenbuconazole.

Relationship between biological agent populations and biocontrol of *Monilinia* spp. in peaches

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Abstract: Nine field experiments were carried out in commercial peach orchards located in Spain and Italy from 2002 to 2004. *Epicoccum nigrum* and *Penicillium frequentans* treatments were applied at flowering and preharvest in a standard schedule to control brown at a concentration of approx. 10^6 or 10^7 conidia ml⁻¹, respectively. Populations of both fungi were estimated on peach surfaces (flowers and fruits) before and after applications as 1) the number of fungal conidia per flower or fruit and 2) the colony forming units (cfu) of each fungi per flower or fruit. The number of *E. nigrum* and *P. frequentans* conidia was 1000 to 10-fold higher respectively than the cfu estimated at the same time. A consistent population of *E.nigrum* (ranging from 10^3 to 10^5 conidia per flower or fruit) and *P. frequentans* (ranging from 10^4 to 10^6 conidia per flower or fruit) were obtained. Our results suggest that fresh conidia were more susceptible to environmental stress than conidial formulations.

Modelling dynamics of airborne conidia of *Stemphylium vesicarium*, the causal agent of brown spot of pear

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Abstract: The BSPcast model has been validated in the pear-growing areas of the Emilia-Romagna region (North Italy) and it gave satisfactory results in identifying infection periods of brown spot, so that it is now in use for advising farmers. Nevertheless, this model produces unjustified alarms when the airborne inoculum of *S. vesicarium* is absent or at low densities. To improve the accuracy of BSPcast, a model (BSPspor) able to simulate the dynamic of inoculum density (i.e. airborne spores) was elaborated. This model allows daily estimation of the potential for inoculum availability, using meteorological data. The model was elaborated using data collected from volumetric spore samplers in several epidemiological conditions (years and locations) and from laboratory experiments. BSPspor calculates an index, cumulated over a 3-day period, based on favourable conditions of temperature and moisture, and corrected by an index of seasonality. To reduce early unjustified alarm, BSPcast outputs can be considered for warnings only when the BSPspor model in the previous days had signalled a peak of inoculum.

Fungicide resistance in apple scab in the province of Québec: an overview of the problem and its implications for disease management

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Abstract: Since no study has been published on fungicide resistance in the province of Québec for over ten years, we conducted a large survey of the incidence of resistance in isolates of *Venturia inaequalis* in commercial orchards. Based on criteria set in the literature, we found that 70 % of the isolates departed from baseline for myclobutanil and 34 % for dodine. Over 60 % of the isolates did not respond to high doses of thiophanate-methyl. No cross-resistance has been observed between the different classes of fungicides. For now, no adverse affect on disease control in commercial orchards has been related to this general loss of sensitivity to post-infection fungicides.

New strategies to improve the efficacy of BSPcast for control of *Stemphylium vesicarium* on pear

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Abstract: Control of brown spot of pear requires fungicide treatments during the growing season. Scheduling fungicide sprays with BSPcast provides fungicide savings ranging from 20 to 70%, but without increasing the disease control levels achieved with the fixed spray schedule. New strategies have been tested in order to increase the efficacy of control using the BSPcast. A BSPcast modified was used and compared to the non modified BSPcast. The BSPcast modified included the new knowledge on the effect of RH during interrupted wetness and used the daily risk ($R=0.2$) as action threshold instead of the 3-day cumulative risk (CR). Trials were performed during two years in an experimental pear orchard in Spain. We can conclude that the use of a daily risk as action threshold does not improve the efficacy on control. On the other hand biological, chemical and mechanical methods were evaluated in field for reduction of ascospore amount. Mechanical methods consisting of leaf shredding or removal were the most effective. Biological control methods based on the application of *Thichoderma* sp. formulates were partially effective. Chemical methods based on copper and urea treatments were ineffective.

Preliminary studies on biology and epidemiology of *Valsa ceratosperma* (*Cytospora vitis*), the causal agent of bark canker on pear in Italy

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Abstract: The Ascomycete *Valsa ceratosperma* (Tode:Fr.) Maire [anamorph *Cytospora sacculus* (Schwein.) Gvritschvili = *C. vitis*] is a new causal agent of bark canker recently reported on pear growing areas in the Emilia Romagna (Italy). The Regional Plant Protection Service isolated the fungus in 2001 and since then reports have greatly increased in all pear growing areas of the region. This is the first occurrence of *Valsa ceratosperma* on pear in Europe while Valsa canker is one of the most important diseases of apple orchards in China, Japan and Korea; in these countries the fungus was only occasionally found on pear and quince. The poor knowledge about the disease on pear led us to undertake various studies on the epidemiological and biological aspects. Observations of the disease evolution were carried out in affected orchards, and laboratory and greenhouse assays made it possible to clarify the preferential ways of fungus penetration and the optimal climatic conditions for spore release. It was also investigated whether phloridzin (a dominant component distributed in leaves, stems, fruits and roots of apple tree) plays an important role in Valsa canker on pear as well as that reported on apple in Japanese studies. Preliminary results confirmed that the fungus infects pear trees through wounds such as the pruning ends; the pathogen can be isolated for a distance of about 5 cm beyond visible lesions and cankers develop rapidly in spring and early summer. Cankers with pycnidia appear in a short time only by the inclusion of a small piece of mycelium in a wound created in the trunk of pear in pot. The studies also showed that pycnidia release spores from February to November, conidia ooze gradually from the different pycnidia inside the cankers and the most important factor for fungus sporulation is relative humidity rather than temperature. Neither perithecia formation nor ascospore release were observed on Valsa cankers.

Virulence of *Stemphylium vesicarium* isolates from pear and other host species

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Abstract: Brown spot, caused by *Stemphylium vesicarium*, is one of the most important pear diseases in Europe. The disease is caused by fungal strains producing host-specific toxins which are responsible for the disease symptoms on some pear varieties. It is known that there is a high degree of differentiation in host specificity among the different isolates of *S. vesicarium*. Pathogenicity and virulence of 78 *S. vesicarium* strains obtained from pear and other host species were studied by a leaf necrosis assay on 3 pear varieties showing different susceptibility to natural brown spot epidemics. The bioassay was performed using conidial suspensions and autoclaved fungal culture filtrates. Strains of *S. vesicarium* showed high variability for both progress of necrotic spot appearance and final disease incidence. Four virulence groups were defined using a multivariate data analysis. Group I included 49 strains from pear, which caused severe necrosis on all the varieties. Group II included only 5 strains isolated from pear which caused severe necrosis on 'Abate Fétel' and 'Conference', as the strains of group I did, but symptoms on 'William' were very light. In group III there were 19 strains from pear which showed less severe symptoms on all the varieties. Finally, group IV was formed by the *S. vesicarium* strains isolated from asparagus, pea, and onion, as well as the uninoculated test. These fungal strains showed only small sporadic necrosis at the end of incubation.

Organic field-testing of compounds to control apple scab (*Venturia inaequalis*) in combination with alleyway cover crops

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Abstract: Field-testing of new potential fungicides acceptable to organic production preventing apple scab (*Venturia inaequalis*) infections on leaf and fruits during primary apple scab infection period was carried out in 2003 and 2004. The testing was done on the variety 'Delorina' in combination with different cover crop treatments, aimed to establish different nitrogen supplies to support tree growth and yield.

Sulphur, had the best effect in these trials and the use of sulphur resulted in an increase in yield, due to more and bigger fruits. Both in 2003 and 2004 the best disease control was achieved with sulphur and some control was also seen with the alternative compounds in 2003. The use of sulphur in combination with a soil treatment that reduces the level of nitrogen available to the trees increased saleable yields. An apparent correlation was found between severity of scab and the flavanol content of the fruits.

The results of this work show that more work is needed in order to find effective alternatives to sulphur and copper fungicides for control of scab in organic apple orchards.

Evaluating the use of RIMpro and Metos weather stations for control of apple scab (*Venturia inaequalis*) in Denmark 2002-2005

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Abstract: The apple scab-warning program RIMpro was tested in an integrated and organic strategy compared to unsprayed and traditional conventional strategy in 2002 to 2004 in the variety Jonagold. The actual discharge of ascospores is compared to the RIMpro estimated value of ejected spores. During the same period a national Internet based scab-warning system build on Metos weather stations and RIMpro software has been developed.

The use of Rimpro scab control strategy with 2 to 4 less sprays during the primary apple scab season controlled apple scab on leaves and fruits at the same level as the traditional strategy. The estimated ascospore discharge seems not to be adjusted to the actual discharge in the beginning of ascospore season under Danish conditions. This is probably because of low temperatures in early spring.

The establishment of the national Internet scab warning system has difficulties collecting the necessary climatic data to run the software program due to break down of the weather stations and data transfer.

Use of bulk ascospore samples for monitoring apple scab fungicide resistance in individual orchards

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Abstract: In regions where apple scab is a problem, growers routinely use fungicides that may be prone to the development of tolerant *Venturia inaequalis* populations. Reduced fungicide efficacy leads to higher scab levels, additional sprays, and can result in crop failure before the problem is identified. On the other hand, regional resistance surveys can lead to large-scale abandon of products that limit available fungicide management options in orchards where resistance is not a problem. We developed an affordable and reliable method to evaluate the efficacy of fungicides against bulk ascospore samples harvested from leaves of individual orchards. The test is done by evaluating *in vitro* mycelial growth using a modified line-intercept method after incubating for 48 hours in a liquid suspension of each fungicide (cyprodinil, dodine, flusilazole, kresoxim-methyl, thiophanate-methyl) and compared to a control. We observed population EC50 shifts for certain molecules in a number of commercial orchards as compared to a organic orchard. These results were confirmed with fungicide efficacy trials done using potted trees exposed both to natural ascospore inoculum in test orchards, and to artificial inoculations using bulk conidia samples in growth chambers. The potted tree results demonstrated practical resistance for both flusilazole and thiophanate-methyl in certain sites, and no resistance to kresoxim-methyl, cyprodinil and dodine. Preliminary results also suggest that flusilazole maintains a higher level of efficacy in curative treatments than for protectant treatments for both tolerant and sensitive spore populations. Ongoing potted tree experiments are aimed at establishing a practical fungicide resistance threshold, which would enable us to advise individual growers based on results from the *in vitro* tests.

Temperature and humidity requirements for germination and infection by ascospores of *Pleospora allii*, the teleomorph of *Stemphylium vesicarium*

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Abstract: *Pleospora allii* is the teleomorph of *Stemphylium vesicarium*, the causal agent of the brown spot disease on pear. The ability of *P. allii* ascospores to cause infection has not yet been demonstrated, and no information is available on environmental conditions favouring ascospore germination and infection. These ecological aspects were investigated by environment-controlled experiments. Dynamics of ascospore germination were observed between 0.5 and 48 hours of incubation at different temperatures (T 5 to 35°C), in water or in dry conditions, with relative humidity (RH) between 100 and 67%. Maximum germination occurred after 48 hours of incubation in water at 21-23°C; few ascospores germinated below 15°C and at 30-35°C. At 100% RH germination decreased by about one third and no germination was observed below 80%. Ascospores were inoculated on leaves of three pear varieties showing different susceptibility under orchard conditions ('Abate Fétel', 'Conference', and 'William' in decreasing order of susceptibility). Leaves were incubated at different T (5 to 35°C), 100% RH, and observed daily for the appearance of necrotic spots. Ascospores caused higher infection on 'Abate Fétel' than on 'Conference', while sporadic symptoms were observed on 'William'. Highest disease incidence occurred at 25°C.

Equations for the distribution of *Venturia inaequalis* ascospores versus time during infection periods

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Abstract: Distribution of *Venturia inaequalis* ascospores versus time during an infection event was investigated by integrating in a dynamic simulation model the available knowledge on the biology of infection processes and the effect of environmental conditions. Processes of spore immigration on leaf surface, germination, appressorium formation, and successful infection establishment were incorporated into the model by elaborating mathematical equations depending on air temperature and length of the wet period. Survival of spores belonging to different development stages (ungerminated, germinated, with appressorium) was also included in the model as a function of temperature, relative humidity, and duration of wetness interruption. Based on comparison with previously published data the architecture of the model and its algorithms can be considered accurate and robust. Nevertheless, validation of model simulations under orchard conditions will be necessary before its use in management decisions.

Climatic conditions prior to green tip of apple affect ascospore maturation in *Venturia inaequalis*

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Abstract: Apple leaves infected with *Venturia inaequalis* (overwintered on the ground) were collected in the following countries: Australia, Belgium, Brazil, Chile, Denmark, France, Germany, Italy, New Zealand, Norway and Sweden (1 to 3 years of sampling in each country, 21 site/year combinations). Samples were collected at green tip, air dried at room temperature and sent via air mail to Norway, where they were kept frozen (-18 °C) until tested. Leaf disks cut from the samples were incubated moist, but without surface wetness at 20 °C to allow continuous ascospore maturation. Each sample was immersed in water twice weekly over four weeks, until the supply of ascospores was exhausted. Ascospores ejected into water were collected and counted. Based upon number of days with rain prior to bud break for the two most extreme sites/years (lowest and highest number of days with rain), we adjusted the degree day accumulation for the biofix of an existing degree-day model of ascospore maturation. To improve performance at drier sites, 11.5 degree days were added to the model biofix for each additional day with ≥ 0.2 mm rain. At wetter sites 11.5 degree days were subtracted for each additional wet day. Regression analysis confirmed a significant correlation between the number of pre-bud break rain events and the subsequent pattern of ascospore release. There was no difference if using 0.2, 1.0 mm or 2.0 mm per day as limits for adjusting the degree day accumulation. These preliminary changes represent simple rainfall-based rules to adjust the ascospore maturity model to improve accuracy based upon weather conditions during the month before bud break of apple.

Application of the BSPCast model to control *Stemphylium vesicarium* in a district of the Emilia-Romagna region

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Abstract: Severe brown spot outbreaks occurred in 1970s and 1980s in the Emilia-Romagna region (northern Italy); from that moment several researches started to study epidemiology of *Stemphylium vesicarium*. At the end of 1990s, the Ferrara district organized, together with the Plant Protection Service, a team to coordinate and provide farmers (about 180000 ha) with all the technical information useful to rationalize the disease control. Information from simulation model was used to compile weekly bulletins for farmers. In those years a meteorological network was developing on the district area, and the data produced by the meteorological stations were used as inputs for model running. At the moment, the BSP-cast model, after a wide validation in the Ferrara district, works daily on all the meteorological stations and the results are spread to technicians and to farmers through bulletins and meetings. In 2002, a new service was activated, in collaboration with the Plant Protection Service service, to spread outputs of the BSP-cast model using SMS. Messages are produced three times a week, starting from the end of flowering to mid august, signalling the risk level for brown spot outbreaks. Since 2004, the service was improved by the daily quantification of spore presence in the orchard air using spore traps.

Resistance management in Vf resistant organic apple orchards

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Abstract: Modern Vf scab resistant apple varieties open the way for organic growers to lower chemical input, higher yields, better skin quality, improved biological control against mites and insect pests and better consumer acceptance of their management practices. Many examples in the past years have shown however that the Vf resistance can be easily overcome by local scab populations in North-Western Europe. Discussions during the meetings of the IOBC pome fruit work group in 2000 in Fontevraud (France) and in 2003 in Lindau (Germany) lead to a set of management practices necessary to prevent gene-flux, and selection towards Vf virulence in the local apple scab populations. Eleven orchards of the Vf resistant apple variety Santana that were planted between 1998 and 2000 were monitored for apple scab lesions on fruits from 2002 to 2005. The results were evaluated in relation to the resistance management practices. We concluded that fungicide treatments against the major primary scab infections are the key factor in the resistance management on Vf resistant apple varieties. From a practical viewpoint, these early season fungicide applications are also necessary for the control of powdery mildew, as the main Vf-resistant apple cultivars appear to be relatively susceptible to powdery mildew. Growers that are not willing treat their orchards with fungicides at all should not plant Vf resistant varieties otherwise, they may well contribute to the rapid demise of Vf in their region.

Infection risk and biological parameters: automating fungal spore count and leaf growth measurements

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Abstract: Beside climate parameters also biological factors are important for estimating fungal disease infection risk. The airborne fungal spore dose and the presence of susceptible plant parts determine the severity of infection. In 2004, the monitoring of these biological factors was optimized and automated for apple scab. Counting of ascospores collected with a Burkard spore trap was automated using a microscope with a motorized object table and a digital camera, and by means of image analysis based on the specific morphology of the scab ascospores. Automated counting started in the scab season of 2005. The detection limit based on the analysis of the spore count of 2004 was ± 25 spores/cm² slide surface (± 20 spores/m³ air). Spores laying next to each other or touching another object on the slide are disregarded by the analysis. The efficacy observed had a high variation (efficacy range 5-50%) partly due to this reason. The efficacy obtained also depended on the background noise present, which in itself depends on climate conditions. Manual counting of these frames with the highest number of ascospores detected overcomes this problem. Until now plant growth monitoring consisted of determining growth of individual bloom clusters and following the phenological evolution. In 2004 vegetation area index (VAI) measurements were incorporated. By up scaling sampling, from a limited numbers of bloom clusters to a whole tree, the effect of biological variation during growth on the measurement is reduced. The utility value of VAI measurement for apple scab warnings are discussed and illustrated with the measurements done in 2005.

Alternaria alternata, causal agent of dead (dormant) flower bud disease of pear

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Abstract: Dead (dormant) flower buds of pear are an important phenomenon in pear production in the Netherlands. Vigorous or unbalanced tree growth and *Pseudomonas syringae* pv. *syringae* are mentioned as likely causes of dead flower buds. Several tree growth control treatments including ethephon, Regalis (Prohexadione-Ca) and root pruning were evaluated. Regalis increased disease incidence. The plant stimulant (foliar fertilizer) Resistim (potassium phosphonate) reduced disease incidence. *Pseudomonas syringae* pv. *syringae* was occasionally isolated from diseased flower buds. However, *Alternaria alternata* was nearly always isolated from diseased buds. Pathogenicity of isolated *A. alternata* was proven on detached dormant flower buds. By identifying the causal agent of dead flower buds disease, an effective control strategy can be developed.

Testing alternative chemicals against apple scab and powdery mildew

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Abstract: Experiments were conducted in glasshouse compartments or polytunnels to investigate the efficacy of several organic-compatible chemicals in controlling apple powdery mildew and apple scab when applied as a protectant, curative and antispore fungicides. Several products resulted in statistically significant reduction of mildew or scab severity; however, the reduction in disease severity achieved by these products, compared to the untreated or conventional fungicides, was very small and still unacceptable in commercial organic production. Only two traditional products, copper and sulphur, controlled scab and mildew effectively. We conclude that in the UK where environmental conditions are very conducive to scab and mildew epidemics, the only feasible solution to control scab and mildew in organic production is to grow cultivars which are resistant to the diseases, especially scab.