

## **BASIS 2020**

# **Use of UV-C radiation and plant defense elicitors for prevention of powdery mildew in potted rosemary.**

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## **EXECUTIVE SUMMARY:**

Most commercial horticultural crops are still protected against plant pathogens by the use of conventional pesticides. However, environmental and safety concerns as well as the threat of pathogens developing resistance, pushed European and British legislation to challenge this status quo. The industry is facing the challenge to control pests and diseases with a reduced chemical assortment and to develop other methods that achieve similar levels of efficacy.

Some of the most economically devastating crop losses are caused by fungal infections and one of the most common groups of fungal pathogens are the powdery mildews. In the last decade the horticultural industry has developed new technology as alternative methods to try and prevent this disease, such as UV-C radiation and plant defense elicitors. While UV-C is now accepted as a practical alternative to pesticides in crops of high economical value (e.g. tomato, cucumber, grapes, marijuana, roses and storage of fruits), very little research has been undertaken to investigate its efficacy on minor crops like rosemary. Even less is known about the performance of plant defense elicitors in commercial applications.

At Vitacress Herbs, powdery mildew is a major problem on rosemary and significant resource is required to keep it under control. Finding alternative, more efficient methods of control would be of significant benefit to the business. The findings of this project indicate that UV-C application can provide 100% protection against powdery mildew in the rosemary crop. No disease control was observed in plants treated with the plant defense elicitor. Neither treatment had any adverse effect on plant growth.

The success of the UV-C treatment in this project will inform business decisions on further investment to use this automated technology for all pot rosemary production, labor savings alone justify the investment. Moreover, the principle of reducing pesticide use is an addition benefit and as UV-C radiation is a physical treatment, there is minimal possibility of pathogen resistance development.

## INTRODUCTION:

### Disease:

**Powdery mildew (PM)** is one of the most common fungal diseases affecting plants across the globe. Although often not lethal to the host, it affects aesthetics and reduces crop yield, hence its agronomic relevance is considerable (Panstruga and Kuhn, 2019).

Powdery mildew pathogens can affect over 9 000 different species of angiosperms, including many vegetables and herbs (Lebeda and Mieslerová, 2010). It is caused by several types of fungal organisms (e.g. *Erysiphe*, *Podosphaera*, *Oidium*, & *Leveillula*) and all need live host to feed and rarely survive when living crop is not present (biotrophic fungi) (Powdery Mildew, 2020).

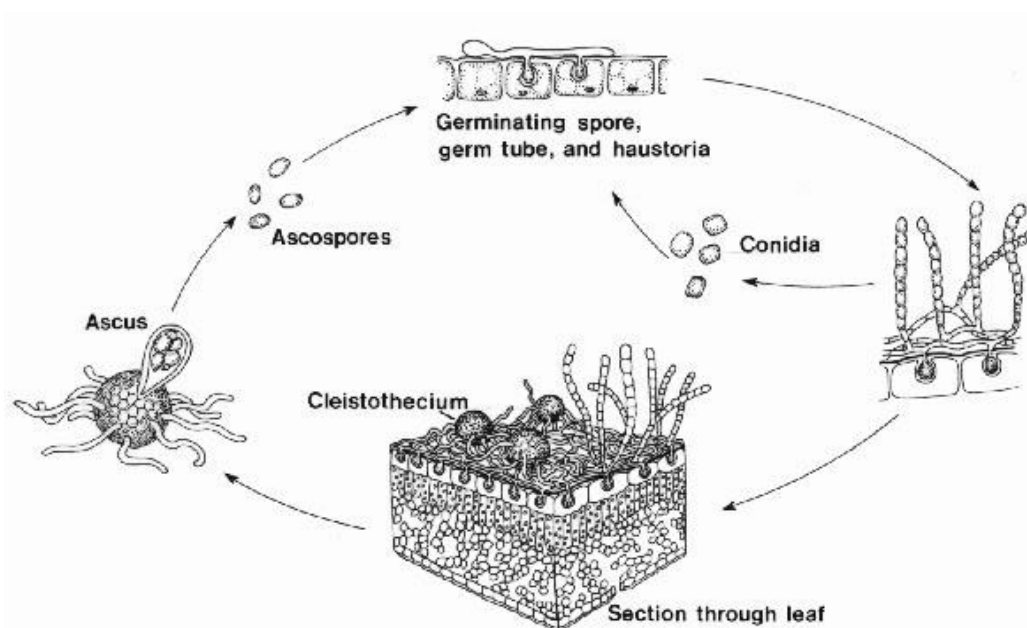


Figure 1 Generalized life cycle of powdery mildew (Powdery Mildew Life Cycle, 2020).

The different genera of powdery mildews have very similar life cycles (Figure 1). Generally, fungal spores germinate on the plant surface, developing a germ tube and small infective structures (haustoria). The haustorium enables penetration into the plant cells and extracts nutrients necessary for fungal growth. In most cases the main body of the fungus is growing outside of the plant surface. Mycelium growing on the plant surface starts to produce new conidiophores (appearing as white, fluffy growth, characteristic for powdery mildews) which contain asexual spores (conidia). The fungus can also produce sexual ascospores from cleistothecia but these have not been observed on pot rosemary at Vitacress. Both conidia and ascospores are dispersed by wind and carry the disease to neighboring plants, however conidia are the main vector transporting the disease and ascospores may not be relevant in the greenhouse environment (Powdery Mildew, 2020).

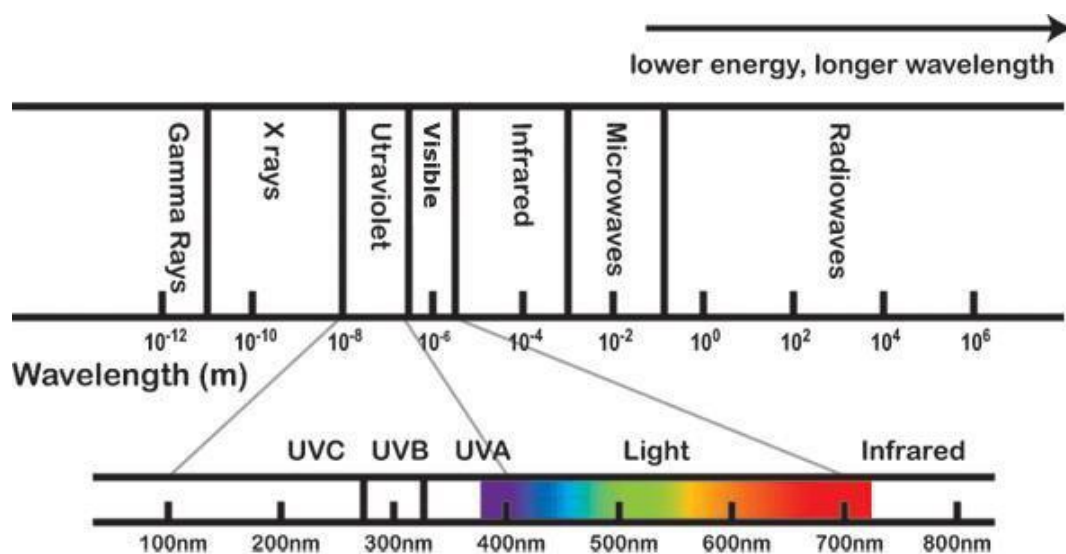
Traditionally this disease was controlled by application of fungicides, as advised in many older handbooks for growers across different specializations (Strand, 1994). Widespread and systematic use of pesticide can have detrimental effects on human health, the environment, and biodiversity. Lastly overuse of pesticides can lead to development of resistance of the pathogen to the active ingredients in use. Those dangers were dully noticed by legislators and numerous acts of law were introduced over the last 35 years to try and maintain pest & disease control whilst ensuring reduced and safe application of pesticides in the European Union and United Kingdom (Food and Environment Protection Act, Control of Pesticide Regulation, Plant Protection Products Regulations, Sustainable Use Directive and Sustainable Use of Pesticides Regulations).

Driven by legal changes, practicalities and necessities of commercial growing, there has been a significant trend to stop treating pesticides as the only serious solution to pest & disease and to incorporate them into program of cultural, mechanical and biological techniques of crop protection know as Integrated Pest Management (IPM) (Helyer, Brown and Cattlin, 2003).

All these factors together stimulated the company to reach for new technologies and non-pesticide tools of plant protection. This project is an attempt to investigate two such ways of preventing rosemary crop from PM infestation and their efficacies: use of UV-C radiation and application of plant defense elicitors.

### UV-C radiation:

**Ultra Violet (UV)** radiation is a part of an electromagnetic radiation spectrum (Figure 2) comprised of three different groups depending on their wavelength: UV-A (315-400 nm), UV-B (280-315 nm) and UV-C (100-280 nm) (Ultraviolet radiation and health, 2020).



*Figure 2. Electromagnetic radiation spectrum (Canada, 2020)*

The disinfectant and pathogen controlling properties of UV light (especially UV-C) were long established – this includes pathogens causing well known airborne diseases in humans. This is achieved by causing damage to genetic material in the cell or the virus (DNA or RNA). UV-C is especially efficient as it is easily absorbed by microorganisms (262nm is known as germicidal spectrum) (Welch et al., 2018).

In the past decade UV-C treatment in prevention of powdery mildew has become of interest in many crops including grapes, strawberries, cucumbers and commercially grown marijuana. It is also widely used to prevent post-harvest disease in production of fruits, giving an indication that it could replace or reduce fungicide use for some diseases in commercial herb growing.

#### **Plant Defense Elicitor (PLE) - Fytosave:**

PLEs are compounds (natural or synthetic) responsible for causing defensive plant reactions, similar to those induced by pathogen infestation. Their plant protection potential was discovered during intensified works on plant signaling pathways. Generally, an impulse caused by PLEs forces plants to release Active Oxygen Species (AOS) and multiple other substances including Pathogen Related Proteins. AOS causes a rapid reaction of plants leading to death of cells affected by pathogens and developing resistance in other parts of the plant. Some of the most well know PLEs are: glycopeptides, carbohydrate polymers lipids & glycoproteins (Thakur and Sohal, 2020).

One of the PDEs that recently proved to be successful in prevention of PM on tomatoes and other fungal diseases in various crop was COS-OGA (Chito-oligosaccharides-Oligogalacturonans) (van Aubel, Cambier, Dieu and Van Cutsem, 2016). COS-GA is the active ingredient in the product Fytosave used in this project.

#### **Powdery mildew on potted rosemary at Vitacress:**

Powdery mildew can affect various herb species including dill, fennel, parsley, mint, thyme, sage lavender, tarragon and rosemary (Wichura, 2012). At Vitacress, rosemary is the most susceptible crop to the disease and a severe outbreak was experienced in the 2019/2020 winter season when nearly 60,000 pots were wasted and extra labour costs were associated with PM control.

Cultural measures are obviously the first way to suppress disease potential and we have seen large differences between varietal susceptibility to powdery mildew and more work is underway to find a more suitable, disease resistant cultivar. We have also improved the watering regime to try and

maintain more even and drier pot moistures. However, the protected growing environment where temperatures (18-20°C) and night-time humidities (80-95%) coupled with close spacing, provide suitable conditions to promote disease epidemics (Powdery Mildew, 2020).

The number of traditional fungicides that are authorized for use in protected herb crops are now limited and the likelihood of losing more active ingredients in the future is high. The duration of the crop from planting to dispatch proves to be additional difficulty as, unlike other herbs grown in our facility (3-8 weeks), rosemary is a relatively long crop (6 months), so control of PM needs to be ensured for half a year, and in a period when plants are most susceptible. The products that can be used to protect rosemary against PM are shown in Table 1.

Our main line of defense is Potassium bicarbonate which gives good curative results but has to be applied weekly, or even twice weekly, and its approval as a Commodity Substance - is likely to be lost in the near future. Its potential full approval replacement, Karma, only allows eight applications per crop which is clearly not adequate for the duration of the rosemary crop. If Potassium bicarbonate alone is not sufficient to give control, we will also use Signum which provides excellent curative and protective results. Signum is limited to two applications per crop and so is only used when really needed. Amistar can also help but it's only really useful when relatively low levels of PM are present, and again, can only be applied twice per crop. Microthiol Special is as effective as Potassium bicarbonate but can only be applied twice per year and leaves significant unsightly deposits on the leaves. Amylo X and AQ 10 are both biopesticides (a bacterium and fungus, respectively) and we have been unable to achieve any control with either, we may just need to learn more about how to use these products. SB plant invigorator is another substance that is incorporated into the spraying programme early in the season, but is only useful when the level of PM is low and can cause browning of Rosemary leaves later in the season. Fytosave is a relatively new product and we wanted to see if it could be effective.

Commercial name	Active ingredients	MAPP number	Type of substance	FRAC code	Maximum number of applications	Harvest interval
<b>Amistar</b>	Azoxystrobin	18039	Pesticide (fungicide)	11	2 per year	14 days
<b>Amylo X</b>	Bacillus amyloliquefaciens	17978	Biopesticide	44	6 per year	N/A
<b>AQ 10</b>	Ampelomyces quisqualis strain AQ10	17102	Biopesticide	BM 02	12 per crop	N/A
<b>Fytosave</b>	COS-OGA	18433	Plant Defense Elicitor	Unclassified	8 per crop	N/A
<b>Karma</b>	Potassium hydrogen carbonate	16363	Pesticide (fungicide)	N/A	8 per crop	1 day
<b>Microthiol Special</b>	Sulphur	16989	Pesticide (Fungicide)/Foliar feed	M2	2 per year	N/A
<b>Potassium bicarbonate</b>	potassium hydrogen carbonate	N/A	Commodity Substance	N/A	N/A	N/A
<b>SB Plant Invigorator</b>	blend of plant safe, physical pest control surfactants	N/A	Plant invigorator	N/A	N/A	N/A
<b>Signum</b>	Boscalid and Pyraclostrobin	11450	Pesticide (fungicide)	7/11	N/A	14 days

*Table 1. Products used to protect rosemary against PM*

The main objectives of this project were to investigate:

1. Does UV-C applied via an automated boom give adequate control of powdery mildew in potted rosemary?
2. Can the plant defense elicitor, Fytosave, prevent powdery mildew development in potted rosemary?
3. Do either of the above two treatment have any deleterious effect upon the crop?

## **LEGISLATION, HEALTH AND SAFETY AND ENVIRONMENTAL CONSIDERATIONS:**

### **Pesticides and environmental considerations:**

As mentioned above, use of plant protection product is heavily regulated by both European law and UK legislation as their incompetent use can be a threat to public health, the environment and efficacy of plant protection. The main aim of this project is to minimise or eliminate those risks while ensuring a satisfactory level of crop protection, all in compliance with current legislation.

The foundation of UK law regarding food safety and environment protection that includes use of pesticides (PART III) is the Food & Environment Protection Act (FEPA 1985). The main aims of the act are: to protect the health of human beings, creatures and plants; safeguard the environment; secure safe, efficient and humane methods of controlling pests; and make information about pesticides available to the public. Acts such as FEPA are at the top of national legislative hierarchy.

The ways of achieving the aims set out in the act of parliament are later laid out in The Control of Pesticides Regulation (COPR 1986). COPR set standards for: definition in detail of those types of pesticides which are subject to control and those which are excluded; prescription of the approvals required before any pesticide may be sold, stored, supplied, used or advertised and allowing for general conditions on sale, supply, storage, advertisement, & use, including aerial application of pesticides (FEPA and COPR, 2020).

COPR since then has been overwritten by EU legislation, but it still regulates some substances relevant to powdery mildew prevention (such as potassium bicarbonate) (Commodity Substance: Potassium Hydrogen Carbonate, 2020). However, in 2009 the EU directive 1107/2009 was introduced. It changed the way pesticides are approved in that the approval system shifted from being a risk based assesment of active ingredients to hazard based. In the new system it is more challanging to prove that new active ingredients are safe, or to renew approvals for active ingredients in use. It is particularly relevant for PM control in that it changes the way that the law is classifying potassium bicarbonate, therefore in the near future this substance is going to be removed from the commodity substance list and will only be available under full pesticide approva (EUR-Lex - 32009R1107 - EN - EUR-Lex, 2020).

In 1992 another relevant piece of legislation was introduced; the Control of Substances Hazardous to Health (COSHH 1992). This legislation focuses on all substances that have potential to cause harm; hence COSH is also an important part of the Health & Safety at work legal system. The focus of

COSHH legislation is on eradication of risk whenever possible or reducing it to minimum levels. In simple terms it forces us to assess risks, eliminate them wherever possible. If this is not possible but a less harmful substance is available, then this should be used. Engineering and operational controls should be used and, as last resort, PPE should be worn (AESTOP principles) (Control of substances hazardous to health (COSHH), 2020).

Following COSHH was The Pesticides (Maximum Residue Levels in Crops, Food and Feeding Stuffs) Regulation (MRL 1994), where maximum residue limits (MRLs) were established as legal requirements. It was then updated and complemented by EC Regulation 396/2005. All food products must be tested and can't be legally distributed or sold if MRL levels are exceeded (EU Maximum Residue Levels (MRLs) - Basic Guidance, 2020). It is important to note that MRLs are not the safety thresholds, they are just: "the highest level of a pesticide residue that is legally tolerated in or on food or feed when pesticides are applied correctly (Good Agricultural Practice)" (ec.europa.eu).

Finally another EU directive was introduced in same year – Sustainable Use Directive (SUD). The SUD is extremely relevant to this project as its primary aim is to create: "National Action Plans aimed at setting quantitative objectives, targets, measures, timetables and indicators to reduce risks and impacts of pesticide use on human health and the environment and at encouraging the development and introduction of integrated pest management and of alternative approaches or techniques in order to reduce dependency on the use of pesticides should be used by Member States in order to facilitate the implementation of this Directive" (EUR-Lex - 32009L0128 - EN - EUR-Lex, 2020). To direct industry toward this aim, the UK introduced the Sustainable use of Pesticides (Plant Protection Products Regulations in 2012).

It is apparent that legislation covering application of plant protection products is extensive, but it also covers storage and transport of such products. This includes Evaluation and Restriction of Chemicals, European Regulation (EC) 1272/2008, Control of Pollution Act, Registration, Water Act, Environmental Protection Act, Water Act and Water Resources Act to mention a few.

Reduction of pesticides use is especially important to keep the water environment safe as underlined by European Union in EU Water Framework Directive (WFD). It sets up the maximum levels of pesticides detected in water. The testing shows that there are multiple plant protection products still found in water, hence changes in rules regarding Local Environmental Risk Assessment for Pesticides (LERAP) were introduced, increasing buffer zones that need to be observed.

### Health and Safety:

The fundamental part of legislation regarding H&S in the UK is Health and Safety at Work Act introduced in 1974 (HASAWA). As usual in case of acts of legislation it sets up general rules and duties covering occupational environment. Those rules and duties apply to employers, employees and self-employed and regulate H&S relations between those groups (Health and Safety at Work etc Act 1974 – legislation explained, 2020). Another important part of UK legislation is COSHH. As mentioned above it is part of H&S regulations, but due to nature of the topic it has significant role in application of plant protection products (including Fytosave, assessed in this project – COSHH attached in appendix 2).

In 1992 an additional legislative act was introduced - Management of Health and Safety Act (MHSA) It was updated/replaced in 1999. Some of the main principles of MHSA are: the necessity of sufficient risk assessment by employer (risk assessments relevant to the project are attached in appendix 3); principles of prevention; H&S surveillance and assistance and employee information. It also clearly sets out duties for employees (The Management of Health and Safety at Work Regulations 1999, 2020).

The Personal Protective Equipment at Work Regulation was also introduced in the same year and was complemented by the Provision and Use of Work Equipment Regulation (PUWER 1998). **Personal Protective Equipment (PPE)** is any equipment that will protect employees against safety and health risk in the workplace. The Regulation states that such equipment should be: supplied by the employer free of charge; fit for purpose (certified CE mark – regulation from 2018) and maintained. In the case of this project, specific PPE equipment was necessary due to the risk UV-C poses to eye: staff in vicinity of working booms were to wear special, protective glasses (as per risk assessment).

## REPORT:

### Project Design:

The principle of the project was to assess UV-C and Fytosave treatments in prevention of PM infestation. Therefore, there were three treatments:

1. Control: no PM treatments
2. UV-C: single pass per day
3. Fytosave: weekly application

The project was set up to achieve similar environmental and physical condition for all of the groups (Figure 3). This aim was executed by:

- Sowing and spacing all groups on the same days (27/08/2020 and 5/09/2020 respectively).
- Using one batch of plant material (Kenyan plugs of 'Perigord' rosemary with 3 unpitched cuttings delivered by one supplier).
- Using one batch of substrate (Summer Mix of Baltic peat).
- Applying the same watering regime;
  - Overhead irrigation – applied through automatic watering booms with main water, without any additional feed. This watering technique was used until plants were spaced
  - Ebb & Flow irrigation – at post spacing stage plants were fertigated each time they have required moisture addition
- Using the same type of standard plastic pot (gray, 10.5cm in diameter).
- Growing crop in the same unit, so all the environmental factors such as light levels, temperature, and relative humidity are as close as possible.
- The same number of pots (2448) in each group and the same growing area of 52 m<sup>2</sup>.

After consultation with Agronomy team it was established that it is acceptable to have 7% of pots affected by PM. If the threshold of 7% was observed the treatment group would be sprayed with conventional fungicide.



Figure 3. Project set up at Vitacress Herbs.

### Treatments (Table 2) and Technical Specification:

The lights used in this project were provided by “Clean Light” with specification as follows:

- Lamp UV 36 watts
- Output UV (W) 12 watts UV (%)
- output after 8000 hours 85%
- Ballast 120V/230V CA 50/60 Hz
- Maximum current 0,29 Amp
- Dimensions 40 cm \*12 cm \* 12 cm
- Weight 1,8 kg
- Material: Aluminum
- Reflector: Parabolic

Multiple lamps were mounted on mobile boom controlled by central panel. The treatment could be applied by manually setting the panel up, or by timer. In both cases only trained personnel can set up the treatment. Boom was travelling over the crop at 11km/h with lights on only going forward (Figure 4). On the way back lights were switching off automatically.

The treatment was applied daily and if possible at the same time of the day (safety concerns if staff working in surrounding area). Over the time when the data regarding this project was collected the crop would have been treated over 60 times.



*Figure 4. Boom with mounted UV-C lights at work.*

**Fytosave** (Ministerially Approved Pesticides Product – MAPP number 18433) is a product that uses COS-OGA to prevent PM and is now approved for use in Horticulture in UK. Although it wasn't originally designed to be used on herbs it was granted Extension of Authorization for Minor Use (EAMU) expiring in 2032.

Fytosave as product with MAPP and EAMU has highly regulated restriction of use for Rosemary (label in appendix 1):

- Field of use: only as fungicide
- User: Professional
- Maximum individual dose: 2l/ha
- Maximum number of treatments per crop: 8
- Application interval: 7 days
- Active ingredient ration in product: 12.5g/l
- Treatment only under permanent protection

Product was applied only by trained personnel (member on **National Register of Sprayers Operators – NroSO**). In line with on label instructions treated area of 52m<sup>2</sup> was sprayed with 5.2l of mixture containing water and 10.4ml of Fytoseve.

Fytosave was applied in hand held applicator (knapsack sprayer) with flat fan nozzle. The output of the sprayer and the nozzle was 1.2l/min. Application interval was observed. During the duration of the project treatment was applied 6 times.

GROUP	Treatment	Method of application	Frequency of application	Rate of application	Maximum number of applications	Application intervals	Harvest interval
UV-C	UC-C radiation	UV-C laps mounted on automatic boom	Daily	11m per minute	N/A	N/A	N/A
Fytosafe	Fytosave	Knapsack sprayer and nozzle	Weekly	2l/Ha	8	7 days	N/A
Control	None	N/A	N/A	N/A	N/A	N/A	N/A

*Table 2. Comparison of treatments and control group.*

## DATA:

### Powdery mildew detection:

The plants were checked daily (except weekends) by the project author to establish if the PM is present in the observed crop. Moreover, regular weekly checks were undertaken by agronomy team member during their crop walk. On top of this outsourced team of agronomists was attending the crop fortnightly. Upon detection, infected pots were counted and percentage of affected crop was established.

Plant with powdery mildew was then assessed in terms of percentage of leaves affected by the disease, to establish severity of infestation.

For first 5 weeks no PM infestation was noticed. Initial signs of PM in the crop appeared in week 6 (detection on 5/10/2020):

All pots affected where used for data collection and then disposed:

- Control – 6 pots affected (0.25%)
- Fytosave – 11 pots affected (0.44%)
- UV-C – 0 pots affected (0%) (Figure 5)

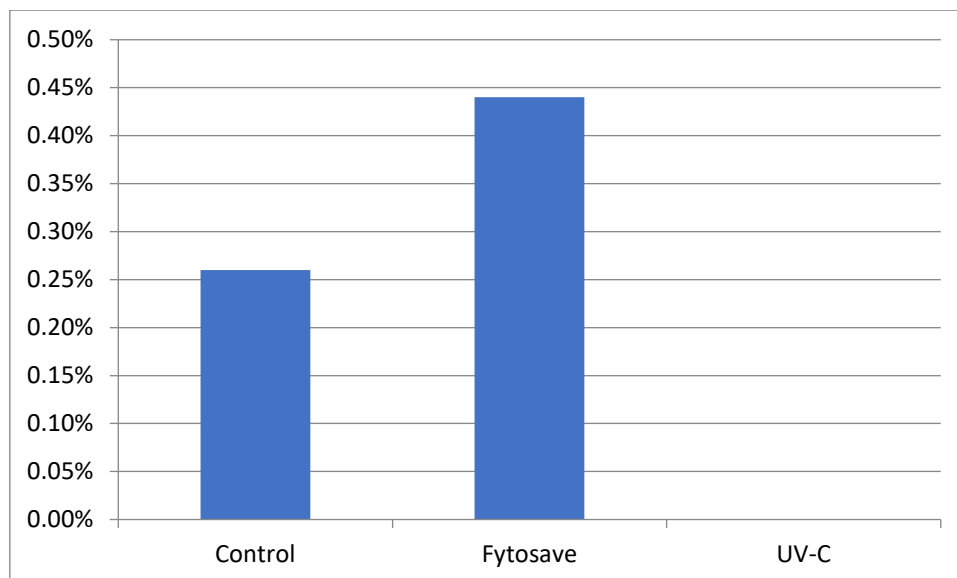


Figure 5. Percentage of pots affected by PM across all groups in week 6.

Most of the pots were at very beginning of infestation process with just single spots of white mycelium growing, however in group Fytosafe, 3 pots were significantly affected, with more than half of the leaves showing fungal growth. The infestation ratio was low, but number of pots with PM in group Fytosave was almost double comparing to Control. There were no plants with PM detected in group UV-C.

In general there was visible difference in the area of leaf affected by the fungal growth in plants that were from group Control & Fytosave (Figure 7), and plants from Fatosave treatment had proportionally more leaves affected (10% against 3.63% in Control Group – figure 6)

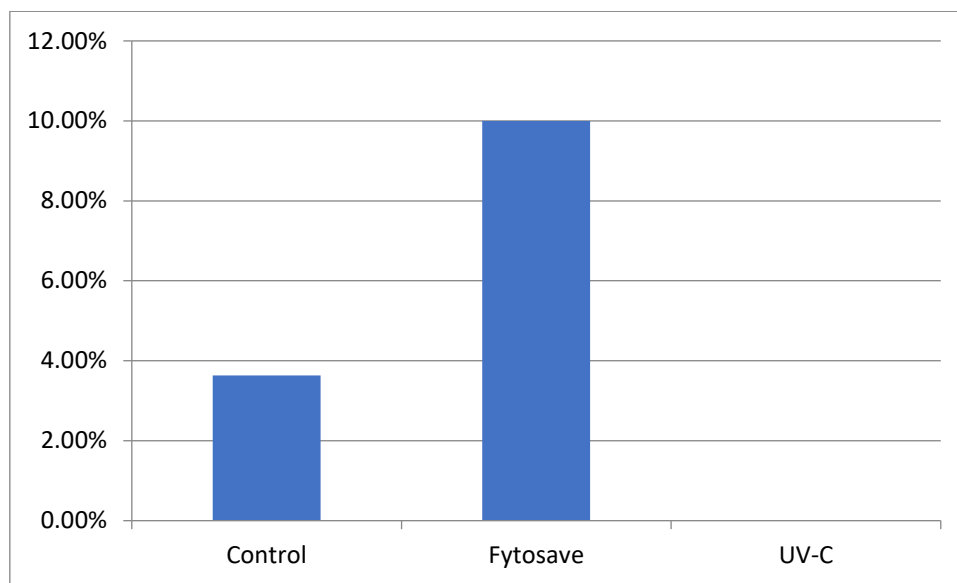


Figure 6. Average Percentage of leaves affected by PM across the groups in week 6.



(Figure 7) . Typical pattern of fungal growth on leaf from control group (left hand side) and group Fytosafe group (right hand side).

In **week 7** higher numbers of pots were found with PM, but proportions of infestation between groups were similar:

- Control – 9 pots affected (0.37% - 0.62% cumulatively)
- Fytosave – 19 pots affected (0.78% - 1.22% cumulatively)

- UV-C – 9 pots affected (Figure 8).

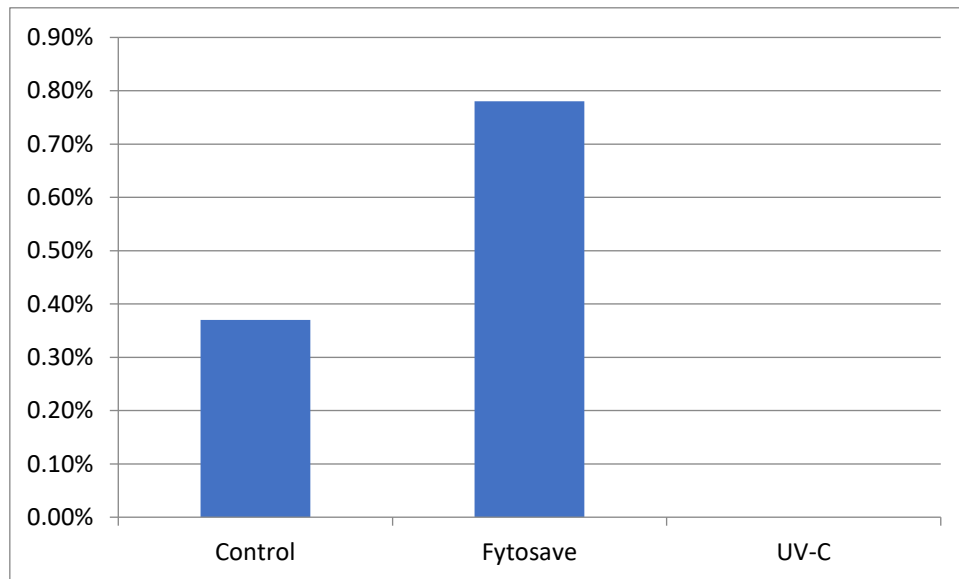


Figure 9. Percentage of pots affected by PM across the treatments in week 7.

Differences in severity of infestation were less significant, however Fytosave treatment was still the most affected one (Figure 9).

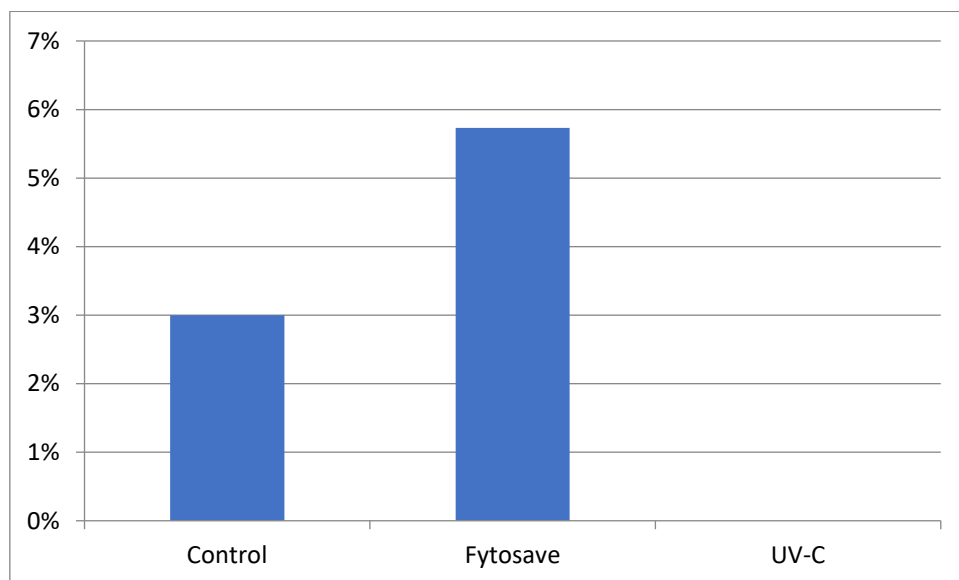


Figure 9. (Average percentage of affected leaves by plant across different treatments).

In **week 8** there was drastic rise in disease detection in both groups affected previously. In cases of Control and Fytosave group weekly count of pot with PM was by far the highest, while UV-C group was still not affected (Figure 10):

- Control - 31 pots (1.37% - 1.99% cumulatively)

- Fytosave – 29 pots (1.29% - 2.51% cumulatively)
- UV-C – 0 pots (0%)

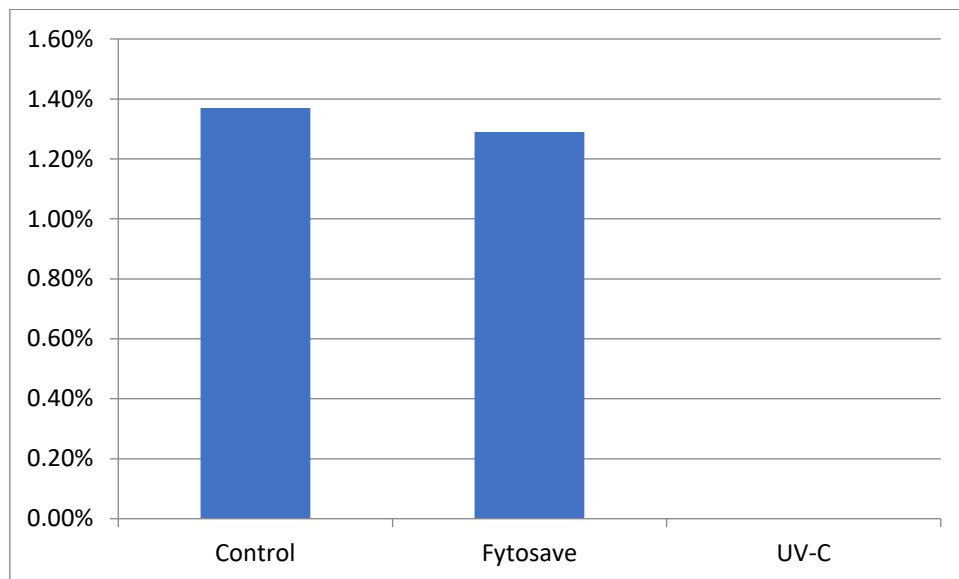


Figure 10. Percentage of plants affected by PM across the treatments in week 8.

On top of this plants were affected badly and rate of leaves showing signs of PM across both groups was much higher than in previous week (Figure 11).

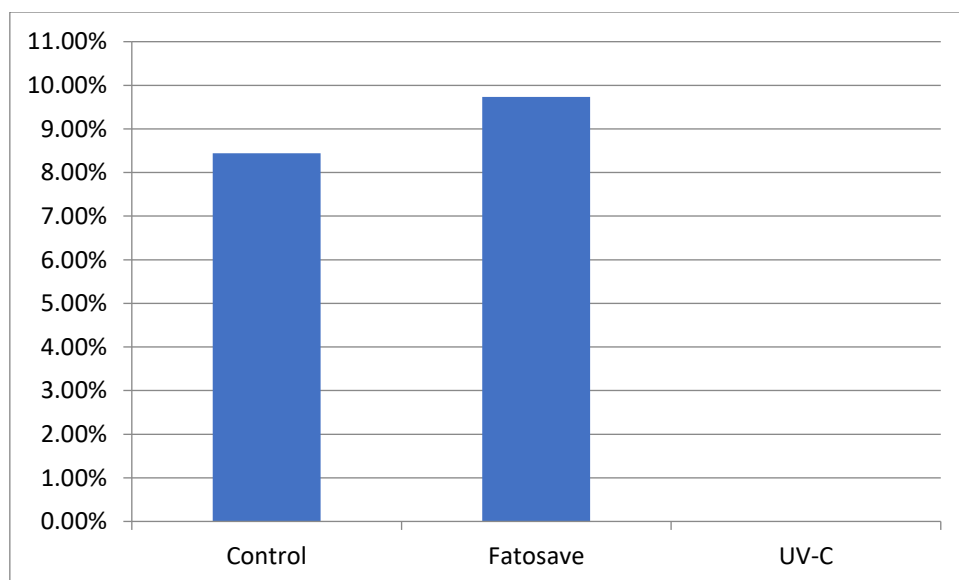


Figure 11. Average number of leaves per plant affected by PM across the treatments.

It is clearly visible that outbreak of the disease accelerated in last week of the trial in both groups affected previously. Looking at cumulative effects of disease Fytosave treatment gave less resistance than control group and in that particular group 2.51% (Figure 12) of pots was affected in 3 weeks

since detection of the disease. This number is not particularly concerning but in the scale of 500 000 pots in production translate to 12 550 wasted pots.

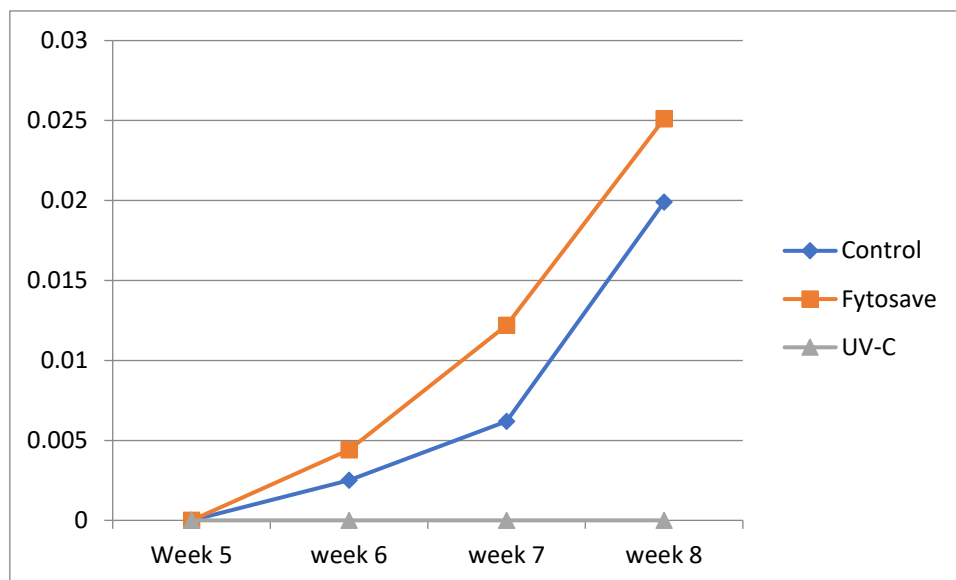


Figure 12. Cumulative percentage of plants affected by PM across the treatments.

### Treatments and their effects on the crop:

The visual checks were performed daily, starting from day 1 (with exclusion of weekends), to monitor for any visible distortions, discoloring or any other unexpected and/or unwanted changes in plant appearance and growing habit.

After plants reached 100mm of heights crop was sampled – 10 pots of each treatment collected in “W” pattern. Height (Figure 13) and cut weight (Figure 114) of each pot was taken and average results compared. The sampling at earlier stage could lead to difference being too small to be relevant.

Visual checks failed to find any differentiation between treatments let alone any deterioration of crop under treatment. All groups were growing in similar rate and in tune with our growing forecast.

The first collection of measurements data confirmed the visual observation. The differences in height and in cut weigh proved to be negligible (between 1-5 mm in height and less than 0.5g in weight on average).

Second set of collected data suggested that, however the characteristic of the crop was changing and UV-C treatment gained in height the differences were still too small to consider them significant.

This was finally confirmed by 3<sup>rd</sup> set of data, collected in the final days of the project also did not show significant differences between treatments. UV-C and Fytosave treatments were slightly heavier and taller than Control group, so it is safe to state that both treatments have no detrimental effect on plant growth and aesthetics.

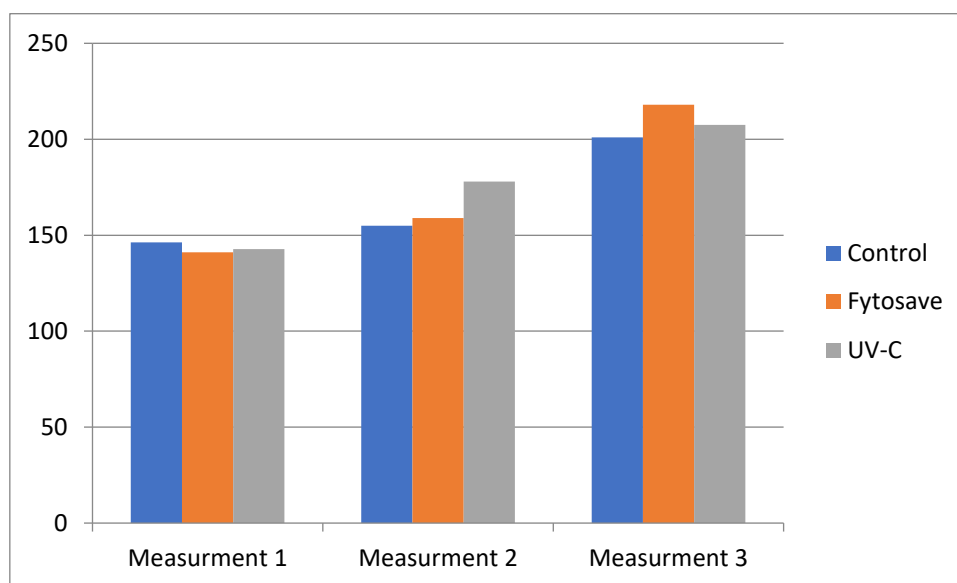


Figure 13. Average height of treated plants in mm across different treatments, at 3 different growth stages.

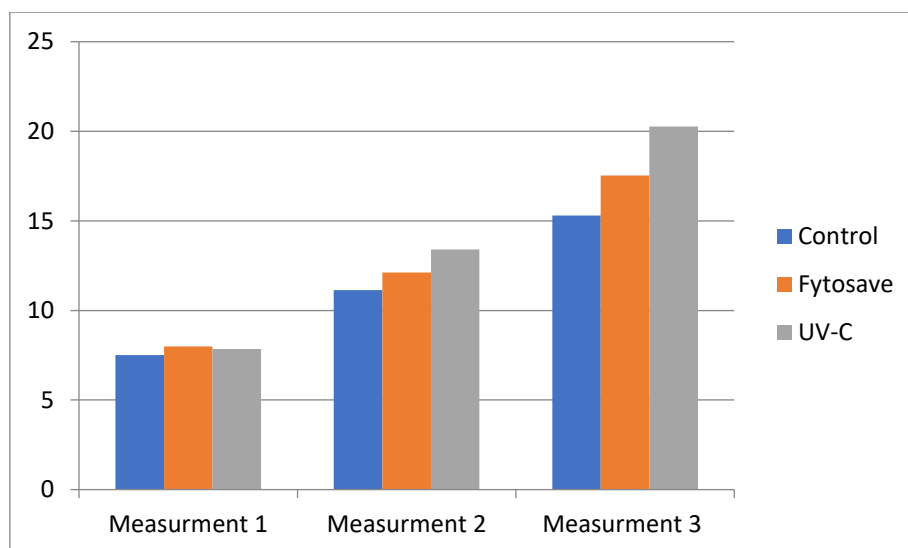


Figure 14. Average cut weight of treated plants in grams across treatment and at different growth stages.

**Financial implications (Table 3):**

Currently, the application of conventional fungicides generates about 18 man hours of labor. At the rate of £10 per hour the estimated cost of work associated with spraying to prevent PM equals £5760 (£180 x 4 weeks x 8 months). This method does not guarantee complete control of disease and serious outbreaks are possible as per last season example (60 000 pots wasted at £0.25 per pot).

Cost of application of Fytosave is going to be very similar to conventional fungicides, as method of application is exactly the same. The efficacy of the product was doubtful and 12 550 pots wasted calculated based on the trial result look rather optimistic. In long run likelihood of significant wastage is high.

There is no cost associated with operating UV-C boom, other than occasional maintenance. Once the boom is set up on the timer, there is no need for human interference. On top of this treatment gave us zero waste.

GROUP	COST OF LABOR	COST OF WASTE	TOTAL COST
UV-C	£ 0	£ 0	£ 0
Fytosafe	£5,760	£ 3, 137 – optimistic assumption	£ 8, 897
Traditional pesticides	£5,760	£ 15, 000	£20, 760

*Tabel 3. Estimated costs of labor and waste in both treatments compared to cost of last season labor and waste*

## **DISCUSSION AND RECOMENDATIONS:**

The results clearly indicate that only UV-C treatment can prevent infestation of PM. Moreover, UV-C proved to be 100% successful in doing so. In the working environment of commercial greenhouse, success rate was quite astonishing and it wasn't matched by any other treatment analyzed in the project, or even application of fungicide in previous years. As physical way of preventing/removing infestation UV-C treatment presents itself as efficient and cost effective solution. The labor cost savings that move away from pesticides application to automatic UV-C operation could be another benefit, with significant financial implications.

It is important, due to UV-C molecular mode of action; we couldn't see any detrimental effects of radiation on plants health and aesthetics, even with relatively high dose of light.

This technology was established as a tool preventing fungal diseases in other crop and now we can finally state with high dose of certainty that it could be used in protection of herbs – in this case rosemary.

On the other hand, analysis suggests that Fytosave does not achieve satisfying level of protection against PM. The results of this treatment were worse than control treatment. In some way application of COS-OGA inhibited rosemary ability to fight the disease. It was easy to eliminate possibility of 'spraying error' in terms of coverage as plants developed disease across all the benches and in many different locations on the single bench.

It is also important to note, that Fytoseve due to its method of application is not going to improve labor budget. It needs to be sprayed over the crop multiple times at different growing stages, so labor implications are similar to spraying conventional fungicides.

The fact, that data is not showing any negative effect of Fytosave on healthy plants, comes as irrelevant consolation.

Firstly, the study provides us with quite remarkable result, which potentially has serious financial implication for the business. UV-C can provide us with completely reliable form of plant protection against PM. Due to its universal germicidal effects it could be also as effective against other fungal disease, including botrytis – second serious disease observed in rosemary crop.

The trial treatments could also be expanded to other herb species; including thyme, mint and sage.

Secondly, use of UV-C could save substantial amount of labor cost – only when considering comparison with application of fungicides against PM. This reduction could go even further, if treatment is going to be applied to fight other pathogens across multiple herb species.

The recommendation, based on the data analyzed in the project is to introduce UV-C as alternative fungicidal treatment on a larger scale and if still successful replace fungicide with it, as preventative method of PM control.

Fytosave shouldn't be, at this point in time considered as reliable way of preventing disease, moreover high cost of applications makes it even less attractive alternative to fungicides.

Finally, following on extreme efficacy of UV-C treatment in preventing PM I would suggest to extend the trial and consider possibility of its use on different spices of herbs and different pathogens (e.g. botrytis in thyme and sage).

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## Appendices:

### Appendix 1; FytoSave label:

# FytoSave<sup>®</sup>

Elicitor to trigger the plants self defense mechanisms

FytoSave is for the control of powdery mildew in cucurbits (greenhouse applications)  
and Solanaceae (greenhouse applications)



**A suspension concentrate formulation  
containing 12.5 g / l COS-OGA**

**FytoSave contains 12.5 g/l COS-OGA**

Keep out of reach of children.  
Do not eat, drink or smoke when using this product.  
Dispose of contents/container to a licensed hazardous waste disposal contractor or collection site  
except for empty clean containers which can be disposed of as non-hazardous waste.

To avoid risk to human health and the environment, comply with the instructions for use.

**MAPP 18433**

Gowan Crop Protection Ltd, Highlands House,  
Basingstoke Road, Spencers Wood,  
Reading, Berks, RG7 1NT.  
(Registered company number: 9852199)

**24 HOUR EMERGENCY TELEPHONE NUMBER:  
+44 (0) 870 820 04 18**

**Gowan<sup>®</sup>**  
CROP PROTECTION LIMITED

Authorisation holder : FytoFend S.A.  
Shake well before use  
Lot No. : See Can

**Pack Size:  
5 L e**

XXXXX-UKFT-01-0418\_V1

**IMPORTANT INFORMATION**

FOR USE ONLY AS A PROFESSIONAL FUNGICIDE AS DIRECTED BELOW

<b>Crops</b>	<b>Max. individual dose</b>	<b>Max. number of treatments per crop</b>	<b>Time of application</b>
Aubergine (greenhouse)	2 l/ha	5	3 fully expanded leaves – complete ripening: fruits reach their typical full maturity colour (BBCH 13-89)
Tomato (greenhouse)	2 l/ha	5	3 fully expanded leaves – complete ripening: fruits reach their typical full maturity colour (BBCH 13-89)
Pepper and chilli (greenhouse)	2 l/ha	5	3 fully expanded leaves – complete ripening: fruits reach their typical full maturity colour (BBCH 13-89)
Courgette and summer squash (greenhouse)	2 l/ha	5	3 fully expanded leaves – third fruit has reached its size and typical shape (BBCH 13 - 73)
Cucumber (greenhouse)	2 l/ha	5	3 fully expanded leaves – third fruit has reached its size and typical shape (BBCH 13 - 73)
Melon (greenhouse)	2 l/ha	5	3 fully expanded leaves – third fruit has reached its size and typical shape (BBCH 13 - 73)
Winter squash and pumpkin (greenhouse)	2 l/ha	5	3 fully expanded leaves – third fruit has reached its size and typical shape (BBCH 13 - 73)

**Other Specific Restrictions**

A minimum interval of 7 days must be observed between applications.

Treatment must only be made under 'permanent protection' situations which provide full enclosure (including continuous top and side barriers down to below ground level) and which are present and maintained over a number of years.

Reasonable precautions must be taken to prevent access of birds, wild mammals and honey bees to treated crops.

To minimise airborne environmental exposure, vents, doors and other openings must be closed during and after application until the applied product has fully settled.

**READ THE LABEL BEFORE USE. USING THIS PRODUCT IN A MANNER THAT IS INCONSISTENT WITH THE LABEL MAY BE AN OFFENCE. FOLLOW THE CODE OF PRACTICE FOR USING PLANT PROTECTION PRODUCTS.**

## SAFETY PRECAUTIONS

### Operator protection

Do not re-enter areas/crops before the spray deposit is completely dry.

### Environmental protection

DO NOT CONTAMINATE WATER with the product or its container. Do not clean application equipment near surface water. Avoid contamination via drains from farmyards and roads.

### Storage and disposal

- STORE IN A COOL, DRY PLACE in accordance with specific instructions and requirements.
- KEEP IN ORIGINAL CONTAINER, tightly closed, in a safe place.
- Protect from frost.
- KEEP AWAY FROM FOOD, DRINK AND ANIMAL FEEDING STUFFS.
- EMPTY THE CONTAINER COMPLETELY and dispose of safely.
- DO NOT RE-USE CONTAINER for any purpose.

### Medical advices

AFTER INHALATION: Fresh air, rest.

AFTER INGESTION: Rinse mouth, rest.

AFTER SKIN CONTACT: Wash with water and soap. Rinse thoroughly. Remove any contaminated clothing and shoes.

AFTER EYE CONTACT: Rinse with plenty of water for 15 minutes.

In case of symptoms, consult a doctor and show him / her the packaging or the label.

Notes for the doctor:

Management: symptomatic treatment.

## DIRECTIONS FOR USE

**IMPORTANT: This information is authorised as part of the Product Label. All instructions within this section must be read carefully in order to obtain safe and successful use of this product.**

### Pest controlled

Cucumber, courgette, summer squash, melon, winter squash and pumpkin – control of powdery mildew.

Aubergine, tomato, pepper and chilli – moderate control of powdery mildew.

### Mixing and spraying

Shake well before use.

Pour Fytosave into the tank half filled with water.

Start agitation during filling and continue until the end of the application. Do not let the mixture remain in the tank.

### Water volume:

Cucumber, courgette, summer squash, melon, winter squash and pumpkin – 500l/ha

Aubergine, tomato, pepper and chilli – 750-1000l/ha.

### Further information

The treatment must be carried out preventatively before signs of powdery mildew. In the context of the use of FYTOSAVE, powdery mildew management must be done in a preventive way to stimulate the plant before signs of any attack.

It is important to use FytoSave as a preventative treatment and in sequences of 2 to 3 successive applications to obtain good stimulation of the plants defenses. The interval between applications should be 7-10 days depending on conditions and disease pressure.

In the case of any established disease or high risk of infection start control with a curative product before applying FYTOSAVE.

Apply FYTOSAVE to healthy crops, avoid application to stressed crops.

Approval Holder and Marketing Company:

FytoFend S.A.

Rue Phocas Lajeune, 25 (B6)

5032 ISNES (Belgium)

+32 81 728 840

FytoSave® is a registered Trademark of FytoFend S.A.

**Container Size: 5 L**

**BATCH NO.: 180400**

**Date of manufacture: 04/2018**

XXXXX-UKBK-02-0418\_V5

## Appendix 2; Fytosave COSHH assessment:



This assessment <b>only addresses the risk of harm to health</b> from the substances listed. Additional risk assessments may be required to control the risk from other hazards associated with this work/the procedures used.		
<b>Assessor</b> Lukasz Sipior <sup>(1)</sup>		<b>Supervisor:</b> Simon Smith
<b>Assessment Date</b> <sup>(3)</sup> 29/08/2020		<b>Dates reviewed</b> <sup>(4)</sup>
<b>HAZARDS IDENTIFIED</b>		
*If the substance has a R45 or R49 risk phrase or a H350 or H350i hazard statement, it must also be registered on your personal carcinogen return (at Occupational Health) <i>where exposure is not adequately controlled</i> .		
<b>Substance</b> <sup>(5)</sup> <i>Fytosave: A suspension concentrate formulation containing 12.5 g / l COS-OGANB.</i>	<b>Hazardous Properties</b> <sup>(6)</sup> <i>None identified</i>	<b>Quantity</b> <sup>(7)</sup> <i>5.2ml weekly for 6 weeks</i>
<b>Additional information</b> <sup>(8)</sup> <ul style="list-style-type: none"> <li>• Workplace Exposure Limits: N/A</li> <li>• R-phrases: N/A</li> <li>• S-phrases: N/A</li> <li>• H and P statements:N/A</li> </ul>		
<b>Emergency Procedures</b> <sup>(9)</sup> <ul style="list-style-type: none"> <li>• Eye contact: Rinse opened eye for several minutes under running water. If symptoms persist, consult a doctor</li> <li>• Inhalation: Supply fresh air; consult doctor in case of complaints</li> <li>• Skin contact: Immediately wash with water and soap and rinse thoroughly. If skin irritation continues, consult a doctor.</li> <li>• Ingestion: Remove the victims from the danger zone. Do not induce vomiting; Do not give anything to drink or</li> <li>• Spill procedure: Do not allow product to reach sewage system or any water course. Dilute with plenty of water. Absorb with liquid-binding material (sand, diatomite, acid binders, universal binders, sawdust</li> </ul>		

**What will the chemical be used for?** *The chemical is going to be used for controlled trial in prevention of Rosemary against Powdery Mildew.* **Who may be exposed?** *Spreayer operator, Staff, Visitors*

**METHODS OF PREVENTION OR CONTROL OF EXPOSURE**

(select all that apply by circling/ticking/highlighting the appropriate statement)

<p><b>1. Engineering controls required<sup>(11)</sup></b></p> <p>N/A</p>	<p><b>2. Access control<sup>(12)</sup></b></p> <ul style="list-style-type: none"> <li>• restricted to competent personnel</li> <li>• special containment facility (storage in locked pesticide store)</li> </ul>
<p><b>3. Special procedures<sup>(13)</sup></b></p> <ul style="list-style-type: none"> <li>• Standard Operating Procedure for spraying pesticides <input type="checkbox"/></li> <li>• Code of practice, <input type="checkbox"/></li> </ul>	<p><b>4. Approved PPE<sup>(14)</sup></b> ( <i>Note: PPE is to be used as the 'last resort' when controlling exposure</i>)</p> <ul style="list-style-type: none"> <li>• gloves etc The glove material has to be impermeable and resistant to the product/ the substance/ the preparation. Due to missing tests no recommendation to the glove material can be given for the product/ the preparation/</li> <li>• the chemical mixture. Selection of the glove material on consideration of the penetration times, rates of diffusion and the</li> <li>• degradation</li> <li>• Material of gloves Chemical-resistant gloves.</li> <li>• eye protection : : Goggles recommended during refilling</li> </ul>
<p><b>Disposal Procedures<sup>(15)</sup></b> (Give details of waste disposal procedure to be used)</p> <ul style="list-style-type: none"> <li>• Are chemicals with risk phrases R50-R59 or hazard statements H400 – H413 (environmental hazards) involved? / No</li> </ul>	
<p><b>TRAINING REQUIREMENTS<sup>(16)</sup></b></p> <p>Pesticide application qualification 1&amp;6</p>	

**HANDLING AND STORAGE REQUIREMENTS** *Keep receptacles tightly sealed, Keep ignition sources away - Do not smoke, Keep the product in its original container. Store in a dark, cool place (not less than 5 ° C)*

(Note any special requirements e.g. ventilation, chemical incompatibility, flash point, etc)

**ASSESSMENT OF RISK USING CONTROLS DETAILED ABOVE<sup>(18)</sup>**

*(Are the hazards/risks suitably controlled, using the control measures detailed above? If not, state the further actions required, e.g. Requirement for a standard operating procedure (SOP), etc)*

*Yes, above measures are sufficient*

**Authorisation by Employer/Supervisor<sup>19</sup>**

I confirm that I have considered and understand the chemical to be used and the associated hazards. I am satisfied that all of the hazards have been identified and that the control measures to be followed will reduce the risks to as low a level as reasonably practicable.

Print name:

Signed:

Date:

**Declaration by Employer/Supervisor<sup>(20)</sup>**


I confirm that I have read this COSHH Assessment and that I understand the hazards and risks involved and will follow all of the safety procedures stated.

**Declaration by employee<sup>201</sup>**

**I confirm that the employee who has signed below is competent to undertake the work. My counter-signature indicates that I am happy for the work to proceed.**

<b>Name (please print)</b>	<b>Signed</b>	<b>PI countersignature</b>	<b>date</b>

Appendix 3; UV-C boom risk assessment:

	
<h3>UV Growing Booms</h3>	
UV light booms for the use of P&D	
Reference:	CR62
Department(s):	
Location:	Phase 1, 2 & 3 Growing
Date of assessment:	07/08/2020 16:36
Date of review:	Never
Accepted/Rejected By: Simon Chant   Reference: CR62   Author: Simon Chant   Last Edited By: Simon Chant	
Page 1 of 7	

Description of activity:		remote booms moving over crop with UV lights	
Hazard		At Risk	
Exposure to UV light		<ul style="list-style-type: none"> <li>• Staff</li> </ul>	
Supporting Files (Viewable online only)		Describe the consequence	
		<ul style="list-style-type: none"> <li>• long exposure can cause sun burn or eye damage</li> </ul>	
		Current Control Measures	
		<ul style="list-style-type: none"> <li>• Signage</li> <li>• PPE - UV protection glasses</li> <li>• Limited exposure time</li> <li>• no closer than 1 bay either side</li> <li>• Occupational health in place</li> </ul>	
Legal Requirements		Initial Risk	Residual Risk
<ul style="list-style-type: none"> <li>• Health and Safety at Work etc Act 2013</li> <li>• Personal Protective Equipment at Work Regulations 1992</li> <li>• Provision and Use of Work Equipment Regulations 1998</li> <li>• Workplace (Health, Safety and Welfare) Regulations 1992</li> </ul>		Possible: Major (12)	Unlikely: Lost Time (6)

Description of activity:	
General walking and working in pathways, moving around and working between benches.	
Hazard	At Risk
Slips or trips	<ul style="list-style-type: none"> <li>Staff</li> </ul>
Supporting Files (Viewable online only)	
<p>Describe the consequence</p> <ul style="list-style-type: none"> <li>While walking the crop there is a risk of slips, trips and falls causing musculoskeletal injury</li> </ul>	
<p>Current Control Measures</p> <ul style="list-style-type: none"> <li>Appropriate Safety footwear must be worn, regular pathway checks, keep area clear of any obstructions</li> </ul>	
Legal Requirements	Residual Risk
<ul style="list-style-type: none"> <li>Health and Safety at Work etc Act 2013</li> <li>Personal Protective Equipment at Work Regulations 1992</li> </ul>	<p>Initial Risk</p> <p>Possible: Trival (3)</p> <p>Residual Risk</p> <p>Unlikely: Trival (2)</p>

Description of activity:			
The UV boom moves down a rail over the crops			
Hazard		At Risk	
Collision.		<ul style="list-style-type: none"> <li>Staff</li> </ul>	
Supporting Files (Viewable online only)		Describe the consequence	
		<ul style="list-style-type: none"> <li>when moving it has the potential to hit someone walking past</li> </ul>	
		Current Control Measures	
		<ul style="list-style-type: none"> <li>Signage</li> <li>Tool box talk</li> <li>Attended by a member of staff whilst boom is in operation</li> <li>First aiders and equipment on site.</li> </ul>	
Legal Requirements		Initial Risk	
<ul style="list-style-type: none"> <li>Provision and Use of Work Equipment Regulations 1998</li> <li>Workplace (Health, Safety and Welfare) Regulations 1992</li> </ul>		High (10) (10)	
		Residual Risk	
		Medium (3) (3)	

Description of activity:		At Risk		Describe the consequence	
Large percentage of work requires staff to work under the glasshouse in hot temperatures					
Hazard		<ul style="list-style-type: none"> <li>• Staff</li> </ul>			
working in hot / humid conditions				<ul style="list-style-type: none"> <li>• Long exposure may cause dehydration, heat stroke, exhaustion, cramps or fainting</li> </ul>	
Supporting Files: (Viewable online only)				<p>Current Control Measures</p> <ul style="list-style-type: none"> <li>• Drinking machines within key areas</li> <li>• Regular rest breaks</li> <li>• Staff awareness as to wearing the correct clothing for the working environment.</li> <li>• Sun screen dispensers in every glasshouse block</li> </ul>	
Legal Requirements		Initial Risk		Residual Risk	
<ul style="list-style-type: none"> <li>• Health and Safety at Work etc Act 2013</li> <li>• Workplace (Health, Safety and Welfare) Regulations 1992</li> </ul>		Possible: Lost Time (9)		Likely: Trivial (0)	

Description of activity:	
Cleaning and general maintenance	
Hazard	At Risk
Maintenance	<ul style="list-style-type: none"> <li>• Staff</li> </ul>
Supporting Files (Viewable online only)	
	<p>Describe the consequence</p> <ul style="list-style-type: none"> <li>• While cleaning and completing general maintenance work there is a low risk from cuts if a bulb was broken or broke while maintaining the boom</li> </ul> <p>Current Control Measures</p> <ul style="list-style-type: none"> <li>• PPE - Gloves, Eye protection.</li> <li>• Competent operator</li> <li>• First aiders and equipment on site</li> <li>• Bulbs encased in a protective sleeve</li> </ul>
Legal Requirements	<p>Initial Risk</p> <p>Residual Risk</p>
<ul style="list-style-type: none"> <li>• Health and Safety (Training for Employment) Regulations 1990</li> <li>• Health and Safety at Work etc Act 2013</li> <li>• Personal Protective Equipment at Work Regulations 1992</li> <li>• Workplace (Health, Safety and Welfare) Regulations 1992</li> </ul>	<p>Unlikely-Minor (5)</p> <p>Remote-Tolerable (2)</p>