Contract report for the Horticultural Development Council

Container grown rose: evaluation of natural products for prevention and control of downy mildew (*Peronospora sparsa*) and improved shelf life

HNS 135

February 2006

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The results and conclusions in this report are based on a series of experiments conducted over one year. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

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AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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GROWER SUMMARY

Headline

Eight natural products and two fungicides were evaluated for control of downy mildew on rose and blackberry. Significant reductions in downy mildew and no adverse effect on crop growth were observed following treatment with Aliette 80WG, Biosept All Clear, Dithane 945 and TKO Phosphite.

Background and expected deliverables

Roses are an important component of the container-grown shrubs market with frequent introductions of new varieties and a high profile in the UK. Downy mildew affects many varieties causing an obvious leaf spot or blotch, sudden premature leaf fall and stunted growth. A range of fungicides are available for control of the disease on production nurseries, and damaging attacks can be largely prevented through use of preventative spray programmes. However, on garden centres and in other areas where the public has access, the range of permissible fungicides with activity against downy mildew is very limited. An increasing number of biostimulants and natural products are currently being marketed that claim to enhance a plant's resistance to disease. There is very little robust scientific evidence to support these claims.

The overall objective of the project is to evaluate some biostimulants and natural products for prevention and control of downy mildew (*Peronospora sparsa*) and improved shelf-life. If products are demonstrated to provide effective control, there will be an environmental benefit to be gained with reduced pesticide usage on nurseries; and a shelf-life improvement to be gained on garden centres from an improved level of downy mildew control.

Summary of the project and main conclusions:

Biology of rose downy mildew

Peronospora sparsa, the cause of rose downy mildew, only affects members of the *Rosaceae* family, including blackberry and cherry laurel. Symptoms on rose occur most commonly on young leaves (where it can be mistaken for black spot) and less commonly on other plant parts. As well as disfigurement, this serious disease causes premature rapid defoliation, stunted growth and shoot death. The disease is highly sporadic and can become epidemic under moist conditions. Outbreaks in spring are most common and varieties differ in susceptibility. *P. sparsa* is spread in the air as an asexual spore and persists in fallen leaves as resting spores (oospores), and may persist in woody tissue as fungal strands. The relative importance of these potential sources in establishing new disease outbreaks is uncertain. Leaf wetness is critical for disease development with prolonged wetness (e.g. 84 h over 10 days) being particularly favourable but trials showed temperature in the range of 5-20°C had little effect on disease development. Control on commercial nurseries is usually achieved by a preventative programme of suitable fungicide sprays, at a maximum of 10-14 days between sprays. Avoiding overhead irrigation greatly reduced occurrence of downy mildew in pot-grown highly-susceptible micropropagated blackberry plants. Strict attention to disposal of affected leaves and trimmings is an important measure to reduce disease risk.

Observations on rose downy mildew in 2005

Epidemic development of downy mildew on container grown roses occurred on several nurseries and garden centres in mid-May 2005. The researchers visited two sites. Both outbreak sites had a tall hedge close to one side of the blocks of plants, and both were watered by overhead sprinkler irrigation. Fungicide treatments had been applied but were inadequate; the plants became unsaleable and had to be cut back to allow re-growth. There were frequent heavy showers around this time; these probably created very favourable infection conditions of prolonged leaf wetness on the susceptible newly emerged leaves.

Natural products for disease control

Information on the composition, mode of action (where known) and evidence for efficacy against downy mildew or related Oomycete fungi is summarised for 18 substances. These comprise five chemical salts (Orophyte, potassium bicarbonate, potassium chloride, potassium phosphite and sodium silicate), seven plant extracts (neem oil, Milsana, laminarin, herbal oils, Citrox P, Biosept All Clear and oilseed rape oil) and six other substances (crab shell powder, Seagold, salicylic acid, Companion, *Muscodor albus* and compost tea).

Pesticide legislation affecting use of natural products

The legal status regarding use of natural products to aid disease control is complex and changing. Any substance that acts as a pesticide or makes pesticidal claims falls within the scope of pesticide legislation and therefore requires approval. This is regardless of the origin of the product, whether it is natural or other. There is no guarantee that natural products are either low hazard or low risk substances by virtue of their being natural.

Products are likely to be judged by the Pesticides Safety Directorate (PSD) as currently outside the scope of UK pesticide legislation if they are: nutritional products that only make general claims to increase resistance to disease by ensuring adequate nutrition, giving resistance to a disorder related to a nutrient deficiency or, increasing the population of beneficial soil micro-organisms, thereby outcompeting soil-borne diseases. PSD consider that the following are effectively plant protection products and therefore within the scope of UK pesticide legislation:

- products claiming to enhance a plant's resistance to a *specific* disease,
- product based on recognised pesticide active substances,
- products working by exerting a direct control on pests or disease (e.g. potassium bicarbonate on powdery mildew),

- products making a claim to provide direct disease control,
- products influencing the life processes of plants (e.g. growth regulators).

Comparison of some fungicides and natural products

Eight natural products (Biosept All Clear, crustacean shell powder, oilseed rape oil, potassium bicarbonate, salicylic acid, SeaGold, sodium silicate and TKO Phosphite) were compared with two fungicides (Aliette 80WG and Dithane 945) for control of *P. sparsa* on rose cvs Gentle Touch and Peek-A-Boo and blackberry cv. Loch Ness in autumn 2005. Plants were grown on Mypex matting in an unheated polythene tunnel with overhead irrigation. Chitin and SeaGold were incorporated into the compost. The other substances were applied as foliar sprays every seven days except for Aliette 80 WG and TKO Phosphite, which were applied every 14 days. The experiment was conducted twice, with 10 applications in the first and eight in the second experiment, except for Aliette 80WG and TKO Phosphite which were applied on five occasions (experiment 1) or four accessions (experiment 2).

In experiment 1, treatments commenced on 18 August, and continued until 19 October. The causal fungus was confirmed on blackberry (sporulation on lower leaf surface) and rose (oospores observed in cleared leaves). On roses, the disease affected around 0.1% of leaf area at the start of the experiment, increased to a peak of 5% on untreated plants by 3 November, and then declined as affected leaves fell. The percentage leaf area affected on 16 November, 1 month after the final spray (Figure 1), was significantly reduced by Aliette 80WG, Biosept All Clear, Dithane 945 and salicylic acid. Dithane 945 left an obvious white spray deposit and salicylic acid significantly reduced the plant vigour score. No treatment increased plant vigour. On untreated blackberry plants, 20% leaf area was affected 1 week after the final spray (Figure 2). This was significantly reduced by Aliette 80WG (6.0%), TKO Phosphite (8.4%), and Dithane 945 (8.5%). Compared with untreated roses, Aliette 80WG and Dithane 945 increased the final plant vigour score.

In experiment 2, treatments commenced on 31 August and continued until 2 November. Levels of downy mildew were very low. On rose, 2 weeks after the final spray, disease incidence was 19% in untreated plants and 6% or less in plants treated with Aliette 80WG, Dithane 945, sodium silicate and TKO Phosphite. Plants treated with sodium silicate were stunted, the leaves being smaller and closer together. None of the treatments significantly reduced % leaf area affected or leaf fall. On blackberry, 2 weeks after the final spray there were no significant differences in disease incidence, severity or plant vigour.

A summary of the effects of treatment on downy mildew, plant vigour and phytotoxicity is given in Table 1.

Financial benefits

Rose downy mildew causes direct losses by rendering plants unsaleable. Additional labour is then required to trim-back plants in an attempt to save them for sale at a later date. Further, because of the adverse effect on the appearance of plants, especially in garden centres, the disease is believed to have contributed to the decline in popularity of rose over the last 20 years. Estimates of the financial value of such losses are not available. Grower and garden centre manager experience indicates sporadic substantial losses.

Figure 1. Effect of fungicides and natural products on rose downy mildew (Experiment 1) -16 November 2005

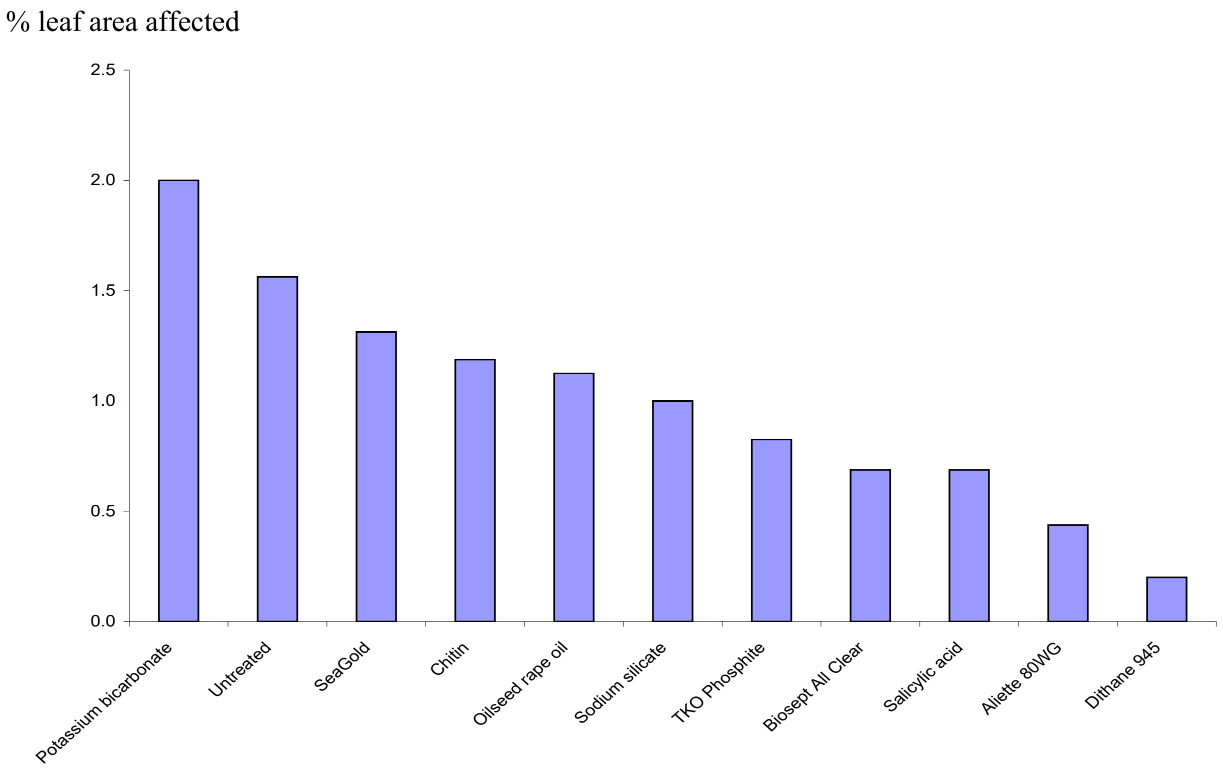

Figure 2. Effect of fungicides and natural products on blackberry downy mildew (Experiment 1) - 25 October 2005

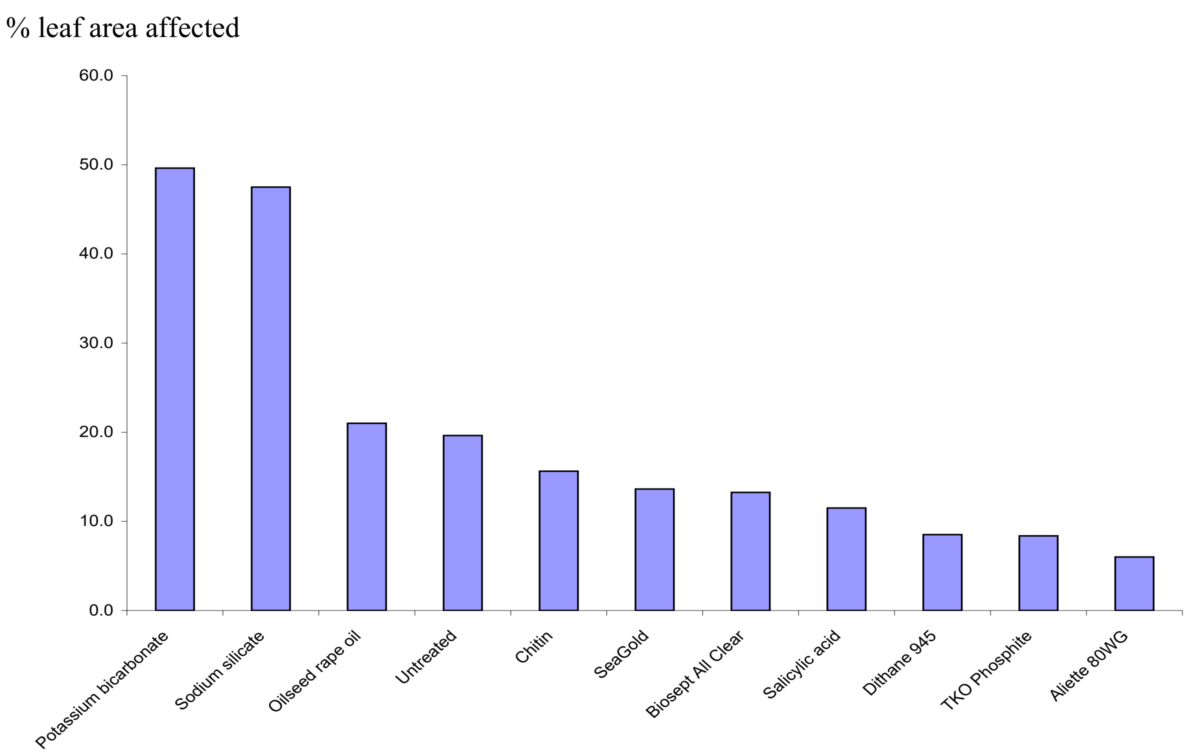

Table 1. Summary of the effects of some Fungicides and natural products on rose and blackberry – 2005.

Treatment[a]	Control of downy mildew		Phytotoxic to:		Plant vigour reduced on:	
	Rose	Blackberry	Rose	Blackberry	Rose	Blackberry
Aliette 80WG (14d)	✓	✓				
Dithane 945	✓	✓				
Biosept All Clear	✓					
Chitin (I)						
OSR oil						
Potassium bicarbonate			✓		✓	✓
Salicylic acid				✓		
SeaGold (I)						
Sodium silicate					✓	✓
TKO Phosphite (14d)		✓				

[a] Products applied as foliar sprays every 7 days, except where indicated
I = compost incorporation

Action points for growers

1. Prolonged wetness duration markedly increases on the risk of downy mildew outbreaks; consider what practical actions can be taken on your nursery to reduce leaf wetness:
   - do not locate container plants in hollows or close to windbreaks
   - consider increased plant spacing
   - time application of irrigation so that leaves dry quickly, if possible

2. Maintain a strict disease management programme in the spring and early summer – newly emerged leaves are particularly susceptible to downy mildew. See HDC Factsheet 12/04 for guidance on suitable fungicides for use on production nurseries.

3. Check leaf spots carefully as downy mildew can be mistaken for black spot. The latter usually has a feathery edge, whereas downy mildew leaf spots are often angular, bounded by the leaf and veins (see HDC Factsheet 12/04)

4. Remove fallen leaves and any trimmings before re-stocking an area. There is limited experimental evidence that fallen leaves may act as a source of pathogen carryover between seasons.

5. Where a natural product is required rather than a chemical fungicide, consider treatment with Biosept All Clear and/or TKO Phosphite. Regular foliar sprays of these substances gave some control of *P. sparsa* on rose and/or blackberry.

6. In home and garden areas, Biosept All Clear, Dithane 945 and TKO Phosphite are permitted and can be used to help reduce the risk of damaging attacks of *P. sparsa*. Dithane 945 gives an obvious spray deposit on leaves.

SCIENCE SECTION

1. Introduction and review of rose downy mildew

Cause

Rose downy mildew is caused by the Oomycete fungus *Peronospora sparsa*. It affects only members of the rose family (*Rosaceae*) and is found virtually everywhere that roses are cultivated. Downy mildew (*Peronospora rubi*) of brambles (*Rubus* spp.) is now considered synonymous with *P. sparsa* (Hall & Shaw, 1987) and isolates from rose and blackberry – red raspberry hybrid can cross-infect (Breeze *et al*, 1994). Other members of the *Rosaceae* susceptible to *P. sparsa* including cherry laurel (*Prunus laurocerasus*) (Hall *et al*., 1992), blackberry (*Rubus fructicosus*), boysenberry (blackberry x red raspberry hybrid), cloudberry (*Rubus chamaemorus*), and arctic bramble (*Rubus arcticus*) (Lindqvist *et al*., 1998). There have been no reports of a race structure in *P. sparsa*. Rose downy mildew was first described in England in 1862 and is now known throughout Europe, USA, Australia, Canada and New Zealand; and recently has been reported in China and South Africa.

Symptoms

Symptoms occur most commonly on leaves but also occur on stem, peduncles, calyces and petals. Leaf symptoms are yellow to purplish and brown spots and blotches, often angular and largely restricted to young plant growth (see HDC Factsheet 12/04). Affected leaves tend to fall prematurely, and a severe attack can lead to stunted plant growth. On stems and peduncles the disease appears as purplish to black streaks; dead tips may develop on calyces and infected twigs may be killed. The symptoms of downy mildew and black spot on leaves can be very similar (Elmhurst *et al*., 2002), resulting in possible misidentification and treatment with an inappropriate fungicide.

Occurrence

The disease is highly sporadic in occurrence (Baker, 1953) and can become epidemic very quickly. It is generally more common on glasshouse-grown roses than plants grown outdoors, though it can be very damaging on tightly-packed outdoor container-grown plants irrigated by overhead watering. It occurs most often in the spring and early summer. The recurrence of the disease sometimes at long intervals indicates an effective means of carryover of the fungus, possibly as resting spores in fallen leaves (Xu & Pettitt, 2002), or sporadic long-distance dispersal of conidia.

Varietal susceptibility

Some cultivars are reported to be more severely diseased than others (Gill, 1977), and severity was not related to the duration of the infection on a plant. Varieties Red Delight and Pink Delight were most seriously affected in a 1950s California outbreak. There is limited information on the relative susceptibility of commonly grown UK varieties. Varieties known to be particularly susceptible include Blue Moon, Silver Jubilee and Whiskey Mac; and Angela Rippon, Gentle Touch, Peek-A-Boo and Warm Wishes among the miniature types.

Disease cycle

Under cool, humid conditions, conidia (also known as sporangia) are produced on the lower surface of leaves. Occasionally they are produced copiously, but more often, under less favourable conditions, spore production is sparse and difficult to detect (hence the Latin name *sparsa*). These conidia, which are carried in the air, are the principal means by which the fungus spreads between plants. Oospores (thick-walled resting spores) can be found in leaves, sepals, flower buds and stems. Oospores in plant parts (e.g. fallen leaves, trimmings) may be a means by which the fungus carries over from one season to the next on a site, although evidence for this role is limited and the method of transmission of the fungus to newly-emerging growth unknown. Oospores extracts from dried, 1-year old rose leaves caused downy mildew when placed on young rose plants grown from tissue culture (T. Pettitt, unpublished). There is also evidence that the fungus may overwinter in stems as dormant mycelium without oospores in rootstock varieties of rose, indicating systemic infection (Aegerter *et al*., 2002).

Infection conditions

The fungus appears to have narrow temperature and humidity requirements. Optimum temperature for germination is 18ºC, with a slight decrease at 21ºC and no germination at 27ºC. Conidia of *P. sparsa* did not germinate at 4ºC, but viability was not reduced. When humidity was kept below 85%, roses remained uninfected (Baker, 1953).

More recently, optimal temperatures for infection and colonisation of rose leaves were reported to be 15 to 20°C and 20 to 25°C respectively (Aegerter *et al.*, 2003). At optimal temperatures, infection required only two hours of leaf wetness. Sporulation has been reported on rose leaves just three days after inoculation, though generally the latent period of infection varies from four to seven days. The critical number of hours of leaf wetness for disease development was an average of 8.4 h per day over 10 days.

Defra-funded research (Xu & Pettitt, 2002) showed that wet periods greater than 16 h are needed to cause a significant amount of infection, while temperature in the range of 5-20°C has no significant effects on the incidence of downy mildew. The incidence of disease increased gradually with increasing duration of wetness from 16 h to 96 h, and then increased sharply from 96 h to 120 h (i.e. 5 days). Moreover, it was found that only 40 spores applied per leaflet resulted in near maximum disease incidence under experimental conditions.

These features make possible extremely rapid build-up of the disease to epidemic proportions during continuous wet periods.

Risk of downy mildew in garden centres and display areas

Downy mildew is strongly favoured by conditions that are likely to occur in sales areas where plants are stood closely together and watered by overhead sprinkler irrigation Drying of wetted leaves will be slow where there is a dense canopy of foliage. In the USA following severe outbreaks on a nursery, it was reported that the main growing and sales area was in a location with poor air-movement, was shady in a good portion of the day, and was watered by overhead sprinklers. The disease was also seen on plants growing in the ground, but symptoms were scarcely noticeable to most growers (Gill, 1977) as they were not obvious.

Fungicide control

In the UK, fungicides shown to give some control of rose downy mildew include Aliette (fosetyl-Al)), Curzate M (cymoxanil + mancozeb), Dithane 945 (mancozeb), Invader (dimethomorph + mancozeb), Filex (propamocarb hydrochloride), Fubol 75 (metalaxyl + mancozeb) and Trustan (mancozeb + cymoxanil + oxadixyl) (O'Neill, 1994; O'Neill *et al*., 2002). On blackberries, Aliette 80WG, Bravo 500 (chlorothalonil), Favour 600 (metalaxyl + thiram), Filex, Fubol 75, Ripost Pepite (mancozeb + cymoxanil + oxadixyl) and Shirlan (fluazinam), all gave significant reductions when applied as foliar sprays; a monthly Aliette drench treatment was also effective. Aliette applied as a compost incorporant reduced plant growth. In New Zealand, sprays of fosetyl-Al + mancozeb at 14 day intervals kept boysenberry foliage almost free of *P. sparsa*, while propamocarb, mancozeb, mancozeb + dichlofluanid were largely ineffective (Tate & van der Mespel, 1983). A short spray-interval and good spray coverage of the leaves are particularly important when conditions are favourable to rapid disease development.

Cultural methods of control

Production with sub-irrigation was demonstrated with pot-grown blackberry to reduce the risk of damaging attacks of *P. sparsa* (O'Neill *et al*, 2002). However, such methods are not always economically feasible or practical for a location. Alternatively, overhead irrigation should be operated during times when leaf surfaces can dry in a relatively short time (Xu & Pettitt, 2002). The severity of downy mildew in overhead-irrigated container roses on a production nursery was slightly reduced by increased spacing of the pots and by placing plants pot tight in north-south rows, as opposed to east-west rows, with a prevailing southerly wind, in order to encourage rapid drying after irrigation (O'Neill, 1994). Disposal of infected leaf litter is also suggested as a measure to reduce the level of primary inoculum and the risk of disease development.

2. Observations on rose downy mildew – spring 2005

Garden Centre visit, Nottinghamshire – 22 May

Purple-coloured angular leaf blotches and obvious leaf fall suggestive of downy mildew were visible on a wide range of varieties. The disease was subsequently confirmed by laboratory examination, where typical sporangia were found on the lower leaf surface. The container-grown plants were arranged in a dense display on raised beds, in a relatively sheltered area around 10 m from a tall hedge at the back of an outdoor display area. Plants had been watered from overhead by hand. Foliar sprays of Systhane (myclobutanil) were reported to have been applied every 14 days. Powdery mildew and black spot were well controlled.

Container rose production nursery, Hertfordshire - 23 May

Typical downy mildew symptoms were observed on many varieties of container-grown roses, with the least disease on small-leafed patio varieties. Affected varieties and symptoms included:

Climbing varieties

Agatha Christie	- bronzed leaves; dead leaves and shoots
All-in-one	- bronzed leaves; dead leaves and shoots
Climbing roses	- angular leaf purpling; whole leaf necrosis; stem damage
Compassion	- angular leaf purpling
Ginger Syllabub	- angular leaf purpling
Iceberg	- severe defoliation; stem purpling

Shrub varieties

Fruhingsgold	- yellow and purple leaves
Max Graf	- yellow and purple leaves

Floribunda variety

Fascination	- brown areas on small leaves

Plants had been cold-stored over winter as bare root material and potted in spring 2005. They were stood close together in blocks of around 10x20 plants, in a level area bounded by mature trees at the eastern edge. Containers were stood on Mypex matting with irrigation uprights in each block to allow overhead watering, generally done once-daily, in the morning. A regular fungicide programme has been applied. The disease had been first noticed on plants in the shade of the trees, and increased dramatically from around 9-16 May. The leaves most commonly affected were mid-way up plants, and around 2-3 weeks old; new shoots were also affected on the more susceptible varieties. A low level of downy mildew had occurred in 2004.

The weather around this time was warm and dry in late April, hail and strong winds in early May, unusually cold and heavy showers in mid-May. At a meteorological station close to the Hertfordshire nursery, the number of rain days (>0.1mm of rain) in each of the 4 weeks proceeding 23 May was 4, 6, 2 and 6 respectively, with totals of 21.2, 2.6, 4.0 and 15.8 mm/week.

3. Natural products with potential for control of rose downy mildew

The following substances have references to Oomycete control. Those marked * were evaluated in experiments in this project in 2005. Products have been grouped as chemical salts, plant extracts and other. Summary information on products, including supplier and diseases reported to be controlled, is given in Appendix 3. The availability of substances for use in the UK is summarised in Table 3.1.

3.1 Chemical salts

3.1.1 Orophyte

The product information states that this is a supplemental foliar feed containing 5.4% phosphorous acid (P_2O_5), 5.0% soluble potash (K_2O) and 0.2% boron combined with a wetting and spreading agent. Potassium is said to be important in speeding the healing of wounds, and its effect on plant vigour provides plants with increased disease resistance. The anti-evaporant and dispersive properties are said to reduce moisture build-up on foliage, enabling leaves to dry faster, leaving less time available for fungal spores to germinate. They are also claimed to protect against pathogen penetration into damaged areas of the plant by drying and sealing sap-sucking insect punctures. For both field and protected crops a rate of 5-6 mL/L is recommended with a water volume of 200-400 L/ha aiming to moisten all leaves on both sides.

According to the supplier, Plant Solutions Ltd., this product may be effective against downy mildew when applied as a 0.25% solution at high volume, either at 7-10 day intervals under low disease pressure, or every 3 days under high disease pressure (Rebecca Dawson, pers. comm.).

3.1.2 Potassium bicarbonate*

This chemical ($KHCO_3$), also known as potassium hydrogen carbonate (99% a.i.), was granted Commodity Substance Approval in May 2004 for use as a fungicide on all protected and outdoor horticultural crops in the UK.

Its use is widespread in UK strawberry production because of its zero harvest interval. It is applied at 5 g/L with a wetter such as Agral or Silwet L-77, principally for the control of powdery mildew (S. Raffle and J. Allen *pers. comm.*). Potassium bicarbonate gave initial control of powdery mildew on apple mint under high inoculum pressure (Bennison & Green, 2004).

A number of researchers have found potassium bicarbonate eradicated powdery mildew across a range of crops. It is thought that the chemical is antagonistic towards fungi, acting as a pH disrupter of osmotic control and this causes damage to the fungal cell wall (Nellist, 2005).

The chemical is also available in the UK as 85% $KHCO_3$ in the product AgriKarb from FarmFos Ltd, and recommended to be mixed with the adjuvant Break-Thru S240 to control powdery mildew (Nellist, 2005). In the USA, Armicarb 100 (85% $KHCO_3$) is sold as a broad spectrum contact foliar fungicide for control of a variety of diseases of agricultural crops, ornamental plants, greenhouse and nursery crops and turf. The product label lists specific crops and their diseases, including *Peronospora* species on blackberries and herbs, *Plasmopara viticola* on grapes and *Bremia lactucae* on lettuce (www.helenachemical.com). In the USA, Armicarb 100 significantly reduced the severity of grape downy mildew (*Peronospora viticola*), but not as well as the standard fungicide programme (Schilder *et al.,* 2002).

3.1.3 Potassium chloride

It has been suggested that potassium chloride possesses contact activity similar to that of chorothalonil (Mann *et al.*, 2004), a fungicide previously shown to give partial control of hebe downy mildew (O'Neill, 1998).

3.1.4 Potassium phosphite*

Phosphorous acid (as phosphonate or phosphite) is the anionic metabolite of the systemic fungicide aluminium tris-O-ethyl phosphonate (fosetyl-Al), which is the active ingredient of Aliette. Both phosphorous acid and fosetyl-Al are effective in controlling diseases caused by Oomycete fungi. Fosetyl-Al has been shown to reduce the severity of downy mildew (*Peronospora sparsa*) on boysenberry (Tate & Van der Mespel, 1983), rose and blackberry (O'Neill *et al.,* 2002), although some treatments were phytotoxic. The mode of action is reported to be direct antifungal activity of phosphonate toward mycelial growth and, perhaps, indirect stimulation of host defences. Unusually, the compounds are systemic in their action in both a basipetal and acropetal direction (Johnson *et al.,* 2004). Phosphorous acid has been shown to have a limited effect in reducing the area of potato blight leaf infection, and its systemic effect has been shown to reduce the incidence and severity of tuber rot caused by this fungus (Johnson *et al.,* 2004).

Potassium phosphite is a potential treatment for rose that some growers currently use to aid control of downy mildew diseases (e.g. on hops) and phytophthora diseases (e.g. strawberry, raspberry). At the Eden Project, phosphite has been used successfully as a foliar spray to control downy mildew on lettuce and onion (T. Pettitt, pers. comm.).

It is reported that foliar sprays containing potassium phosphate salts can also prevent powdery mildew. The salts seem to stimulate a systemic effect that builds up the plant resistance. Dibasic potassium phosphate is slightly less effective as a fungicide than the monobasic salt (Quarles, 2005).

Phosphite products available as foliar fertilisers in the UK include:

a) Farm-Fos-44

This is a liquid foliar fertiliser consisting of an aqueous solution of potassium phosphite, available from Farm-Fos Ltd, Hereford. It is derived from potassium hydroxide and phosphorus acid, has a neutral pH (7.0) and an N:P:K content of 0:32:29. By analysis it consists of phosphorus pentoxide (23% by weight) and potassium oxide (21% by weight). It can be used as a foliar spray (concentration should not exceed 1%), as a plant drench or dip, in mixture with compost, or by fertigation. As a high volume spray it is recommended at 0.25% (2.5 L/1,000 L water). The suggested rate of use on ornamentals is 2.5 to 10 L of product per ha, usually repeated every 14 days. It has been used as a foliar feed on hops and found to give some control of downy mildew. Plants should not be sprayed at temperatures over 21^0C.

b) TKO Phosphite 0-29-26

This product is a highly concentrated phosphate/potassium nutrient solution containing mono and di-potassium salts of phosphorus acid. It is derived from potassium hydroxide and phosphorus acid and has an N:P:K ration of 0:29:26. By analysis it consists of phosphorus pentoxide (29%) and potassium oxide (26%). Application is to the soil and / or the leaves. The solution is absorbed quickly through leaves and roots to correct deficiencies and improve plant growth and vigour. It is claimed to increase root mass and reduce summer stress. Phosphorus plays a key role in photosynthesis and root development.

There are no label claims for activity against diseases (www.growthproducts.com). As a foliar feed on outdoor nursery and tree crops, treatment is recommended every 30 days from transplanting at a concentration of 1 L/400 L water (i.e. 2.5 ml/L). It is recommended that copper containing products are neither applied together with nor 20 days prior to or 10 days after application of TKO Phosphite. Surfactants and adjuvants should not be mixed with it.

3.1.5 Sodium silicate*

Silicates contain oxygen and silicon combined with one or more elements. Silicon is accumulated in the shoots of many plants, and there is evidence that increased silicon offers protection against fungal diseases, especially powdery mildew (Belanger *et al.*, 1995). The mode of action may be due to its high pH (11) having a direct affect on leaf surface fungi; uptake of the applied silicon into cell walls; increased silicon accumulation in reaction to epidermal injuries. Sodium silicate can protect plants against disease, with experiments having shown the protection of cucumbers against the Oomycete fungus (*Pythium* spp.) and powdery mildew. Organic gardeners have traditionally used sprays containing extracts of the horsetail (*Equisetum arvense*) which contains 15-40% natural silica (Quarles, 2005).

3.2 Plant extracts

3.2.1 Neem oil or neem seed extract

Extracts from seeds, leaves and bark of the neem tree (*Azadirachta indica*) are known to be effective against crop pests, and there are some records of antifungal properties. A significant reduction (80-90%) in the severity of grapevine downy mildew was reported following neem seed extract or commercial neem product application either as a protectant or a curative spray to leaves inoculated with *P. viticola*. The efficacy is due to preventing zoospore formation and/or release from sporangia. The antifungal components are apparently different from the less stable azadirachtin and related insecticidal substances (Achimu & Schlösser, 1992). Neem also contains sulphur compounds which have fungicidal properties (Quarles, 2005).

Neem oil as Bug Me Not (Amazing Neem Products) at 10 mL/L applied to lettuce plants in a glasshouse inoculated with downy mildew (*Bremia lactucae*) reduced the severity of infection. It was also shown to be an effective treatment for the management of lettuce downy mildew in an organic field trial (Gladders, 2002). In the USA, a neem-oil formulation, Trilogy, has been approved for use on foods, while Rose Defence and Triact (for control of powdery mildew, rust, black spot, botrytis, downy mildew and other common diseases) are designed for use on ornamentals. Neem can be purchased which has either fungicidal or insecticidal properties (Quarles, 2005).

Neem oil was not used in the rose downy mildew trail, because azadirachitin, the active ingredient of Neem, is listed under Directive 91/414, and until it is approved by the Pesticides Safety Directorate, UK growers cannot use Neem Oil as a pesticide (HDC News, November 2004).

3.2.2 Milsana

This is an extract of the Giant Knotweed (*Fallopia sachalinensis*, formerly *Reynoutria sachalinensis*). According to a US Environment Protection Agency factsheet, when sprayed on plants the extract causes the plants to activate an internal defence system that prevents growth of certain fungi, especially powdery mildew and grey mould. The extract is approved in the USA for use on ornamental plants grown in greenhouses (Benmhend, 2005). In Germany it is permitted for use on protected tomatoes as a plant tonic. Italian researchers have found that Milsana reduced powdery mildew infection on cucumber by 50%. Sprays protected roses from powdery mildew, but were less effective than oils and soaps, and repeated sprays induced a greener and glossier colouration of the leaves, but they became brittle to the touch (Quarles, 2005).

On vine, Milsana gave moderate control of downy mildew (*Plasmopara viticola*), as well as powdery mildew and *Botrytis cinerea*, although it was out-performed by standard fungicides (Schilder *et al.,* 2002).

Milsana applied at 1.5 mL/L before and after inoculation of apple mint with powdery mildew gave some control (Bennison & Green, 2004). Milsana is recommended at 0.5% on outdoor crops, and 0.3% on indoor. The efficacy of Milsana is increased with the addition of the wetter Trifolio-S Forte at 0.25% (Stefan Reissner, Biofa, *pers. comm.*)

3.2.3 Laminarin

Laminarin is a storage polysaccharide of the Kelp seaweed (*Laminaria digitata*) and acts as an elicitor of plant resistance. In plant cell suspension cultures, laminarin has been shown to induce defence responses, including activation of defence-related enzymes, production of reactive oxygen species, and the accumulation of salicylic acid, phytoalexins and pathogenesis-related proteins such as chitinase and β-1,3-glucanase (Aziz *et al.,* 2004; Minami, 2004). No products based on laminarin were identified during a search for potential substances for use on rose.

3.2.4 Herbal oils

A range of plant oils has been evaluated for control of potato, an Oomycete fungus like rose downy mildew. Oils from various plant species inhibited growth of *infestans* in culture. These include lemon balm (*Melissa officinalis*), yarrow (*Achilea millefolium*) and coriander (*Coriandrum sativum*). Some essential oils such as those from hyssop (*Hyssopus officinalis*) and thyme (*Thymus vulgaris*) have also been shown to reduce blight severity on potato plants using a 1:500 dilution in water. Caraway (*Carum carvi)* and dill *(Peucedanum graveolens)* did not reduce fungal growth in culture, but did reduce plant infection severity. Peppermint oil (*Mentha x piperita*) caused inhibition in blight cultures, but did not reduce disease severity on plants when applied pre- and post-inoculation (Quintanilla *et al.*, 2002). Some effect of peppermint oil has been found on downy mildew of brassicas (*Peronospora parasitica*) (Lawson *et al.,* 1998). A commercial formulation of mint oil (Funga-stop) is available in the USA to help control soilborne pathogens. Solutions of cumin or clove oil completely inhibit sugar cane rot, and basil oil can inhibit growth of soilborne pathogens (Quarles, 2005). Thyme oil gives some control of *P. parasitica* on *Arabidopsis* (T. Pettitt, pers. comm.).

3.2.5 Citrox P

This is a disinfectant based on extracts of citrus fruit, formulated with biodegradable surfactants manufactured by Agralan Ltd. The label claims that it is effective against a wide range of bacteria fungi and viruses. For most applications it is diluted 1:150 with water, and uses include disinfection of cuttings, bulbs, corms, seeds, sand beds, trays and rockwool slabs. If applied through a fogger or mister it is diluted 1:15. According to the supplier, water that has been treated with Citrox P to disinfect it can be sprayed onto crops (Mike Abel, *pers. comm*.).

3.2.6 Biosept All Clear Concentrate*

Biosept All Clear and Biosept Crop Gold are formulations of plant extracts and grapefruit oil that 'activate plant flavonoids'. Biosept All Clear is recommended for use on ornamentals and non-edible crops, whereas Biosept Crop Gold is recommended for use on edible crops. Biosept is claimed to stimulate all plant growing areas so that plants treated before infection by pathogens or infestation by insects will be stronger and therefore less susceptible to attack. There is a range of spray application rates from 2 to 8 mL/L, with an interval of 7 to 10 days. A higher rate is recommended initially on diseased plants. According to the label, Biosept helps plants naturally to protect themselves against fungal and bacterial disease and when used as a regular treatment may also reduce the need for conventional treatments (http://www.plantsolutionsltd.com/biosept.htm).

3.2.7 Oilseed rape oil*

Oilseed rape oil applied twice as a spray at 20 mL/L, with a 7 day interval, gave good control of lettuce downy mildew (*Bremia lactucae*) on glasshouse plants (Gladders, 2002).

Emulsified vegetable oil sprays of sunflower, olive, oilseed rape, peanut, soybean, corn, grapeseed or safflower can control powdery mildew on apple trees, roses, and possibly other plants. Oils probably work by helping to repel the water that is needed for fungal growth (Quarles, 2005).

Vegetable oil used at three tablespoons per US gallon of water (3.8 L) with half a teaspoon of detergent soap, agitating constantly during application, is recorded as controlling powdery mildew (Online Information Service for Non-Chemical Pest Management in the Tropics, PAN Germany, see http://oisat.org/control_methods/other_substances/horticultural_oil.html).

3.3 Other

3.3.1 Crab shell powder*

Chitin, a component of crustacean shells, has been shown to improve the health of various plant species. Although there are no specific references for control of rose downy mildew, incorporation of chitin into the soil was found to reduce rose black spot (A. Hall pers. comm). The incidence and severity of several fusarium diseases caused by *Fusarium oxysporum* (e.g. celery yellows, cyclamen wilt) were reduced significantly by pre-plant chitin amendments of soil. Chitin was shown to increase bacterial and actinomycete populations in field soil (Bell *et al.,* 1997).

Chitosan (partly de-acetylated chitin) has been used to induce resistance in many plant species against various pathogens. Some of the effects of chitosan treatment are lignification and increased activity of enzymes associated with plant defence against fungal pathogens (Eikemo *et al.,* 2003). In the USA, chitosan as the product Elexa provided moderate control of downy and powdery mildew (*Plasmopara viticola* and *Uncinula necator)* in a vineyard (Schilder *et al.,* 2002). Chitosan reduced strawberry crown rot (*Phytophthora cactorum*) symptoms, with an enhanced effect when the time between treatment and inoculation was increased from 2 to 20 days. Disease was reduced best at lower chitosan concentrations of 10 to 50 μg a.i. per plant (Eikemo *et al.,* 2003). No chitosan product marketed for use on plants in the UK was found during this study.

3.3.2 Seagold*

This product is derived from shrimp and crab meal and the seaweed Egg Wrack (*Ascophyllum nodosum*). It also includes 4% humic acids derived from leonardite (a carbon deposit). The formulation is high in organic matter and natural chitin. It also contains organic carbon, ureic nitrogen, phosphoric anhydride and calcium, with a chemical composition of 4% nitrogen, 5% phosphate, 0.05% soluble potash, 15% calcium and 1% magnesium. It is manufactured for Triad Energy Resources Inc. (www.triad-organic.com) in the USA. The label recommendation is for incorporation into soil at 10 to 15 cm before planting, at 250 – 500 lbs / acre depending on soil type. It is recommended primarily for the control of nematodes and the diseases they carry. The application of Seagold increases the chitin content of the soil, which increases the population of bacteria, actinomycetes and fungi. Seagold can be used as an organic fertiliser as it contains plant nutrients and other natural ingredients that may stimulate plant growth.

3.3.3 Salicylic acid*

This chemical, found in aspirin, has been used to induce host resistance in several plant species. Applied as a spray at 0.2 g/L, it significantly reduced the leaf area affected by downy mildew on lettuce (Gladders, 2002).

3.3.4 *Bacillus subtilis / Bacillus pumulis*

The bacteria *B. subtilis* GB03 is marketed in the USA as the product Companion. The label states that there are not less than 5.5 x 10^{10} colony forming units per US gallon (3.8 L). Companion also contains sucrose, monosaccharides, condensed fermented plant extracts, dextrin, an organic sequestrant and a wetting agent. It is marketed as a 'biological fungicide' for the prevention, suppression and control of soil borne diseases on a wide range of plants in greenhouses and planting beds. According to the label the *B. subtilis* quickly colonises the developing root system. Companion suppresses disease, providing control of root diseases such as *Pythium, Rhizoctonia, Phytophthora, Fusarium* and is effective at preventing these diseases when used as a cutting dip. The label suggests that Companion can be used in combination with reduced rates of chemical fungicides to enhance and prolong disease control. Companion has been shown to increase root mass on many greenhouse plant materials. It can be applied as a drench at seeding and transplanting or as a drench, sprinkler irrigation or spray throughout the plant's life. For bedding plants, foliage plants, flowers and woody ornamentals a dilution of 16 US fl. Oz. per 100 US gallons of water (1 mL/L) at 14 day intervals is recommended.

Experiments with fresh and powdered formulations of *B. pumulis* strains INR7 and SE34, and fresh *B. subtilis* GBO3 rhizobacteria used as seed treatments reduced the severity of downy mildew (*Sclerospora graminicola*) on pearl millet seedlings in the glasshouse and field and enhanced plant growth (Raj *et al.*, 2003).

3.3.5 *Muscodor albus*

Root rot caused by the Oomycete fungus *Phytophthora capsici* was controlled in bell pepper and cosmos when they were planted into compost containing the fungus *M. albus. Rhizoctonia solani* was also controlled in broccoli seedlings. The mode of action was believed to be biological fumigation from volatiles produced by *M. albus* (Mercier & Manker, 2005).

3.3.6 Compost teas

Compost teas have been used on field-grown roses on nurseries in Devon and Suffolk for three years and no downy mildew has been observed during this time (D. Hutchinson, pers. comm). HDC funded work on evaluating the potential benefits of compost-teas for disease management is in progress.

Table 3.1. Summary of availability of natural products for use on rose plants in the UK and evidence of efficacy against downy mildew fungi

Group and substance	Permitted under UK pesticide legislation*		Evidence of efficacy against downy mildews
	On roses in commercial production	On roses in home and garden areas	
Chemical salts			
Orophyte	✓	✓	No
Potassium bicarbonate	✓	X	Yes
Potassium chloride	-	-	No
Potassium phosphite	-	-	Yes
Sodium silicate	-	-	Limited
Farm-Fos-44	✓	✓	Limited
TKO Phophite	✓	✓	Yes
Plant extracts			
Biosept All Clear	✓	✓	No
Citrox P	X	X	No
Herbal oils	-	-	Yes
Laminarin	-	-	No
Milsana	-	-	Yes
Neem oil	X	X	Yes
Oilseed rape oil	-	-	Yes
Other			
Crab shell powder	-	-	No
Companion	-	-	Limited
Compost tea	✓	✓	No
Muscodor albus	-	-	Limited
Salicylic acid	-	-	Yes
Seagold	✓	✓	No

* See section 4 for further information
- not marketed in the UK for use on plants

4. Pesticide legislation affecting use of natural products

The legal status regarding the use of natural products to aid disease control is complicated. The following points are given for guidance only. Before using any material, read and carefully follow the label conditions. If there is doubt, consult the manufacturer and/ or the Pesticides Safety Directorate (PSD), the UK competent authority on pesticide regulation.

Any substance that acts as a pesticide or makes pesticidal claims falls within the scope of pesticide legislation and therefore requires an approval. This is regardless of the origin of the product, whether it is 'natural' or otherwise. A fuller definition of the scope of the pesticide regulations is given on Regulation 3 of the Control of Pesticides Regulations (1986) (as amended) and in Regulation 2 of the Plant Protection Products Regulations (2003). There is no guarantee that natural products are either low hazard or low risk substances by virtue of their being natural; some natural products are known to be highly toxic to man.

EU Directive 91/414

The UK Control of Pesticides Regulations, 1986 (COPR) and the EU Plant Protection Products Directive (91/414), implemented in the UK by a series of Plant Protection Products Regulations (PPPR), regulate the use of pesticides in the UK. At present there is a period of transition as existing pesticide active substances are re-evaluated for inclusion, or not, on a list of authorised substances (known as Annex 1 of EU Directive 91/414). The programme of reviewing existing active substances is designed to ensure that plant protection products are supported by up-to-date information on safety and efficacy. New pesticide active ingredients need to be authorised at the EU level before a product can be authorised at the national level.

The active substances being reviewed for possible inclusion on Annex 1 are arranged in four stages, or lists. List 4 covers micro-organisms, plant extracts and substances authorised for use in human and animal food stuffs, among other materials. This includes, for example, fatty acids, potassium hydrogen carbonate, citrus/grapefruit extracts, rapeseed oil, sunflower oil, thyme oil (and other oils), seaweed, chitosan, sulphur, *Trichoderma harzianum*, hydrogen peroxide, peracetic acid and sodium hypochlorite (www.europa.eu.int/comm/food/plant/protection/index). The deadline for review of list 4 substances is the end of 2008.

If an active substance is listed on Annex 1 under EU Directive 91/4/4, then it is considered to be a pesticide active substance. For example, the active ingredient of neem oil, azadirachitin, is listed under EU Directive 91/414 and consequently the product requires approval. Marketing of an unapproved product is an offence under the pesticide regulations. Where PSD identifies such products and establishes an offence has been committed, enforcement action will be taken, including, where it is in the public interest, prosecution which may result in a fine or custodial sentence.

Situation of use

When a substance is approved as a pesticide in the UK, a label is issued that contains statutory Conditions of Use. One condition is the 'situation of use'. This condition dictates whether a pesticide can be used as an amateur product in the `home and garden` or as a professional product in `commercial horticulture`. If plants are treated in areas where the general public have access, such as on garden centres, the pesticides must be approved for use in the home and garden. Details of products approved for use in the home and garden is given on the PSD website (www.pesticides.gov.uk) 'garden database'. The number of pesticides approved for use in the home and garden situation is very limited compared with commercial production.

Home and garden pesticides

The PSD `garden database` was examined and products permitted on ornamentals were listed. Based on knowledge of the active ingredients, it is considered that the following may give some control of rose downy mildew:

- Natures Answer Natural Fungus and Bug Killer (20g fatty acids + 5.2 g/L sulphur)
- B & Q Garden Fungicide spray (1 g/L copper sulphate)
- Murphy Traditional Copper Fungicide (58.8% copper oxychloride)
- PBI Dithane 945 (800 g/kg mancozeb)

Commodity Substances

Commodity substances are chemicals that have a number of different industrial uses, one of which is as a pesticide and therefore is regulated by PSD. For example, potassium hydrogen carbonate is approved by PSD as a Commodity Substance for use as a horticultural fungicide on all edible and ornamental crops, both outdoors and under protection to control powdery mildew. A commodity substance approval allows use only for commercial crop production and *not* for home and garden use. Commodity substance approvals relate to the use of the chemical only; it is not permitted to market a product containing a commodity substance as a pesticide.

Other substances

There are some substances used on plants, for the purpose of improving growth for example, where it is not currently clear whether they are pesticides or not. Many of these are often described as 'natural products' or `plant stimulants`. Eventually, it appears that the EU will require registration of some of these substances as pesticides (see above).

Nutritional products

PSD have indicated certain situations where some nutritional products can currently be used in the UK without contravening pesticide regulations.

A substance that only makes general claims to increase resistance to disease, by the following means, is *outside* the scope of pesticide legislation (PSD reference AAHL/33/2003):

- by ensuring adequate nutrition

- by giving resistance to a disorder which is related to nutrient deficiencies
- by increasing population of beneficial soil micro-organisms, thereby out-competing soil-borne diseases

PSD consider that the following are effectively plant protection products and *within* the scope of the pesticides legislation:

- products claiming to enhance a plant's resistance to a *specific* disease
- product based on recognised pesticide active substances (e.g. neem)
- products working by exerting a direct control on pests or disease (e.g. potassium bicarbonate)
- products making a claim to provide direct disease control
- products influencing the life processes of plants (e.g. growth regulators)

<u>Other products that make no claim for disease control</u>
At present, if the label or technical literature accompanying a product recommended for use on plants in the UK makes no claim for disease control (or pest, weed or growth control), it is not subject to UK pesticide legislation and can be used by growers in both the commercial and home and garden areas, providing:

1. It is not considered by PSD effectively to be a plant protection product and within the scope of pesticide legislation (see the list above, under Nutritional Products, of materials automatically considered to be pesticides).
2. Its use is not restricted by other legislation.

Based on the above, it appears that the following products would currently be permitted for use on ornamental plants in the home and garden area without contravening current UK pesticide legislation. PSD would need to assess product information such as the active ingredient, its mode of action and the precise wording of a label claim before being able to confirm if this is correct, or not.

- Orophyte (foliar feed)
- Biosept All Clear (plant growth stimulant)
- TKO Phosphite 0-29-26 (foliar fertiliser)
- Farm-Fos-44 (foliar fertiliser)

<u>Further information</u>
Further details on pesticide legislation and approval are given in the UK Pesticide Guide 2006 and on the Pesticides Safety Directorate Webstite (www.pesticides.gov.uk).

5. Evaluation of some fungicides and natural products - Experiment 1

Introduction

A range of natural products, applied either as a series of sprays or as a compost incorporation, were tested against two currently approved products for their efficacy against downy mildew on infected micro-propagated rose plants and blackberry plants. Both rose and blackberry plants were affected by a low level of downy mildew when treatments commenced

Methods

All treatments were applied as foliar sprays except treatments 5 and 9, which were incorporated in Table 5.1 to the compost 12 days before the first foliar sprays were applied. Treatments 2 and 11 were applied fortnightly, all other foliar sprays were applied weekly.

Table 5.1. Fungicide treatments used in Experiment 1

Treatment	Product	Active ingredient	Rate
1	Control (water spray)		-
2	Aliette 80 WG	80% fosetyl-aluminium	2.5 g/L
3	Dithane 945	80% mancozeb	2.5 g/L
4	Biosept All Clear	Grapefruit oil & plant extracts	4 ml/L
5	Chitin	Crab shell powder	10 g/L compost (1% w/v)
6	Oilseed rape oil		20 ml/L
7	Potassium bicarbonate (food grade) + Silwet L-77		5 g/L + 1 ml/L wetter
8	Salicylic acid		0.2 g/L
9	Seagold	Calcified seaweed	2.2 g/L
10	Sodium silicate		10 g/L
11	TKO Phosphite 0-29-26	100% phosphite	2.5 ml/L
12	Control (water spray)		-

Plants were received as micropropagated plugs and potted on. Each plot was made up of two rose plants (var. Gentle Touch) and two blackberry plants (var. Loch Ness) laid out pot thick. All plants were known to have had, or were showing symptoms of downy mildew. Each treatment was replicated four times in a randomised complete block design.

Plants were grown in a polythene tunnel on Mypex matting and irrigated with overhead sprinklers. Blocks were arranged in the same direction as the sprinklers and equidistant either side of the sprinkler line. Plots were spaced at least 0.5m apart to avoid spray drift between treatments. The sides of the tunnel were lowered to reduce air movement, except on hot, sunny days.

Spray treatments were applied when plants were 15cm tall using an Oxford precision sprayer with a single 02F110 nozzle, to the point of run-off (approx. 430 mL/m^2). Spray treatments were applied over a period of 8 weeks from 14 September to 2 November (14, 21, 28 Sep; 5, 12, 19 Oct).

Plants were assessed every 14 days commencing from the first spray until 1 month after the final spray. They were assessed for percentage infected leaves, an estimate of the number of fallen leaves, plant vigour and any phytotoxic effects. A total of 8 assessments were carried out.

Results and discussion

Full results of all assessments are shown in Appendix 1. Key results are tabulated below.

Rose

Purple leaf spots typical of downy mildew were noticed at very low levels on four of the 11 treatments at the start of the experiment on 17 August. The levels remained very low until 27 September when it was seen at higher levels and was present in all treatments. The percentage leaf area affected carried on increasing up to 3 November (to affect 4.9% on untreated plants), after which there was a decline, probably due to leaf fall caused by the disease. At the final assessment, the leaf area affected on untreated plants was 1.6%, and significantly lower (P=0.051) following treatment with Dithane 945 (0.2%), Aliette 80WG (0.4%) and Biosept All Clear (0.7%) (Table 5.2).

At an assessment on 3 November (2 weeks after the final spray), there were significant differences in leaf fall, with greater leaf fall following potassium bicarbonate, salicylic acid and chitin treatment, and least following Biosept All Clear (Table 5.1). Plant vigour at this time was significantly reduced (compared with untreated plants) by potassium bicarbonate. None of the treatments increased plant vigour.

Blackberry

Sporulating downy mildew was present on the blackberries from the start of the trial and the severity stayed at around 20% leaf area affected until 25 October, when levels started to reduce. On 25 October, three treatments (Aliette 80WG, Dithane 945 and TKO Phosphite) reduced disease to less than 10%, compared with 20% on untreated plants (Table 5.3). Potassium bicarbonate and sodium silicate significantly increased the percentage leaf area affected. Aliette 80WG, Dithane 945 and TKO Phosphite also significantly reduced the incidence of plants with downy mildew on new growth (Table 5.3). Plant vigour was increased by Aliette 80WG and Dithane 945 and reduced by potassium bicarbonate and sodium silicate.

Phytotoxicity

Several of the treatments had a marked direct effect on the appearance of leaves or on plant growth. Dithane 945 left an obvious white spray deposit, still visible 4 weeks after the final application. Rose leaves treated with oilseed rape oil appeared shiny. Leaflets of rose plants treated with potassium bicarbonate were very small, while on blackberries the leaf edges were burnt. Salicylic acid resulted in burnt patches on blackberry leaves. Sodium silicate left a slight white spray deposit, but more obviously rose plants were stunted, the leaves being smaller and closer together; this was first noticed 1 month after the first application. No adverse effects were noticed following treatment with Aliette 80WG or TKO Phosphite. On plants treated with Biosept All Clear, the leaves remained on the plants for longer in comparison with other treatments. The chitin and SeaGold compost incorporation treatments both resulted in much darker green leaves, especially at around 21 days after potting.

Table 5.2. Effect of some fungicides and natural products on rose downy mildew, established disease – November 2005 (Experiment 1)

Treatment	% leaf area affected (16 Nov)	Leaf fall index (0-3) (3 Nov)	Plant vigour (0-5) (3 Nov)
Untreated	1.6	1.9	2.1
Aliette 80WG	0.4	2.1	2.3
Dithane 945	0.2	2.1	2.3
Biosept	0.7	1.4	2.1
Chitin	1.2	3.6	1.8
OSR oil	1.1	2.8	1.9
Potassium bicarbonate	2.0	3.9	1.5
Salicylic acid	0.7	3.5	1.6
Sea Gold	1.3	3.1	2.0
Sodium silicate	1.0	2.5	2.0
TKO Phosphite	0.8	2.8	2.1
Significance	0.051	0.002	0.015
SED between treatments	0.53	0.60	0.21
Vs untreated	0.46	0.52	0.19

Treatments applied 18 August - 19 October.

Table 5.3. Effect of some fungicides and natural products on blackberry downy mildew, established disease – 25 October 2005 (Experiment 1)

Treatment	Mean % leaf area affected	Mean % plants with new growth affected	Plan vigour index (0-5)
Untreated	20.2	81	1.8
Aliette 80WG	6.0	38	2.4
Dithane 945	8.5	38	2.4
Biosept	13.2	50	2.1
Chitin	15.6	88	1.9
OSR oil	21.0	75	1.8
Potassium bicarbonate	49.6	100	1.3
Salicylic acid	11.5	63	2.0
Sea Gold	13.6	100	2.0
Sodium silicate	47.5	100	1.1
TKO Phosphate	8.4	25	2.1
Significance	<0.001	0.001	<0.001
SED between treatments	8.8	19.9	0.25
Vs untreated	7.6	17.3	0.22

Treatments applied 18 August - 19 October.

6. Evaluation of some fungicides and natural products - Experiment 2

Introduction

The same range of natural products and fungicides were tested for their efficacy against downy mildew on two varieties of micro-propagated rose plants and one variety of blackberry. None of the rose plants were showing any evidence of downy mildew infection at the start of the experiment. The blackberry plants had a low level of natural infection but had received a commercial spray fungicide programme up until 27 August.

Methods

All treatments (Table 6.1.) were applied as foliar sprays except treatments 5 and 9, which were incorporated in the compost 13 days before the first foliar sprays were applied. Treatments 2 and 11 were applied fortnightly, all other foliar sprays were applied weekly.

Table 6.1. Fungicide treatments used in Experiment 2

Treatment	Product	Active ingredient	Rate
1.	Control (water spray)	-	-
2.	Aliette 80 WG	80% fosetyl-aluminium	2.5 g/L
3.	Dithane 945	80% mancozeb	2.5 g/L
4.	Biosept All Clear	Grapefruit oil & plant extracts	4 ml/L
5.	Chitin	Crab shell powder	10 g/L compost (1% w/v)
6.	Oilseed rape oil		20 ml/L
7.	Potassium bicarbonate (food grade) + Silwet L-77		5 g/L + 1 ml/L wetter
8.	Salicylic acid		0.2 g/L
9.	Seagold	Calcified seaweed	2.2 g/L
10.	Sodium silicate		10 g/L
11.	TKO Phosphite 0-29-26	Phosphite	2.5 ml/L
12.	Control (water spray)	-	-

Each plot was made up of two rose plants (var. Gentle Touch), two rose plants (var. Peek-a-boo) and two blackberry plants (var. Loch Ness) laid out pot thick. Each treatment was replicated four times in a randomised complete block design.

Plants were grown in a polythene tunnel on Mypex matting and irrigated with overhead sprinklers. Blocks were arranged in the same direction as the sprinklers and equidistant either side of the sprinkler line. Plots were spaced at least 0.5 m apart to avoid spray drift between treatments. Sides of the polytunnel were lowered to reduce air movement, except on hot, sunny days.

Spray treatments were applied using an Oxford precision sprayer with a single 02F110 nozzle, to the point of run-off (approx. 430 mL/m^2). Spray treatments were applied over a period of 10 weeks from 31 August to 2 November (31 Aug; 7, 14, 21, 28 Sep; 5, 12, 19, 26 Oct; 2 Nov).

Plants were assessed every 14 days, commencing from the first spray for % infected leaves, an estimate of the number of fallen leaves, plant vigour and any phytotoxic effects. A total of 6 assessments were carried out.

Results and discussion

Full results of all assessments are shown in Appendix 2. Key results are tabulated below.

Rose

Downy mildew occurred at a very low level in this experiment. On 16 November, 2 weeks after the final spray, 19% of untreated plants showed symptoms of downy mildew, compared with only 6% of plants treated with Aliette 80WG, Biosept All Clear and TKO Phosphite. Over 30% of plants treated with Dithane 945 were affected, possibly a reflection of the long interval (28 days) since this last application of this protectant fungicide. The percentage leaf area affected remained at less than 1% throughout the experiment. No significant differences were recorded in percentage leaf area affected, leaf fall or plant vigour (Table 6.2).

Blackberry

On 16 November, 2 weeks after the final spray, there were no significant differences in disease incidence, % leaf area affected or plant vigour (Table 6.3).

Table 6.2. Effect of some fungicides, commodity substances and natural products on rose downy mildew - 16 November 2005 (Experiment 2)

Treatment	% plants affected	% leaf area affected	Leaf fall index (0-5)	Plant vigour (0-5)
Untreated	19	0.6	2.3	1.7
Aliette 80WG	6	0.1	2.5	1.9
Dithane 945	31	0.4	1.7	1.9
Biosept	6	0.1	1.6	1.9
Chitin	19	0.3	1.7	1.9
OSR oil	13	0.3	1.7	2.0
Potassium bicarbonate	13	0.1	1.6	1.8
Salicylic acid	19	0.6	1.7	1.8
SeaGold	50	1.2	2.2	2.1
Sodium silicate	0	0.0	1.7	1.8
TKO Phosphite	6	0.0	1.5	2.1
Significance	0.011	0.131	0.683	0.463
SED between treatments	11.8	0.394	0.616	0.195
Vs untreated	10.2	0.341	0.534	0.168

Treatments applied from 31 August to 2 November.

Table 6.3. Effect of some fungicides, commodity substances and natural products on blackberry downy mildew - 2005 (Experiment 2)

Treatment	% plants with new growth affected (11 Oct)	% plants affected (16 Nov)	% leaf area affected (16 Nov)	Plant vigour (0-5) (16 Nov)
Untreated	31	100	5.9	2.0
Aliette 80WG	75	100	5.5	2.0
Dithane 945	25	100	5.5	2.1
Biosept	88	100	3.8	2.1
Chitin	75	100	5.6	2.1
OSR oil	50	100	5.8	2.0
Potassium bicarbonate	63	100	4.0	2.0
Salicylic acid	100	88	4.5	2.3
SeaGold	38	100	4.6	2.1
Sodium silicate	50	100	4.0	2.0
TKO Phosphite	50	88	4.5	2.0
Significance	0.043	0.463	0.790	0.523
SED between treatments	24.0	7.2	1.526	0.129
Vs untreated	20.8	6.3	1.3231	0.112

Treatments applied from 31 August to 2 November.

7. Comparison of Aliette 80 WG application methods and rates

The effect of application method and rate of use of Aliette 80WG on control of downy mildews on blackberry, hebe and rose, from a series of earlier studies, is summarised in Table 7.1.

On young micropropagated blackberry plants, Aliette 80 WG was particularly effective (92% control) when applied as a drench at monthly intervals. A drench treatment was moderately effective on patio rose plants (50% control), but largely ineffective when applied to woody hybrid-T roses (15% control) (Table 7.1).

Aliette 80WG applied as a spray every 14 days gave moderate control on blackberry (35% control), hebe (66-71% control) and rose (46-52% control). When extra wetter was added to Aliette 80WG, efficacy against hebe downy mildew was unaffected when Aliette was used at 2.5 g/L and reduced when used at 1.25 g/L.

Table 7.1. Effect of Aliette 80WG applied by different methods and at different rates on control of downy mildews on blackberry, hebe and rose

Year (project)	Pot size (L)	Application method[a] (nº of treatments)	Rate (g/L)	Volume (mL) per plant	Dose product /plant (mg)		Control of downy mildew[d] (%)
					Trt.	Total	
<u>Blackberry</u>							
1995	0.5	S (x6)	5.0	5	25	150	34.5
(SF 39)		D (x3)	1.0	50	50	150	**91.8**
		I (x2)	0.9	300	270	540	**54.6**[c]
<u>Hebe</u>							
1998							
(HNS 79)	3.0	S (x4)	2.5	3.5	8.8	35	**70.8**
		S + Cod (x4)	2.5	3.5	8.8	35	**88.1**
		S + Sil (x4)	2.5	3.5	8.8	35	**70.8**
		S (x4)	1.25	3.5	4.4	18	**65.5**
		S + Cod (x4)	1.25	3.5	4.4	18	19.8
		S + Sil (x4)	1.25	3.5	4.4	18	37.4
<u>Rose</u>							
1993	3.0	S (x6)	5.0	4	20	120	48.2
(HNS 53)		D (x3)	2.0	300	600	1800	**50.0**
	4.0	S (x11)	5.0	4	20	220	**51.9**
		Drench (x5)	2.0	300	600	3000	14.6
1994 (HNS 53)	4.0	Spray[b] (x7)	5.0	4	20	280	46.0

[a] sprays (S) applied at 14d intervals; drenches (D) at 28d intervals around the plant base; incorporation (I) at potting.
[b] treatment from first symptoms
[c] Severe plant stunting
[d] Assessed 7-14 days after final spray as reduction in % leaf area affected; reductions of >50% are shown in bold.

In the present work, Aliette 80WG and TKO Phosphite were both applied as foliar sprays. In Experiment 1, which had the greater disease pressure, the level of control achieved on rose was 41% with Aliette 80WG and nil with TKO Phosphite (Table 7.2). In Experiment 2, at the lower disease pressure, both chemicals gave more than 80% control. On blackberry, Aliette 80WG and TKO Phosphite gave moderately effective control in Experiment 1 (58-67%), and apparently little control in Experiment 2. The latter result is a reflection of the very low disease levels and there was no statistically significant reduction in downy mildew by either chemical.

Table 7.2. Effect of Aliette 80WG and TKO Phosphite on control of downy mildew on blackberry and rose – 2005

Exp.	Pot size (L)	Product	No of sprays[a]	Rate (g/L)	Volume (mL) per plant	Dose of product per plant (mg)		Control of downy mildew[b]
						Trt.	Total	(%)
Blackberry								
Exp. 1	1.0	Aliette	10	2.5	8.6	22	215	**67**
		TKO Phosphite	10	2.5	8.6	22	215	**58**
Exp. 2	1.0	Aliette	10	2.5	8.6	22	215	7
		TKO Phosphite	10	2.5	8.6	22	215	24
Rose								
Exp. 1	1.0	Aliette	10	2.5	4.3	11	108	41
		TKO Phosphite	10	2.5	4.3	11	108	0
Exp. 2	1.0	Aliette	10	2.5	4.3	11	108	**83**
		TKO Phosphite	10	2.5	4.3	11	108	**100**

[a] Sprays applied at 14 d intervals

[b] Assessed 14 days after final spray as reduction in % leaf area affected; reductions of >50% are shown in bold.

8. Overall conclusions

1. The review of this literature highlighted that rose downy mildew risk is strongly associated with increasing duration of leaf wetness. On one nursery with severe downy mildew in May 2005, rain occurred on 18 days out of 28 prior to severe disease.

2. Natural products demonstrated to have same activity against downy mildew fungi include various chemical salts (potassium bicarbonate, potassium phosphite and sodium silicate), plant extracts (herbal oils, Milsana, neem oil, oilseed rape oil) and other substances (*Bacillus subtilis, Muscodor albus* and salicylic acid).

3. Natural products permitted for use on rose in the home and garden area and marketed in the UK for use on plants include Orophyte, Biosept All Clear and phosphite (e.g. Farm-Fos-44).

4. Downy mildew was significantly reduced on rose at one or more assessments, by Aliette 80WG applied at 14 day intervals and by Biosept All Clear and Dithane 945 applied at 7 day intervals. Sprays of potassium bicarbonate and salicylic acid significantly increased leaf fall.

5. Downy mildew was significantly reduced on blackberry by sprays of Aliette 80WG and TKO Phosphite at 14 day intervals and by Dithane 945 at 7 day intervals. Sprays of potassium bicarbonate and sodium silicate significantly increased the disease, compared with untreated plants.

6. Sprays of potassium bicarbonate and sodium silicate stunted growth of roses. Salicylic acid resulted in burnt areas on blackberry leaves

9. Technology transfer

Project meeting with Tim Pettitt, 16 November 2005.
Project progress update to BRGA, December 2005 (HDC)

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APPENDIX 1: Data summary for Experiment 1

Table 1. Effect of some fungicides and natural products on rose downy mildew – Experiment 1, incidence of affected plants.

Treatment	% plants affected						
	17 Aug	31 Aug	27 Sep	11 Oct	25 Oct	03 Nov	16 Nov
Untreated	19	13	50	75	75	88	88
Aliette 80WG	0	0	50	88	50	88	75
Dithane 945	25	13	13	50	0	50	38
Biosept	13	38	13	50	25	88	63
Chitin	0	0	50	100	50	100	88
OSR oil	0	25	50	63	75	75	88
Potassium bicarbonate	25	0	25	75	50	100	100
Salicylic acid	0	0	38	50	50	100	75
SeaGold	0	0	50	75	63	100	88
Sodium silicate	0	38	38	63	38	100	75
TKO Phosphite	0	0	50	88	63	100	88
Significance	0.126	0.265	0.281	0.508	0.198	0.029	0.428
SED between treatments	12.3	18.8	19.6	24.8	27.3	14.3	23.6
Vs untreated	10.7	16.3	16.9	21.5	23.7	12.4	20.5

Table 2. Effect of some fungicides and natural products on rose downy mildew – Experiment 1, % leaf area affected.

Treatment	% leaf area affected						
	17 Aug	31 Aug	27 Sep	11 Oct	25 Oct	03 Nov	16 Nov
Untreated	0.4	0.1	0.7	1.0	0.9	4.9	1.6
Aliette 80WG	0	0	0.7	1.0	0.4	2.9	0.4
Dithane 945	0.3	0.1	0.1	0.6	0	2.8	0.2
Biosept	0.3	0.4	0.1	0.9	0.3	2.4	0.7
Chitin	0	0	0.7	1.3	0.4	10.1	1.2
OSR oil	0	0.3	0.9	1.1	1.1	5.4	1.1
Potassium bicarbonate	0.4	0	0.4	1.7	0.8	12.0	2.0
Salicylic acid	0	0	0.5	1.0	0.4	14.3	0.7
SeaGold	0	0	0.8	1.9	0.7	7.9	1.3
Sodium silicate	0	1.0	0.4	1.0	0.8	7.5	1.0
TKO Phosphite	0	0	0.4	1.2	0.6	6.5	0.8
Significance	0.552	0.128	0.553	0.639	0.310	0.383	0.051
SED between treatments	0.29	0.33	0.38	0.57	0.44	5.30	0.53
Vs untreated	0.26	0.28	0.33	0.50	0.38	4.59	0.46

Table 3. Effect of some fungicides and natural products on rose downy mildew – Experiment 1, plant vigour.

Treatment	Plant vigour (0-5)						
	17 Aug	31 Aug	27 Sep	11 Oct	25 Oct	03 Nov	16 Nov
Untreated	2.1	2.3	1.9	2.4	2.3	2.1	2.2
Aliette 80WG	2.1	2.0	2.4	2.1	2.1	2.3	2.3
Dithane 945	2.1	2.0	2.5	2.3	2.5	2.3	2.1
Biosept	2.0	2.0	2.6	2.1	2.3	2.1	2.1
Chitin	2.1	2.3	2.9	2.1	2.5	1.8	2.3
OSR oil	2.1	2.0	2.4	2.4	1.9	1.9	2.0
Potassium bicarbonate	2.1	1.9	1.5	2.0	2.0	1.5	1.8
Salicylic acid	2.0	2.1	2.3	1.9	2.3	1.6	1.9
SeaGold	2.3	2.6	2.5	1.9	2.6	2.0	2.5
Sodium silicate	2.1	1.9	2.0	2.0	2.0	2.0	2.0
TKO Phosphite	2.3	2.0	2.3	2.3	2.4	2.1	2.0
Significance	0.404	0.014	0.013	0.118	0.051	0.015	0.086
SED between treatments	0.11	0.19	0.33	0.21	0.23	0.21	0.21
Vs untreated	0.09	0.17	0.29	0.18	0.20	0.19	0.18

Table 4. Effect of some fungicides and natural products on rose downy mildew – Experiment 1, incidence of plants with new growth affected.

Treatment	% of plants with new growth affected				
	27 Sep	11 Oct	25 Oct	03 Nov	16 Nov
Untreated	31	0	0	31	0
Aliette 80WG	38	0	0	38	25
Dithane 945	0	0	0	13	0
Biosept	13	25	0	0	0
Chitin	25	0	0	25	0
OSR oil	50	0	0	25	13
Potassium bicarbonate	13	13	13	38	25
Salicylic acid	13	0	0	38	0
SeaGold	38	0	0	50	0
Sodium silicate	0	0	0	50	0
TKO Phosphite	50	0	0	13	0
Significance	0.092	0.443	0.367	0.584	0.032
SED between treatments	19.1	11.4	5.0	24.3	9.6
Vs untreated	16.6	9.9	4.3	21.0	8.3

Table 5. Effect of some fungicides and natural products on rose downy mildew – Experiment 1, leaf fall.

Treatment	Leaf fall index				
	27 Sep	11 Oct	25 Oct	03 Nov	16 Nov
Untreated	0.9	1.9	1.3	1.9	2.3
Aliette 80WG	0.6	1.4	1.5	2.1	2.4
Dithane 945	0.4	1.6	1.5	2.1	2.1
Biosept	0.1	0.5	1.0	1.4	1.3
Chitin	0.1	1.1	1.1	3.6	3.3
OSR oil	0.6	1.3	2.3	2.8	3.0
Potassium bicarbonate	1.8	2.9	2.3	3.9	3.0
Salicylic acid	1.1	2.0	2.9	3.5	3.3
SeaGold	0.4	2.4	2.1	3.1	3.1
Sodium silicate	0.4	1.1	1.4	2.5	2.9
TKO Phosphite	0.6	1.4	1.9	2.8	2.3
Significance	0.174	0.016	0.016	0.002	0.027
SED between treatments	0.58	0.58	0.51	0.60	0.58
Vs untreated	0.50	0.49	0.44	0.52	0.49

Table 6. Effect of some fungicides and natural products on blackberry downy mildew – Experiment 1, incidence of affected plants.

Treatment	% plants affected				
	17 Aug	31 Aug	27 Sep	11 Oct	25 Oct
Untreated	81	94	100	100	100
Aliette 80WG	88	100	100	100	100
Dithane 945	100	100	88	88	100
Biosept	100	88	100	100	100
Chitin	100	100	100	100	100
OSR oil	100	100	100	100	100
Potassium bicarbonate	75	88	100	100	100
Salicylic acid	100	100	100	100	100
SeaGold	100	100	100	100	100
Sodium silicate	100	100	100	100	100
TKO Phosphite	75	88	100	100	100
Significance	0.162	0.784	0.367	0.367	-
SED between treatments	12.8	10.4	5.0	5.0	-
Vs untreated	11.1	9.0	4.3	4.3	-

Table 7. Effect of some fungicides and natural products on blackberry downy mildew - Experiment 1, % leaf area affected.

Treatment	% leaf area affected						
	17 Aug	31 Aug	27 Sep	11 Oct	25 Oct	03 Nov	16 Nov
Untreated	19.4	15.3	26.2	19.6	20.2	15.1	10.4
Aliette 80WG	13.2	20.9	7.9	7.6	6.0	5.0	6.2
Dithane 945	16.9	17.3	14.6	12.7	8.5	8.5	4.9
Biosept	24.0	17.8	9.5	7.9	13.2	8.1	8.1
Chitin	31.6	36.8	19.2	17.6	15.6	19.9	18.4
OSR oil	19.8	17.8	38.8	23.4	21.0	16.5	10.0
Potassium bicarbonate	25.6	20.4	54.4	54.4	49.6	44.9	36.0
Salicylic acid	20.8	30.9	17.2	10.9	11.5	10.4	6.5
SeaGold	21.1	17.9	19.4	18.1	13.6	11.5	6.2
Sodium silicate	45.6	50.6	38.8	53.8	47.5	46.2	31.6
TKO Phosphite	12.6	17.2	18.7	13.7	8.4	6.4	3.7
Significance	0.016	0.004	<0.001	<0.001	<0.001	<0.001	<0.001
SED between treatments	8.13	8.77	9.8	8.9	8.8	8.3	6.5
Vs untreated	7.04	7.60	8.5	7.8	7.6	7.2	5.6

Table 8. Effect of some fungicides and natural products on blackberry downy mildew – Experiment 1, plant vigour.

Treatment	Plant vigour (0-5)						
	17 Aug	31 Aug	27 Sep	11 Oct	25 Oct	03 Nov	16 Nov
Untreated	2.3	2.2	2.0	1.9	1.8	1.9	1.7
Aliette 80WG	2.0	2.3	2.6	2.4	2.4	2.4	2.1
Dithane 945	2.1	2.1	2.6	2.4	2.4	2.4	2.6
Biosept	2.1	2.4	2.6	2.3	2.1	2.3	2.3
Chitin	1.9	2.3	2.1	1.8	1.9	1.8	1.9
OSR oil	2.0	2.3	1.6	1.9	1.8	1.8	1.8
Potassium bicarbonate	2.0	2.3	1.5	1.3	1.3	0.9	1.0
Salicylic acid	2.1	2.0	1.9	2.0	2.0	1.9	1.9
SeaGold	2.0	2.0	2.0	2.1	2.0	1.8	1.8
Sodium silicate	1.6	1.8	1.1	1.1	1.1	0.6	0.8
TKO Phosphite	2.1	2.1	2.4	2.0	2.1	2.3	2.3
Significance	0.095	0.112	<0.001	<0.001	<0.001	<0.001	<0.001
SED between treatments	0.19	0.18	0.32	0.27	0.25	0.29	0.29
Vs untreated	0.16	0.16	0.28	0.23	0.22	0.26	0.25

Table 9. Effect of some fungicides and natural products on blackberry downy mildew – Experiment 1, incidence of plants with new growth affected.

Treatment	% of plants with new growth affected					
	31 Aug	27 Sep	11 Oct	25 Oct	03 Nov	16 Nov
Untreated	0	100	81	81	81	94
Aliette 80WG	13	50	38	38	75	100
Dithane 945	0	75	13	38	25	38
Biosept	0	100	38	50	88	100
Chitin	25	100	88	88	100	100
OSR oil	13	100	63	75	75	88
Potassium bicarbonate	13	100	88	100	100	100
Salicylic acid	25	88	100	63	100	100
SeaGold	0	100	88	100	88	88
Sodium silicate	13	100	88	100	88	100
TKO Phosphite	0	88	75	25	75	100
Significance	0.507	0.003	0.003	0.001	0.035	<0.001
SED between treatments	14.8	12.1	21.1	19.9	19.6	12.8
Vs untreated	12.8	10.5	18.3	17.3	17.1	11.1

APPENDIX 2: Data summary for Experiment 2

Table 1. Effect of some fungicides and natural products on rose downy mildew – Experiment 2, incidence of affected plants.

Treatment	% plants affected				
	28 Sep	11 Oct	25 Oct	16 Nov	02 Dec
Untreated	12.5	21.9	12.5	18.8	53.1
Aliette 80WG	6.3	6.3	6.3	6.3	50.0
Dithane 945	6.3	25.0	12.5	31.3	31.3
Biosept	6.3	0.0	0.0	6.3	25.0
Chitin	0.0	12.5	0.0	18.8	31.3
OSR oil	12.5	0.0	0.0	12.5	37.5
Potassium bicarbonate	0.0	0.0	0.0	12.5	31.3
Salicylic acid	6.3	0.0	0.0	18.8	56.3
SeaGold	25.0	6.3	12.5	50.0	68.8
Sodium silicate	6.3	6.3	6.3	0.0	25.0
TKO Phosphite	0.0	6.3	0.0	6.3	12.5
Significance	0.675	0.113	0.496	0.011	0.270
SED between treatments	12.2	10.5	8.9	11.8	21.4
Vs untreated	10.6	9.1	7.7	10.2	18.5

Table 2. Effect of some fungicides and natural products on rose downy mildew – Experiment 2, % leaf area affected.

Treatment	% leaf area affected				
	28 Sep	11 Oct	25 Oct	16 Nov	02 Dec
Untreated	0.3	0.4	0.2	0.6	4.0
Aliette 80WG	0.1	0.3	0.1	0.1	1.5
Dithane 945	0.1	0.3	0.1	0.4	1.2
Biosept	0.1	0.0	0.0	0.1	0.9
Chitin	0.0	0.4	0.0	0.3	0.6
OSR oil	0.1	0.0	0.0	0.3	1.6
Potassium bicarbonate	0.0	0.0	0.0	0.1	0.6
Salicylic acid	0.0	0.0	0.0	0.6	1.8
SeaGold	0.5	0.1	0.1	1.2	2.8
Sodium silicate	0.1	0.1	0.3	0.0	0.5
TKO Phosphite	0.0	0.2	0.0	0.0	0.4
Significance	0.450	0.483	0.576	0.131	0.367
SED between treatments	0.221	0.254	0.160	0.394	1.792
Vs untreated	0.192	0.220	0.138	0.341	1.552

Table 3. Effect of some fungicides and natural products on rose downy mildew – Experiment 2, incidence of plants with new growth affected.

Treatment	% of plants with new growth affected				
	28 Sep	11 Oct	25 Oct	16 Nov	02 Dec
Untreated	0.0	0.0	0.0	0.0	28.0
Aliette 80WG	0.0	0.0	0.0	0.0	19.0
Dithane 945	0.0	0.0	0.0	0.0	0.0
Biosept	0.0	0.0	0.0	0.0	0.0
Chitin	0.0	0.0	0.0	0.0	0.0
OSR oil	0.0	0.0	0.0	0.0	6.0
Potassium bicarbonate	0.0	0.0	0.0	0.0	0.0
Salicylic acid	0.0	0.0	0.0	0.0	0.0
SeaGold	0.0	0.0	0.0	6.0	6.0
Sodium silicate	0.0	0.0	0.0	13.0	0.0
TKO Phosphite	0.0	0.0	0.0	0.0	0.0
Significance	-	-	-	0.443	0.441
SED between treatments	-	-	-	5.7	16.3
Vs untreated	-	-	-	4.9	14.2

Table 4. Effect of some fungicides and natural products on rose downy mildew – Experiment 2, leaf fall.

Treatment	Leaf fall index				
	28 Sep	11 Oct	25 Oct	16 Nov	02 Dec
Untreated	0.03	0.53	1.22	2.34	2.34
Aliette 80WG	0.13	1.00	1.38	2.50	2.00
Dithane 945	0.06	0.50	0.88	1.69	2.06
Biosept	0.00	0.50	0.69	1.63	1.88
Chitin	0.19	0.44	0.88	1.69	1.88
OSR oil	0.00	0.44	0.81	1.69	2.13
Potassium bicarbonate	0.00	0.31	0.56	1.56	1.50
Salicylic acid	0.13	0.44	0.69	1.69	2.00
SeaGold	0.06	0.44	1.13	2.19	2.13
Sodium silicate	0.00	0.31	0.81	1.69	2.13
TKO Phosphite	0.13	0.50	0.88	1.50	1.44
Significance	0.670	0.383	0.802	0.683	0.919
SED between treatments	0.109	0.247	0.480	0.616	0.637
Vs untreated	0.095	0.214	0.416	0.534	0.552

Table 5. Effect of some fungicides and natural products on rose downy mildew – Experiment 2, plant vigour.

Treatment	Plant vigour (0-5)				
	28 Sep	11 Oct	25 Oct	16 Nov	02 Dec
Untreated	2.25	1.81	1.91	1.72	1.72
Aliette 80WG	2.25	1.69	1.88	1.88	1.88
Dithane 945	2.19	2.19	2.13	1.88	1.94
Biosept	2.06	1.81	1.94	1.94	1.88
Chitin	2.13	1.88	1.75	1.88	2.06
OSR oil	2.25	2.00	2.00	2.00	1.94
Potassium bicarbonate	2.06	1.88	1.94	1.81	1.94
Salicylic acid	2.13	1.94	2.00	1.81	1.94
SeaGold	2.38	2.38	2.00	2.06	2.19
Sodium silicate	2.19	1.94	1.75	1.75	2.00
TKO Phosphite	2.13	1.94	2.00	2.13	2.13
Significance	0.850	0.082	0.423	0.463	0.497
SED between treatments	0.187	0.199	0.155	0.195	0.215
Vs untreated	0.162	0.173	0.134	0.168	0.186

Table 6. Effect of some fungicides and natural products on blackberry downy mildew – Experiment 2, incidence of affected plants.

Treatment	% plants affected				
	28 Sep	11 Oct	25 Oct	16 Nov	02 Dec
Untreated	100.0	100.0	100.0	100.0	93.8
Aliette 80WG	100.0	100.0	100.0	100.0	87.5
Dithane 945	100.0	100.0	100.0	100.0	100.0
Biosept	100.0	100.0	100.0	100.0	87.5
Chitin	100.0	100.0	100.0	100.0	100.0
OSR oil	100.0	100.0	100.0	100.0	100.0
Potassium bicarbonate	100.0	100.0	100.0	100.0	87.5
Salicylic acid	100.0	100.0	100.0	87.5	87.5
SeaGold	100.0	100.0	100.0	100.0	100.0
Sodium silicate	100.0	100.0	100.0	100.0	100.0
TKO Phosphite	100.0	100.0	100.0	87.5	75.0
Significance	-	-	-	0.463	0.404
SED between treatments	-	-	-	7.2	11.3
Vs untreated	-	-	-	6.3	9.8

Table 7. Effect of some fungicides and natural products on blackberry downy mildew – Experiment 2, % leaf area affected.

Treatment	% leaf area affected				
	28 Sep	11 Oct	25 Oct	16 Nov	02 Dec
Untreated	7.8	8.2	7.4	5.9	6.2
Aliette 80WG	7.9	5.6	6.3	5.5	5.1
Dithane 945	9.5	7.6	8.5	5.5	4.8
Biosept	3.8	8.6	5.4	3.8	4.8
Chitin	10.3	10.5	6.8	5.6	3.6
OSR oil	5.5	7.4	8.9	5.8	6.1
Potassium bicarbonate	5.3	9.6	8.0	4.0	3.6
Salicylic acid	4.8	5.1	8.4	4.5	4.4
SeaGold	4.9	5.0	6.4	4.6	8.8
Sodium silicate	4.7	5.1	7.5	4.0	6.3
TKO Phosphite	7.9	8.8	6.8	4.5	4.0
Significance	0.538	0.383	0.925	0.790	0.810
SED between treatments	3.292	2.629	2.370	1.526	2.843
Vs untreated	2.851	2.277	2.053	1.321	2.462

Table 8. Effect of some fungicides and natural products on blackberry downy mildew – Experiment 2, incidence of plants with new growth affected.

Treatment	% of plants with new growth affected				
	28 Sep	11 Oct	25 Oct	16 Nov	02 Dec
Untreated	31	31	38	44	69
Aliette 80WG	50	75	75	88	75
Dithane 945	50	25	63	63	88
Biosept	38	88	63	75	75
Chitin	50	75	63	50	50
OSR oil	50	50	75	75	00
Potassium bicarbonate	25	63	50	38	75
Salicylic acid	63	00	88	38	50
SeaGold	25	38	50	63	75
Sodium silicate	50	50	38	75	75
TKO Phosphite	50	50	13	38	38
Significance	0.946	0.043	0.279	0.614	0.438
SED between treatments	29.2	24.0	27.3	29.3	24.9
Vs untreated	25.3	20.8	23.7	25.4	21.5

Table 9. Effect of some fungicides and natural products on blackberry downy mildew – Experiment 2, plant vigour.

Treatment	Plant vigour (0-5)				
	28 Sep	11 Oct	25 Oct	16 Nov	02 Dec
Untreated	2.25	2.06	2.13	2.00	2.13
Aliette 80WG	2.38	2.00	2.00	2.00	1.88
Dithane 945	2.25	2.25	2.00	2.13	2.00
Biosept	2.63	2.13	2.13	2.13	2.00
Chitin	2.38	2.13	2.00	2.13	2.00
OSR oil	2.50	2.25	2.00	2.00	2.00
Potassium bicarbonate	2.25	2.00	2.00	2.00	2.13
Salicylic acid	2.63	2.25	2.00	2.25	2.13
SeaGold	2.63	2.50	2.13	2.13	2.00
Sodium silicate	2.25	2.25	2.00	2.00	1.88
TKO Phosphite	2.38	2.00	2.00	2.13	2.13
Significance	0.568	0.260	0.538	0.523	0.783
SED between treatments	0.252	0.193	0.096	0.129	0.177
Vs untreated	0.218	0.167	0.083	0.112	0.153

Table 10. Effect of some fungicides and natural products on blackberry downy mildew – Experiment 2, no. leaves.

Treatment	Average no. leaves per plant				
	28 Sep	11 Oct	25 Oct	16 Nov	02 Dec
Untreated	10.38	11.56	12.69	13.25	13.31
Aliette 80WG	10.50	11.00	11.50	12.63	14.62
Dithane 945	10.25	11.00	11.25	11.63	12.88
Biosept	11.63	11.75	13.38	13.50	14.00
Chitin	8.50	10.00	11.25	12.25	12.25
OSR oil	11.00	10.75	10.88	12.38	12.88
Potassium bicarbonate	10.13	11.13	12.50	13.00	14.13
Salicylic acid	10.75	12.00	12.63	12.00	12.88
SeaGold	11.00	13.00	14.63	14.63	15.38
Sodium silicate	11.63	11.63	12.50	13.75	13.38
TKO Phosphite	11.88	12.63	13.25	13.63	14.38
Significance	0.327	0.602	0.139	0.824	0.721
SED between treatments	1.218	1.325	1.244	1.666	1.595
Vs untreated	1.055	1.148	1.077	1.443	1.381

APPENDIX 3: Summary information on natural products and commodity substances. The products listed give some control of Oomycetes, fungi or other foliar pathogens of roses.

Product	**Active ingredients**	**Supplier**	**Mode of action**	**Some Diseases controlled**	**Crop types on which used**	**Method of use**	**Reference source**
Biosept All Clear & Biosept Crop Gold	Plant extracts including grapefruit oil	www. plantsolutionsltd.com	Chemical induction of plant resistance.	Protection against fungi & bacteria claimed	Ornamental and edible crops	Foliar spray	Product leaflet
Citrox P	Citrus fruit extracts & surfactants	www.agralan.co.uk	Anti-fungal, bacterial & viral (disinfectant)	Bacteria, Fungi Viruses		Foliar spray, or with irrigation water. Dip for propagating material.	Product leaflet
Companion	Bacillus subtilis GB03	www.growth products.com	Microbial suppression	Soil-borne *Phytophthora* *Pythium*	Ornamental plants, shrubs & trees.	Foliar spray, drench or with irrigation water	Product leaflet
Compost tea (aerated & non-aerated)	Bacteria & fungi including the genera *Bacillus, Serratia, Penicillium* & *Trichoderma*	www. fargro.co.uk	Inhibition of spore germination. Antagonism & competition with pathogens. Induced plant resistance.	Downy mildew Potato blight Powdery mildew	Glasshouse & field grown edible & ornamental crops.	Foliar spray	Diver, 1998. Scheuerell & Mahaffee, 2002. HDC Annual Report HNS 125, 2004.

Appendix 3. Cont……

Product	Active ingredients	Supplier	Mode of action	Some Diseases controlled	Crop types on which used	Method of use	Reference source
Crab shell powder (experimental)	Chitin Chitosan (when partly de-acetylated)	Oceans Organics Ltd.	Chemical and microbial (natural soil flora) induction of plant resistance	Black spot As chitosan; Powdery mildew, Downy mildew. Crown rot (*Phytophthora)*.	Rose Grape Strawberry	Compost incorporation In solution	Hall *pers. comm.* Schilder *et al.,* 2002. Eikemo *et al.,* 2003
Experimental	*Bacillus subtilis/ Bacillus pumilus*		Microbial induction of plant growth resistance	Downy mildew	Pearl millet	Seed treatment	Raj *et al*., 2003
Herbal oil (experimental) Peppermint	Peppermint oil		Anti-fungal chemical	Downy mildew	Brassica	Foliar spray	Lawson *et al.,* 1998.
Herbal oils (experimental) Lemon balm, Yarrow, coriander, Hyssop, Thyme & Peppermint	Essential oils		Chemical inhibition of fungal growth in fungal culture.	Potato blight (*Phytophthora infestans)*.			Qunintanilla *et al.*, 2002.

Appendix 3. Cont……

Product	**Active ingredients**	**Supplier**	**Mode of action**	**Some Diseases controlled**	**Crop types on which used**	**Method of use**	**Reference source**
Laminarin (experimental)	Polysaccharide from Kelp *Laminaria digitata*		Chemical induction of plant resistance.	Downy mildew, Powdery mildew, & Grey Mould (in culture)	Grape		Minami, 2004
Milsana	Extract of giant knotweed (*Fallopia sachalinensis*)	www. Biofa-farming.com	Activates host defence (protectant)	Downy mildew Powdery mildew Grey Mould	Grapes, glasshouse ornamentals, roses, cucumbers, herbs	Foliar spray. Supplier recommends together with wetting agent TrifolioS-forte	Schilder *et al.,* 2002 Benmhend, 2005 Quarles, 2005 DEFRA, 2004 Reissner, Biofa *pers. comm.*
Muscodor albus (experimental)	Muscodor albus		Anti-fungal from microbial volatiles	*Phytophthora capsici*	Pepper	Compost incorporation	Mercier & Manker, 2005
Neem Oil / Neem seed extract	Extract from Neem tree (*Azadirachta indica).* Azadirachtin a.i.	Not licensed for use in the U.K.	Anti-fungal chemical (against zoospores)	Downy mildew Powdery mildew Rose black spot Grey Mould	Grape Lettuce Ornamentals	Foliar spray	Acimu & Schlösser, 1992. DEFRA, 2002. Quarles, 2005
Oilseed rape oil (experimental)	Culinary vegetable oil		Antifungal activity.	Downy mildew Powdery mildew	Lettuce Various crops	Foliar spray, with or without wetter	DEFRA, 2002. www. OISAT.org Quarles, 2005.

Appendix 3. Cont……

Product	Active ingredients	Supplier	Mode of action	Some Diseases controlled	Crop types on which used	Method of use	Reference source
Orophyte	5.4% Phosphorous acid P_2O_5 5.0% Potash K_2O Wetting agent	www. plantsolutionsltd.com	Chemical induction of plant resistance. Antifungal through desiccation	Foliar fungi Downy mildew	Field & protected crops Soft fruit	Foliar spray	Product leaflet Rebecca Dawson, Plant Solutions Ltd. *pers. comm.*
Potassium bicarbonate (commodity substance)	Potassium hydrogen carbonate $KHCO_3$		Antifungal activity.	Powdery mildew	Horticultural crops including raspberries, herbs.	Foliar spray, with a wetter	Neillist, 2005. DEFRA, 2004. Scott Raffle ADAS *pers. comm.*
Salicylic acid (experimental)	Salicyclic acid (aspirin)		Chemical induction of plant resistance.	Downy mildew	Lettuce	Foliar spray	DEFRA, 2002.
Seagold (derived from shrimp & crab meal, seaweed *Ascophyllum nodosum*, and leonardite)	Organic matter and ureic nitrogen, phosphoric anhydride, organic carbon, chitin.	www. triad-organic.com	Chemical and microbial (natural soil flora) induction of plant resistance	Label claim for breakdown of chitin cell walls of nematodes & some fungi (not Oomycetes)	Not specified	Soil incorporation or top dressing	Product leaflet
Silicon (experimental)	Sodium silicate		Chemical induction of plant resistance.	Powdery mildew	Glasshouse cucumber. Wheat & barley	Foliar spray, or with irrigation water	Bowen *et al.,* 1992. Belanger *et al.,* 1995.

Appendix 3. Cont……

Product	Active ingredients	Supplier	Mode of action	Some Diseases controlled	Crop types on which used	Method of use	Reference source
TKO Phosphite 0-29-26	29% Phosphate P_2O_5 26% Potash K_2O (phosphorus acid salts)	www.growth products.com	Chemical induction of plant resistance. Antifungal activity.	No label claims *Phytophthora* tuber blight	Outdoor nursery stock, vegetables & fruit, indoor crops. Potato	Foliar spray, drench or with irrigation water according to crop	Product leaflet Johnson *et al*., 2004