

addVANTAGE Pro 5.0

Plant Protection and Irrigation Extensions





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Table Of Contents

Table Of Contents	1
Chapter 1. Introduction	5
The Disease Triangle	5
A Flexible Plant Protection System	6
Associations	7
Big Farms	7
Service Providers	8
Individual Users	8
Some Explanations About the Models	8
Installing the Extensions on your System	9
Adding Extensions to an Area	9
Configuring Extensions	10
User Input	12
More about Treatments	16
The Chemicals Service	18

Chapter 2. Using the Extensions	21
The Apple Scab Extension	22
Disease Symptoms and Development	22
Using the System Against the Apple Scab	23
The Apple Powdery Mildew Extension	26
Disease Symptoms and Development	26
Using the System Against the Powdery Mildew	27
The DSV Extension	30
Tom-Cast	30
Late Blight of Potato and Tomato	30
Setup and Operation	31
The Grape Downy Mildew Extension	33
Disease Symptoms and Development	33
Using the System Against the Downy Mildew	34
The Grape Powdery Mildew Extension	39
Disease Symptoms and Development	39
Using the System Against the Powdery Mildew	40
The Bunch Rot of Grapes Extension	44
Disease Symptoms and Development	44
Using the System Against the Bunch Rot of Grapes	45
The Heat Units Extension	48
Model Operation	49
Calculation Methods	49
More About Cutoff Methods	54
Sensor Placement	56
Configuring Extension Options	56
Daily Operation	58
Sources of Phenology Models	58
The Lettuce Downy Mildew Extension	62
Disease Symptoms and Development	62
Model Operation	62
Field Setup	63
Setup and Operation	63
Daily Operation	64

The Potato Blight Extension _____	66
Disease Symptoms and Development _____	66
Using the System Against the Potato Blight _____	66
The Downy Mildew of Hop Extension _____	72
Disease Symptoms and Development _____	72
Using the System Against the Downy Mildew of Hop _____	73
Setup and Operation _____	73
The Tomato Late Blight Extension _____	77
Disease Symptoms and Development _____	77
Setup and Operation _____	77
The Strawberry Powdery Mildew Extension _____	80
Disease Symptoms and Development _____	80
Setup and Operation _____	80
The Strawberry Bunch Rot Extension _____	83
Disease Symptoms and Development _____	83
Setup and Operation _____	83
The Pistachio Blight Extension _____	86
Disease Symptoms and Development _____	86
Setup and Operation _____	86
The Evapotranspiration Extension _____	89
Factors Affecting ETo _____	89
The Influence of the Soil Moisture _____	90
Setup and Operation _____	90
The Soil Moisture Extension _____	92
Setup and Operation _____	92
Custom Soil Type Configuration _____	94
Index _____	95

Chapter 1. Introduction

This manual details the installation and use of the Plant Protection and Irrigation extensions supplied with the addVANTAGE Pro 5.0 package. For information about the installation and use of the addVANTAGE Pro 5.0 software, please read the *addVANTAGE Pro 5.0 User Guide*. The guide is provided on the installation CD, or can be downloaded from Adcon Telemetry's website at <http://www.adcon.at>.

CAUTION The Plant Protection extensions are tools that help you correctly manage an optimized spraying program against some diseases. They are not, and should not be seen as, decision instruments. A computer program cannot make decisions—the humans who are using it must decide whether a certain recommendation should be followed.

The Disease Triangle

The disease triangle (Figure 1) is composed of:

- The host
- The pathogen
- The environment

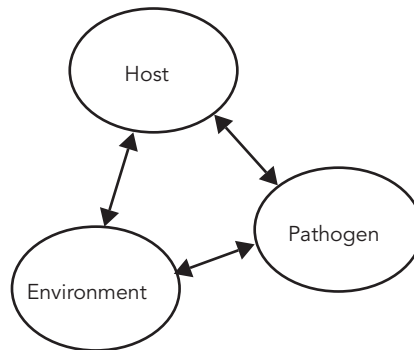


Figure 1. The Disease Triangle

The pathogen is the causal organism. The host is the plant or crop. The environment is a measurable set of conditions that need to occur. Disease and the resultant damage are what occurs when all three are present.

If the host is not susceptible, no symptoms will exist. If the pathogen is not present, but the host is susceptible and the environmental conditions are favorable, no symptoms will exist. Finally, if the host is susceptible and the pathogen is present, but the environment is not favorable, symptoms will again not exist.

Models typically estimate the likelihood of disease risk or infection. When risk or pressure is high, you should intensify control strategies. When the environmental conditions are not favorable for disease, your control strategies can be less intensive because the risk of disease is lower.

The models allow a great degree of control for a wide range of diseases. Because of the modular approach used, they can be easily upgraded as soon as new versions are available. In addition new models are constantly implemented, so please check Adcon Telemetry's website for latest releases.

A Flexible Plant Protection System

The centralized nature of the system allows the use of many observation points (the RTUs), which are sending their data to the addVANTAGE Pro server where the intelligence is located—the algorithms processing the information stored in the local database. Couple this with the ability to install the stations at distances up to several tens of miles, and you have

an idea of the large coverage you can get with the system. By using an appropriate number of RTUs, you can control regions of thousands of acres.

Of course, you can also use the system for smaller areas. Farmers having small farms can use their PCs to log in via the Internet to an addVANTAGE server and consult their data. Several possibilities are discussed below.

Associations

Large systems have a number of stations—this could be anything between 10 and several hundred. They collect the data from the RTUs, store it on the local hard disk, and process it according to the model. Large systems usually have a server available on the Internet with a fixed IP address through which other subscribers can log in and inspect the data from one or more stations. These large systems with the Internet server apply to bigger farms or, if several farmers pool their resources to form an association, they can also acquire such a system.

The server must be supervised by an administrator appointed by the members of the association. Administrators make sure that the system operates properly and the required maintenance is done in a timely manner. They also use the appropriate resources to inform the participating farmers of the warnings issued by the system (e.g. via e-mail). In order to successfully fulfill their duties, it is important that administrators have sufficient plant protection knowledge.

The advantage of such a solution is that the costs for each farmer are reduced, offering to all participants valuable information about the necessity of treatments. Good results can be obtained by applying a strict spraying methodology, based on the information delivered by the system.

Big Farms

The solution above applies to big farms. In such cases, the advantages of the system are obvious because a single person, the plant protection specialist, can have good control over the entire acreage. He or she can concentrate the necessary human and material resources on the right spot and at the right time.

Service Providers

A service provider can buy or lease the system, and then install the stations to individual farmers wanting better control of the diseases. By offering the farmers a value-added service, the provider can easily recoup his investment in one to three years. You can read more about this issue in the *addVANTAGE Pro 5.0 User Guide*.

Individual Users

Individual users can use a web browser on a computer with Internet access to log in to an addVANTAGE Pro server (if they have an account) and use the data from one or several stations placed near their fields. Based on a warning issued by the system, the users can take the protective measures that suit them the best.

Some Explanations About the Models

Various parameters such as infection conditions, incubation periods, pressure indices, a.o. are computed by using climatic data measured in the field and data provided by the user. Depending on how the model was originally developed and validated, the sensors must be placed accordingly—sensor height can vary from 30 cm to 2 m from ground. As an example, for vine and apple models, place the sensor unit in the vegetation; whereas, for the potato model, use the 2 m height. See each model's description for additional information about this subject.

Most fungi develop in close correlation to the meteorological parameters. For instance, the downy mildew (*Plasmopara viticola*) needs specific temperatures and leaf wetness conditions for sporulation, as well as darkness. Such conditions are not very often recorded, so it becomes possible to predict with quite a high degree of precision the right time when infections may occur.

On the contrary, other fungi like powdery mildew (*Uncinula necator*) have a specific development cycle that prohibits the use of classical modelling methods because it has a relatively wide range of climatic conditions deemed as favorable. In such cases, multiple regression relations have been statistically or empirically derived, leading to a so-called *pressure index* of the disease. The index is then used to allow for a flexible but effective spraying program.

Installing the Extensions on your System

The installation procedure is very similar to that of the addVANTAGE Pro 5.0 Server (it is assumed that the server is already installed). If you did not install the free extensions package when you installed your addVANTAGE Pro 5.0 Server, complete the following steps:

1. Insert the distribution CD-ROM in your computer's CD drive.
2. Using the Explorer navigate to the CD, locate the program `addVANTAGEPRO5.0FreeExtensions` and start it (by double-clicking it).
3. Follow the instructions given by the installation program.

If you want to remove the free extensions from your computer, you will find an Uninstaller in the **Adcon ▶ addVANTAGE Pro 5.0 ▶ addVANTAGE Pro 5.0 Free Extensions** group that will remove the extensions' files.

Adding Extensions to an Area

Extensions can be added only to areas. To add an extension to an area, complete the following steps (Figure 2):

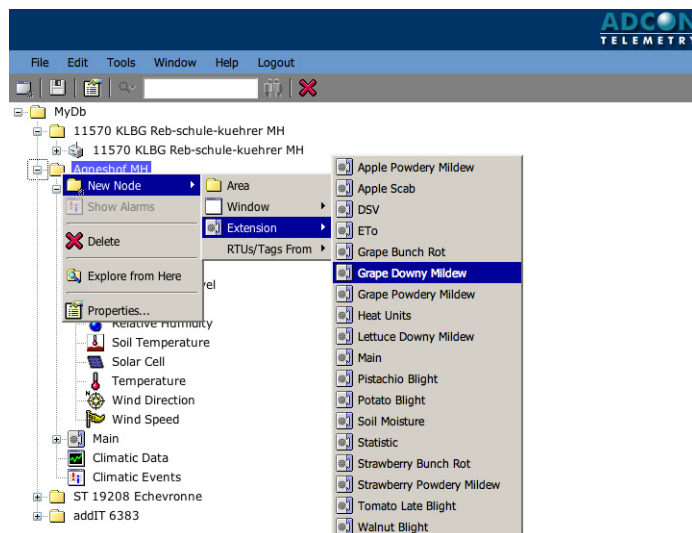


Figure 2. Adding an extension to an area

1. Open an Explorer.

2. Select the area you want a certain extension added to.
3. Right-click the highlighted area and select the **New Node ▶ Extension ▶ extension** menu.

Note: Only one extension of a certain type is allowed per area.

Configuring Extensions

Depending on the extension, you might need to perform a certain amount of configuration work. To display an extension's properties (Figure 3), you can highlight the extension and select **Edit ▶ Properties...**, or you can right-click the extension in Explorer and select **Properties...**

Figure 3 shows the properties specific to the Grape Downy Mildew extension. Note that the **General**, **Extension**, **Security**, and **Inputs** tab properties are found in all extensions.

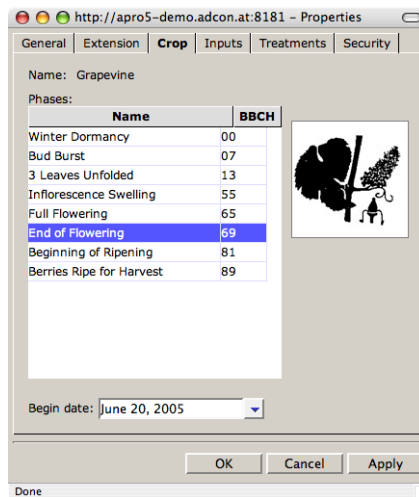


Figure 3. Extension properties window, Crop tab

The **General** tab displays the extension attributes. The **Extension** tab allows you to enable or disable individual models/features and, depending on the particular extension, could contain customization elements (these are dealt with separately for each extension). Depending on the individual models, the software might need other types of information to work properly. For example, for some diseases, you can choose between two different models (e.g. the Grape powdery

mildew extension). Please refer to each individual model's description for more details about such possibilities.

The **Inputs** tab (Figure 4) allows you to set the input tags for the extension. The extensions have an intelligent algorithm that searches for the appropriate tags, but only within the extension's own area. If not all tags are present and the auto-discovery feature fails, you must manually intervene to identify the necessary tags. If multiple tags of the same type exist on a given area, you will also have to manually select which tag type you want the extension to use. However, you can copy tags from other areas if you need the same type of tag in more than one area.

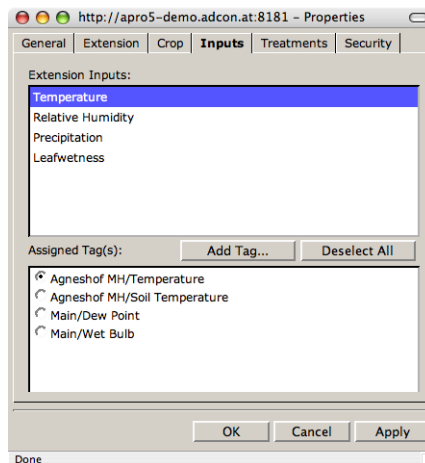


Figure 4. Selecting extension input tags

Some extensions have additional tabs. For example, all plant protection extensions have a **Treatments** tab used to inform the extension that a chemical treatment was applied, and a **Crop** tab that is used to specify and monitor the phenological stages of the crops.

Use the **Security** tab (Figure 5) to set the appropriate privileges for users and groups. You'll find complete information about privileges and security in the *addVANTAGE 5.0 User Guide*.

Changing extension properties can cause an automatic recalculation of the input data. Due to the improved method used to implement extensions, this operation usually takes only a couple of seconds, or at most several minutes (it depends on the extension and the amount of data to process). The properties that can cause a recalculation are those

in the **Crops**, **Treatments**, **Inputs**, and **Extension** tabs. You can also force a recalculation of an extensions by selecting it in an Explorer, right-clicking, and choosing **Recalculate**.

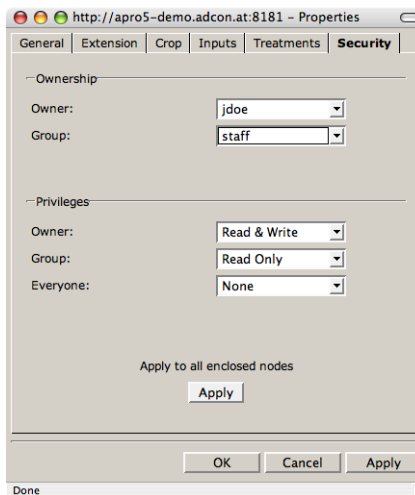


Figure 5. Extension properties window, Security tab

More About Input Tags Slot Interval

addVANTAGE Pro 5.0 collects and stores raw data from tags at variable intervals. However, most tags are collected at the default 15-minute interval. The extensions are programmed to cope with data intervals at other rates, but in general there is a limit to this. Specifically, it doesn't matter to the extension if the rate is less than 15 minutes, but stretching it to several hours may affect the proper operation of some extensions. Most extensions operate with average values for larger intervals (e.g. one hour or even one day), therefore they will be less affected by longer intervals between data points.

The bottom line is that even though most extensions can still properly operate with different data rates for individual input tags, you should avoid stretching the intervals between data points to more than one hour.

User Input

The Plant Protection extensions use two types of data: climatic data, collected by the measuring stations in the field; and user data, such as phenological phases, type of cultivar, treatments, and so on. Obviously,

the model's results are heavily dependent on the correctness of the user-supplied data.

Depending on each individual extension, several configuration dialog boxes for user data input may be present, but some of them are standard for all the models and are described in the following paragraphs.

To access the extension's configuration panels, highlight the extension and select **Edit ▶ Properties...** or right-click the extension in an Explorer and select **Properties...**

Start Date

In principle, the system can be installed anytime, but starting it at the beginning of the growing season has certain advantages. However, the software has the necessary provisions for being set to the actual development state of the culture and disease. If this is the case, you have to synchronize the models with the existing situation in the field. Do this by using the **Crops** panel, which sets the proper phenological phase.

To set the season's starting date, complete the following steps (Figure 6):

1. Highlight the extension and select **Edit ▶ Properties...**
2. Click the **Crop** tab.
3. Make sure the first phase in the **Phases** list is selected.
4. Use the calendar to set the **Begin date** and click Apply.

Generally, the first phenological phase corresponds with the year's begin in the northern hemisphere, that is the 1st of January. After you set the date of the first phase, all other phases are automatically computed from the defaults programmed for each crop.

Climatic conditions during certain seasons could differ from the pre-programmed defaults, so Adcon recommends that you verify at regular intervals whether the model is in synchronicity with the field conditions. If this is not the case, use the method described above to change each individual phase's date accordingly.

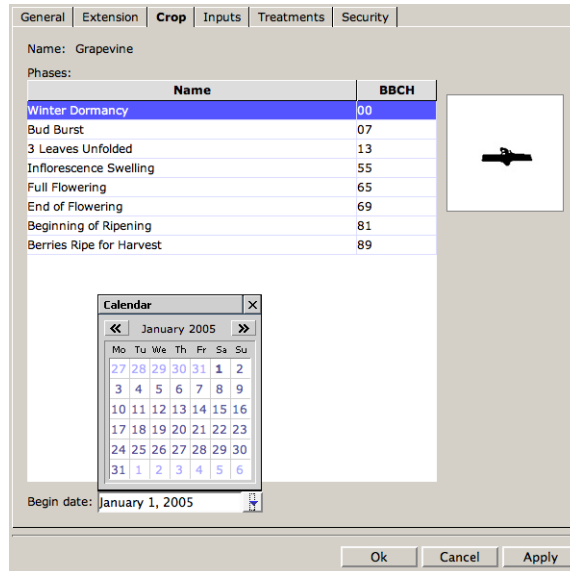


Figure 6. Setting the season's start date

Treatments

A spraying application usually follows a treatment recommendation (displayed in the Events list). To inform the model you applied a field treatment, do the following (Figure 7):

1. Highlight the extension and select **Edit ▶ Properties...**
2. Click the **Treatments** tab.
3. Select the chemical you applied in the field from the list; you can view the chemical's properties by clicking the **Properties...** button.
4. Click the **Treat** button and use the calendar and time controls to select the correct treatment date and time.
5. Press **OK** and then **Apply** when you are done.

Note: If you want to add a spray for more than one disease (even if the chemicals used are identical), you have to perform this operation for each individual disease for which the treatment is valid.

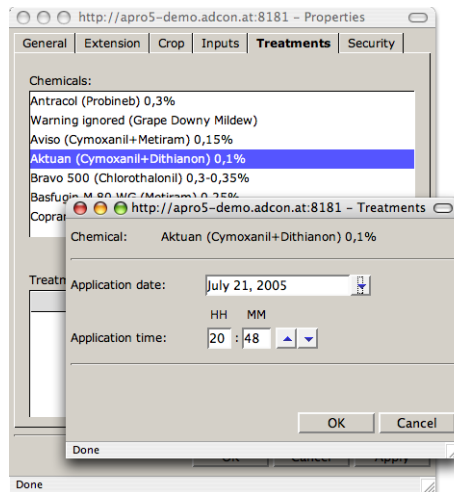


Figure 7. Applying a treatment

If you decide that you don't need to apply a treatment, e.g. if other circumstances determine a treatment is not warranted, you must select the entry "Warning ignored" from the chemicals list.

Note: Whatever the case is, you must either apply a treatment or choose to ignore the warning. Failure to do so will leave the current alarm active and no new warnings will be issued.

If the chemical you want to apply is not in the system's database, you must first add it. For more details about adding to or modifying the chemicals database, see "The Chemicals Service" on page 18.

Removing or Modifying a Treatment

If you added a treatment and you find out at a later date that it was incorrect (either the date of application, or the type of chemical), you can edit or even delete the treatment. Proceed as follows (Figure 8):

1. Highlight the extension and select **Edit ▶ Properties...**
2. Click the **Treatments** tab.
3. Select an applied chemical from the lower list (**Treatments:**) and click the **Edit...** button to change the treatment data, or the **Remove** button to cancel the treatment.
4. Click the **Apply** button.

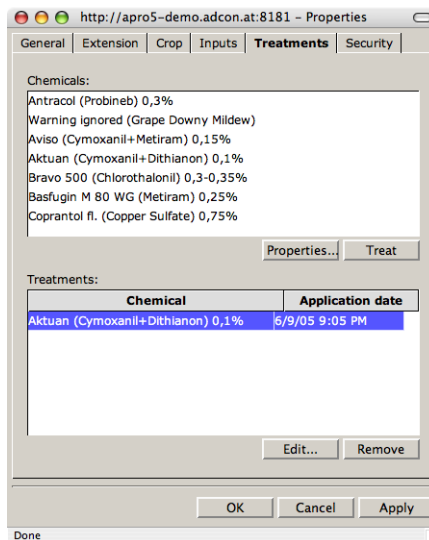


Figure 8. Remove/edit an already applied treatment

The system automatically recalculates the model's new data and updates the results in the Events list.

More about Treatments

The two basic types of treatments are *curative* and *preventive*. Generally, the models based on computed indexes (disease pressure or infection indexes) are more prevention-oriented. The models observing the states of the disease (like grape downy mildew or apple scab) can lead to preventive spraying, that is, towards the end of an incubation (about 70 – 80%). The treatment might prove unnecessary if the next infection condition isn't met at the right time. You could wait until the next infection condition before executing a treatment, but then it will be curative and have to be carried out as soon as possible. Certain risks are inherent in such an approach, but specific conditions can be evaluated to take the appropriate measures.

It is worth noting that the vast majority of curative products are systemic, and they can easily induce resistance if they are used too often. To avoid such a situation, you can use several alternative products, although the choice won't always appear very broad. Preventive treatments applied at specific development phases of the vegetation can also help substantially.

During certain phenological phases, the plants' sensitivity to some diseases is higher. In particular, the young organs (young leaves, flowers, and so forth) with a thin epidermis offer vulnerable surfaces to the fungi, so they must be carefully protected.

Treatments with curative fungicides minimize the outbreaks if they are applied soon after the infection conditions are reported. Each fungicide has its own way of acting on the diseases. An important issue arising is, of course, the pathogen's resistance to the product. In any case, these limits can vary. For example, in the case of apple scab, the maximum limit could be 96 hours after infection, for some products. Currently, no product can guarantee sufficient protection if applied later. This form of disease fighting offers the most in terms of fungicide economy.

The following factors influence the effectiveness of the plant protection measures:

- Climate
- The state of the vegetative organs, leaves (wet or dry)
- Contact or systemic fungicide
- Preventive, curative, or eradicating effect
- Growth stage
- Spray coverage quality

Washoff Limit

Contact fungicides (averaging 8 to 10 days of control) are washed away after a specific amount of precipitation, meaning that the controlled period is over. Therefore, you have to be aware of the manufacturer's information when adding chemical products in the database. Exact values are difficult to state, so adjust them according to your practical knowledge and pertinent information received from the product manufacturer or distributor.

Systemic products (averaging 14 to 20 days of control) are not washed away by precipitation, except if a heavy rain falls in the first 2 hours after application. In such cases the system will neither observe nor report the washoff for systemic products. The delay between the actual treatment and the time when the system is informed about the treatment is usually long enough to justify such an implementation decision.

The Chemicals Service

This service is automatically activated if you have at least one extension that requires it. In general, these are the Plant Protection extensions.

The addVANTAGE server's default database contains a number of known chemicals used to fight diseases and pests. You can also add your own chemicals or edit the existing ones.

Only users with administrator rights are allowed to edit the default database (also called system-defined chemicals). However, all users can maintain their own chemicals database (user-defined chemicals).

To access the chemicals database, select **Tools ▶ Chemicals**. A window appears, containing a list of chemicals (Figure 9). You can select either the system- or user-defined chemicals from the **Show** combo box.

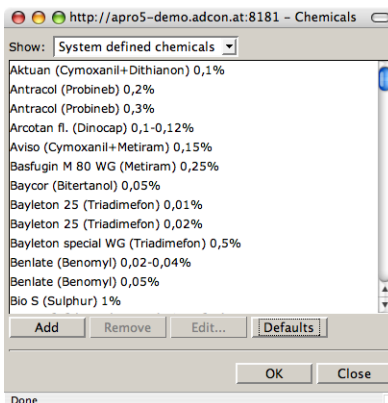


Figure 9. The Chemicals window

You can add, remove, or edit chemicals according to the rights you have. Follow these steps to add or edit a chemical:

1. Select the appropriate list of chemicals in the **Show** combo box.
2. Select **Add...** or **Edit...** as appropriate. The window shown in Figure 10 appears.
3. Type the name of the chemical in the **Name** field.
4. Select either **Systemic** or **Contact** for the **Type**.
5. Enter the **Controlled duration** in days. This is the number of days the chemical treatment will be effective. The extensions use this

information to determine if the plants are safe or not, in case of an imminent outbreak.

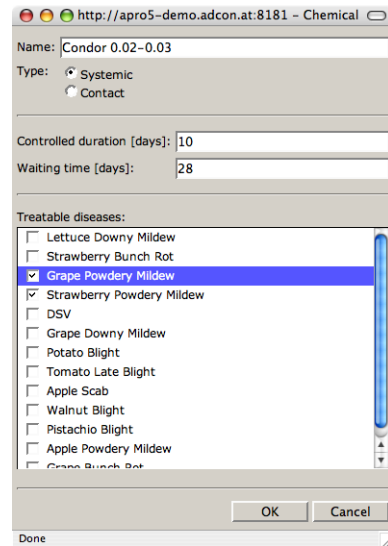


Figure 10. Adding or editing chemicals

6. Enter the **Waiting time** in days (optional). This is the number of days that the sprayed plants cannot be consumed. This information is not used by any extension at this time.
7. Select the diseases for which the chemical is effective in the **Treatable diseases** list of checkboxes.
8. Select **OK** to confirm the changes and return to the Chemicals window.

Note: If you are in doubt about certain parameters of the chemicals you are using, contact the manufacturer of the respective product.

The **Defaults** button reloads the system-defined chemicals database with the original defaults built into the distribution package.

CAUTION If you click **Defaults**, you will be informed that all the changes to the system-defined chemicals will be lost. If you proceed, you will lose all your changes. The custom-defined chemicals will not be affected.

Chapter 2. Using the Extensions

This section describes the operation of the Plant Protection and Irrigation extensions. It is not intended to be an extensive compendium on plant protection or irrigation techniques and methods; rather, it focuses on the particular models implemented in the extensions included in the software package addVANTAGE Pro 5.0. For more details about a particular model, consult the References included at the end of each extension description or try to get in contact with the model's authors.

Adcon Telemetry does not assume any responsibility for the results obtained by using a given model, but only for the correctness of its implementation.

The Apple Scab Extension

The disease originated in Europe and was first observed in Sweden by Fries in the year 1819. It was successively recorded in 1833 in Germany, in 1834 in the USA, in 1845 in England, and in 1862 in Australia.

At present, the disease is widespread at a worldwide level, being found in almost all apple-growing areas and especially those characterized by humidity and moderate temperatures. In many countries it is considered the main apple disease.

The fungus multiplies in two ways: the sexual (teleomorphic) form and the asexual (anamorphic) form. The sexual multiplication represents the saprophytic form of the fungus, which develops on the fallen, wilted, degrading leaves, and not on the live leaves, hence the non-parasitic character. This form of existence and reproduction is specific to the autumn/winter/beginning of spring period—the period corresponding to the falling of the leaves, followed over the winter by their degradation and the beginning of bud break of the trees. The sexual saprophytic form of the fungus is known under the name of *Venturia inaequalis* (Cooke) Wint. or *Endostigme inaequalis* (Cooke) Syd.

The asexual form promotes massive multiplication during the entire growing season of the apple and pear trees, having an exclusively parasitic character. It develops upon different organs of the host plant (flowers, fruit, leaves, young branches), organs that it may damage severely. The asexual parasitic form of the fungus is known under the name of *Fusicladium dendriticum* (Wallr) Fuckel and originates in the spring, in a proportion of approximately 90% of the sexual form, respectively *Venturia inaequalis*. The rest of the overwintering source is due to the actual parasitic form, which within reduced limits manages to survive the rigors of winter, either in the form of mycelia, or in the form of conidia, especially in the cracks of the branches.

Disease Symptoms and Development

The fungus may develop on the different components of the floral organs: sepals (most often), petals, ovaries, floral peduncles. The consequence of the infections may be the abortion and the falling of the flowers.

On the growing leaves that are heavily attacked by the fungus, the tissues develop unequally, with deformities; leaves often fall before the end of the growing season. The early falling of the leaves leads to the reduction in nutrition of the tree, which automatically results in less of

the fruit crop and the formation of a reduced number of fruiting buds for the following year.

The disease also occurs on the leaves, usually in the form of spots. For the sensitive varieties and in optimum climatic conditions for the pathogen, the apple scab fungus may cover the entire leaf, without a delimitation of the spots; in such situations total necrosis and early defoliation follow.

The fruit is vulnerable to attack from the beginning of their formation to harvest. If they are transported to storage with the conidia, or if they are in contact with affected fruit, the development of the fungus during storage is also possible. Most of the infected fruit, immediately after formation and during the first vegetation period, cannot continue growth and falls off.

In the area of the spots, the pulp of the fruit hardens and stagnates in its growth, which leads to deformation, as a consequence of the unequal growth between the attacked and healthy parts. In the years favorable for the evolution of the fungus, the harvest losses may reach values between 30% and 98%, and what remains is of inferior quality and cannot be stored.

The pathogen may also develop on the branches—the *hyphae* (the fungus filaments) penetrate deep into the cellular layers of the branch. However, the attack on the branches is a scarcer phenomenon and it appears, generally, only on the very sensitive varieties or in uncared-for orchards.

Using the System Against the Apple Scab

The damages caused by apple scab generate important production losses. As a result, there is a general tendency to overutilize the chemical methods against the disease. That means sometimes more fungicides than necessary are used. An efficient fight against the disease can be realized by integrating the observation of three factors: phenology, biologic reserve, and ecology. In the case of the *Venturia inaequalis*, the objectives of the prognosis are:

- The knowledge of the biological reserve of the fungus, the existing reserve in its perfect form in the leaves infected during the autumn of the previous year
- The recording of the evolution of the fungus and of its infectious potential, under the influence of the climatic factors, from the

forming of the perithecia to the scattering of the ascospores in the environment

Infection periods and their intensities are detected using the Mills table, with the corrections made by McHardy. The processing begins normally with 1st of January, although this is not an absolute necessity.

After installing the model on all the areas placed in apple orchards, you have to set up, besides the phenological phases, the degree-day option (see Figure 11). McHardy and Gadoury (1982) have issued a curve of ascospore maturation, depending on the degree day summation. They found that at about 300 degree days (base 0°C), approximately half of the ascospores are mature.

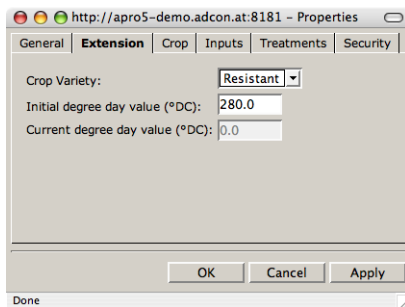
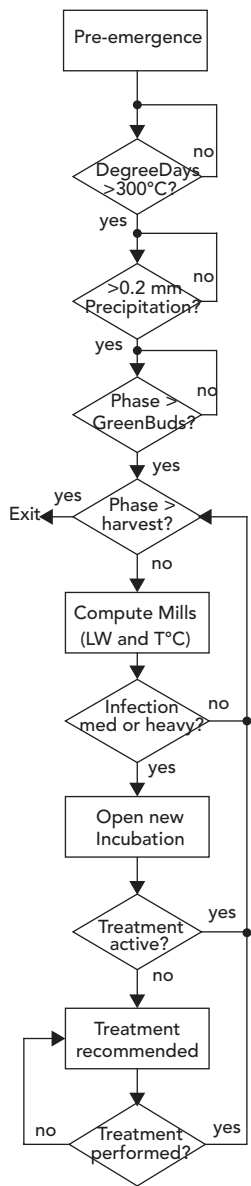


Figure 11. Apple scab Options dialog box

The next event the model is waiting for is the projection of the ascospores. This follows when a rain of at least 0.2 mm (.01 in) is detected. Having reached this state, the model issues the event *ascospore projection possible* in the Events list and waits for the phenological phase “green buds” to be reached. The order of these events may vary; it is important only that all the conditions are met (green buds and ascospores projection).

The model enters the phase of checking and recording all the infection conditions by using the Mills table. Depending on the leaf wetness duration and the temperature, different infection conditions are detected: light, moderate, or heavy. The interruptions in the leaf wetness duration are ignored if they are less than 8 hours when the RH is under 90% and 48 hours when the RH is over 90%. For longer dry-time periods, the model resumes and waits for a new infection condition.

If the leaf wetness duration is sufficient, an infection condition event is reported, for example, *infection conditions 3 (moderate), 49 hours*. That

means it was the third infection condition detected since the season's beginning, it was a moderate one (as per the Mills table), and the effective Mills duration (without valid leaf wetness interruptions) was 49 hours.

If the infection was moderate or heavy, and no active treatment is ongoing, a warning is issued. Normally, a light infection does not indicate a serious attack, so no warning is issued. However, if you have an extremely sensitive cultivar or a particularly high disease pressure in the orchard (ascertained by the use of spore traps or by close examination of the trees), you should consider the opportunity of a treatment even though the infection was light.

If the event *treatment recommended* is announced in the Events list you have to start treating as soon as possible. You have several fungicides to choose from, but few of them still have a good curative effect after more than 72 hours. After 96 hours, no fungicides can help fight the outbreak.

After each infection condition, the software computes the incubation period. The incubation has no direct influence on the model, but it is provided as supplemental information. If the fungicide used against the disease was systemic, the incubations are terminated; otherwise, they are computed until they reach an end, using the Jones table.

As long as an incubation is active, you will see the Mills-Jones index as a daily event. It tells you how many days the incubation needs if the current temperature conditions remain unchanged. This information may be used to ascertain the next critical period to come (a new massive spore generation).

The Apple Powdery Mildew Extension

The disease was observed for the first time in 1877, in the USA (Iowa) by Bassey. In the USA the area most affected by the disease is the Pacific Northwest, an area in which important damages to the fruit are recorded (Hickey and Yoder, 1991). The powdery mildew may be considered as being present all over the world, wherever apples are grown. Of course, the intensity of the attack is graded from one geographical area to another, depending on the climatic conditions specific to the area and especially on the year (Lazar, 1982; Butt, 1988; Hickey and Yoder, 1991).

Regarding the extensive spreading of the fungus, in general the phytopathologists agree upon the causes:

- The appearance of orchards of an intensive type, which usually include heavy cropping, fertilization, and irrigation
- The use of cultivars characterized by high productivity and quality, and often also by a sensitivity towards the pathogen
- The use of fungicides not specific for the fungus

Disease Symptoms and Development

The disease is specific to the apple tree but the pear tree, admittedly more rarely, can also be attacked (Vukovits, 1976; 1990; Hickey and Yoder, 1991). For both species various organs are attacked: the buds, the blossoms, the leaves, and the young branches. The fruit is also attacked, but the phenomenon is more scarce and appears only in conditions extremely favorable for the fungus. The *Podosphaera leucotricha* fungus is an ectoparasite, its development taking place on epidermal cells. The germination filaments penetrate inside the cells, expand, and form haustoria that absorb the cellular juice (Vonica 1975).

The presence and development of the fungus' mycelium inside the buds leads to the weakening of their vitality. Consequently, a sensitivity to frost is produced, and a certain percentage of buds no longer develops, dries up, and falls off. Certain infected floral buds, even if they do not perish but continue their development, nevertheless ensure the possibility of further development of the fungus.

For the blossoms attacked by powdery mildew, the sepals deform and remain narrow and small. The petals also remain small and narrow, lengthen, and become fleshy, with a tendency of becoming greenish. These blossoms, in a later phase, turn brown, remain sterile, dry up, and fall off.

The attacked leaves are shorter, narrower, rigid, and folded towards the superior side, which gives them a boat-like appearance. On the leaves that are advanced in growth, upon the inferior side, as a consequence of the secondary infections, small, whitish spots appear, which expand with time, occupying large surfaces of the leaf and gradually passing onto a brown or reddish color. Such leaves become rigid, and can also become tattered due to the wind. Finally, the attacked leaves dry up and fall off the branches long before the healthy ones.

The development of the fungus on the shoots has its source either directly from the overwintering mycelium present on the shoots, or following the secondary infections. On the shoots, powdery and white-grayish mycelium forms. On the strongly attacked shoots, a number of leaves larger than the normal ones appear. Some of these leaves are of narrower dimensions, lengthened, and contorted.

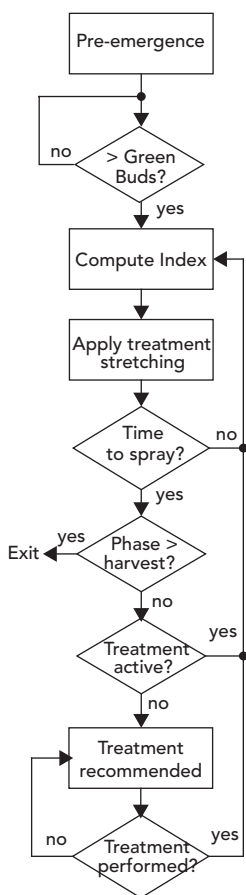
The presence of the powdery mildew on the fruit is less common. For the fruit in a more advanced growth stage, the attack is evidenced through the burn produced by the fungus, on the epidermis, in the form of a network of irregular, serous, brown lines. Sometimes, following the secondary infections, the characteristic structure of powdery mildew appears. Respectively, the whitish growth and often the attacked fruit fall off before maturing. The fruit are admittedly less affected by powdery mildew, but due to the attack on the buds, inflorescences, leaves, and shoots, the apple harvest is much diminished.

Using the System Against the Powdery Mildew

The powdery mildew model implemented is a variation of the Kast model, developed for the grape powdery mildew, to which developmental similarities have been observed. The start of the computation is based on the phenological phase "green buds," rather than an estimation based on climatic parameters recorded over winter. However, you should note that temperatures during winter that are under -24°C , due to the destruction of a part of the resistance mycelium, reduce the overwintering reserve for the following spring by approximately 50%. Therefore:

- At temperatures below -24°C , part of the infected buds perish.
- At temperatures below -28°C , all the infected buds are destroyed and, at the same time, the resistance mycelium also perishes.

After entering the active phase, the model computes daily the disease pressure index and uses it to dynamically interpolate the appropriate time span between treatments. You'll see an index value in the Events



list every day, showing the actual estimated disease pressure. You can also set up the index to display in graphical form (Figure 12) as the extension generates an index tag.

Before starting the model, set the sensitivity of your cultivar by selecting the extensions properties and then clicking the **Extension** tab.

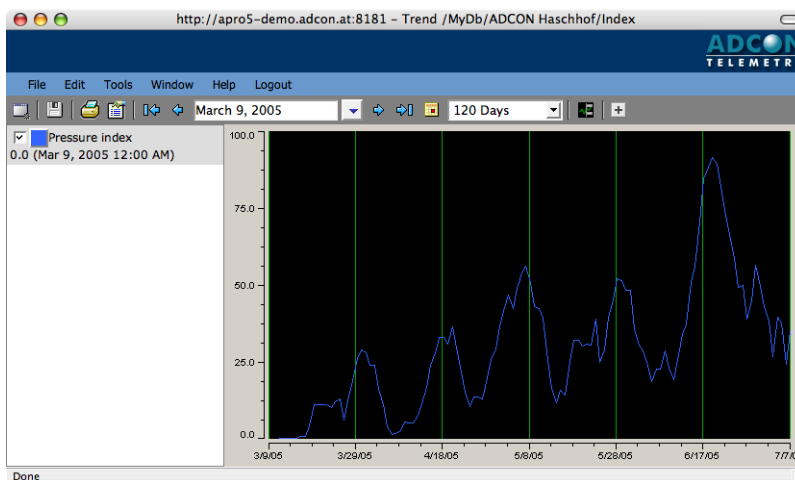


Figure 12. Apple powdery mildew index shown as trend

There are several thresholds for issuing warnings, according to the sensitivity of the organs' evolution through various phenological phases.

References (for both Apple Extensions)

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2. Gadoury D. M., McHardy W. E., 1982- "A model to estimate the maturity of ascospores of venturia inaequalis." Phytopathology, Vol. 72, 7, pp. 901 - 904.
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5. Oberhofer H., 1985 - "Der Apfelschorf. Lebensweise und Bekämpfung." Südtiroler Beratungsring für Obst- und Weinbau. Lana, Italien; 120pp.

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7. Hickey K. D. and Yoder K. S., 1991 - "Powdery Mildew." In: Compendium of apple and pear diseases; edited by A. L. Jones and H. S. Aldwinkler, APS Press, pp. 9 - 10.
8. Kahl E., Russ K., Vulkovits G. und Bohm H., 1976 - "Wichtige Krankheiten und Schädlinge im Obstbau," 5. Auflage, Wien.
9. Vulkovits et al., 1990 - "Krankheiten, Schädlinge und Nützlinge im Obstbau," 2. Auflage, Wien, pp. 54 - 55.
10. Kast, W. K., 1994 - "A Step by Step Risk Analysis (SRA) Used for Planning Sprays Against Powdery Mildew (OiDiag-System)." Proceedings of the Second International Workshop on Grapewine Downy and Powdery Mildew Modelling, Freiburg Germany.

The DSV Extension

The DSV extension calculates the Disease Severity Values on several crop pathogen systems. Two primary models are implemented (Tom-Cast for black mold of tomato and late blight of tomato and potato), but you can use the extension for other crops as well. Based on the work of Fry, the DSV model has been useful in assessing disease risk for a variety of crop diseases including black mold on tomato, *Alternaria* on carrot, and *Septoria* on celery.

Tom-Cast

Tom-Cast was designed to help decide when to apply fungicides to control tomato fungal diseases. It calculates DSV as a function of duration in hours of leaf wetness and average temperature during leaf wetness. These values are calculated daily from noon to noon, and then totaled to generate an accumulated DSV.

A spray is recommended when the accumulated DSV reaches the threshold you predefined. Define this threshold according to the susceptibility of the variety. After you apply a treatment, the index is reset and accumulates until the next time the threshold is reached.

The following guidelines have been used to initiate spray control for the tomato black mold:

- Susceptible: 12 – 14 DSVs
- Intermediate: 14 – 16 DSVs
- Tolerant: 16 – 18 DSVs

Late Blight of Potato and Tomato

Also known as Wisdom Tom-Cast or Blight-Cast, this model has two stages. It calculates DSV using duration in hours of high relative humidity and average temperature during the high relative humidity. Points are accumulated each day until the pre-programmed threshold is reached (typically 18 in total). At that point, the onset of disease is expected for the first time.

A spray is recommended and, if a treatment is applied, the index is reset to 0. The model enters its second cycle. It calculates the accumulated DSV based this time on the leaf wetness and the daily average temperature, noon to noon, according to the Tom-Cast model. A second threshold is now used. Each time the accumulated DSV reaches

it, a warning is issued. The index is reset if a treatment is applied. Figure 13 shows a DSV index in a Trend panel.

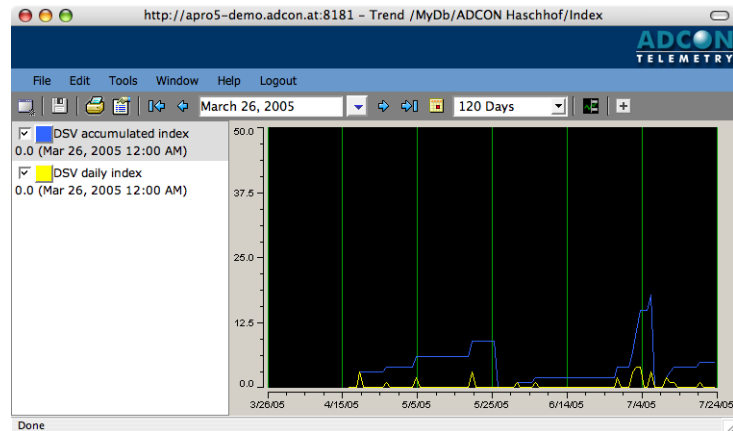


Figure 13. DSV extension output tags in a Trend panel

The recommended value for the second threshold depends on the history of the attack's severity:

- 30 for light history
- 20 for moderate history
- 15 for severe history

Setup and Operation

Follow these steps to set up a DSV extension on an area:

1. Add the DSV extension to the desired area (see also "Adding Extensions to an Area" on page 9).
2. Select the extension's properties and click the **Extension** tab.
3. Select between Tom-Cast and Wisdom Tom-Cast models, set the proper thresholds, and click **Apply** (Figure 14).
4. Click the **Crop** tab and select the crop for which the extension should calculate the model.
5. Adjust the date of the phenological phase, then click **Apply**.

*Note: Interpret the **Emergence** phase quite generically in this case because it depends heavily on the model, crop, and disease. For example, the Tom-Cast model for black mold of tomato recom-*

mends the start (that is, advancing to the **Emergence** phase) when you observe the first red fruit.

6. Click the **Inputs** tab and make sure all input tags are correctly assigned to the extension inputs. If you make any changes, click the **Apply** button.

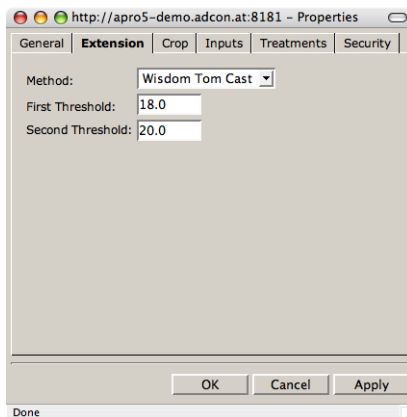


Figure 14. DSV settings dialog box

7. Click the **General** tab and make sure the extension is enabled, then click **OK**.

Note: The combo sensor must be installed in the vegetation, taking care that the leaf wetness sensor is surrounded by leaves.

References

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The Grape Downy Mildew Extension

The grape downy mildew (*Plasmopara viticola*) was observed the first time in North America by European colonists, on the wild vines, as well as on the cultivated ones. In Europe, it was noticed for the first time in France in 1878 (the Gironde department) by Deluja. The pathogen was brought into the country with the phylloxera resistant root stock material.

In 1879 the newly appeared disease is confirmed to be the downy mildew, caused by the *Plasmopara viticola* fungus. Within two years of being identified, it spread over the whole of Europe. The disease also spread in other continents: South America (Brazil, 1890), Africa (South Africa, 1907), Australia (1916-1917), and New Zealand (1926).

In 1888 Berlese and DeToni established the scientific name that is maintained today: *Plasmopara viticola* (Berk. et Curt.) Berl. et DeToni.

Disease Symptoms and Development

The fungus may establish itself on all the green organs of the vine having stomata: leaves, shoots, tendrils, inflorescences, berries, and clusters.

The leaves are attacked in all phases, from the youngest to the oldest ones. However, the pathogen more easily infects the younger leaves, which are more susceptible; in older leaves, the penetration of the fungus into the tissues is limited and the consequences are less severe. After the infection and towards the end of the incubation period, upon the upper side of the leaves, discoloration spots with a yellow-oily aspect can be distinguished (hence the name of *oil-spots*). In a later phase, specifically after 1 – 2 days, upon the underside of the leaves, a fine white cottony growth appears, representing the sporangiophores and sporangia of the fungus.

Gradually, with the evolution of the disease, the cellular content between the two epidermis layers of the leaf is destroyed by the fungus mycelium. Following the destruction of the tissues, the affected area is subject to necrosis. The necrosed spots grow together, and the leaves finally dry and fall off the shoot. The grape trunk may suffer a partial or total defoliation.

The manifestation of the disease has a negative influence on the healthiness of the entire trunk. Therefore the assimilation surface of the leaves is reduced and, as a consequence, the growth of the shoots

decreases, growth is retarded, the berries and the clusters in their ensemble do not develop to their potential in quality or quantity, and the crop suffers a negative influence. Usually, the grape trunks that have experienced a partial or, more seriously, total premature defoliation suffer in the following year, beginning with an increased susceptibility to frost during winter.

The shoots are less affected. When the infection takes place, this occurs in the growth tip areas. The attack may be recognized by the presence of discolored spots, of a more or less elongated shape, upon which a white cottony growth, formed of sporangiophores and sporangia, may appear. The tissues upon which the mycelium has developed turn brown and necrose, the shoot portion curls and dries up, and the shoot is suppressed in its growth.

The tendrils may also be affected; the attack is carried out through a process similar to that of the shoots. Following the attack, marked by the presence of the white cottony growth formed by the conidiophores and conidia, a browning appears, followed by drying up.

The quality of the crop is affected in multiple ways: the sugar content of the berries is much reduced, the alcohol percentage decreases, and acidity increases. The wines produced from the grapes affected by downy mildew are preserved with difficulty as negative phenomena may appear during storage (driveling, cracking, souring, thick vine).

Using the System Against the Downy Mildew

Many researchers worked on the evaluation of optimal methods to fight efficiently against downy mildew (Lalancette et al. 1988, Nieder G. 1992, Bleyer 1993, Hill 1992, Kast 1989, Bläser 1978). The warning for chemical treatments in the rational scientific setting is based most often upon three criteria: ecological, biological, and phenological. The Grape Downy Mildew model uses a similar approach by combining the information recorded in the field with the data you supply.

You have the option to let the model start upon the occurrence of a certain degree-day value, computed with a base of 8°C (the default is set for 170 degree-days, computed starting with the first of January), or based on the first heavy precipitation (precipitation based option, see also Figure 15). When this limit is reached, the model assumes the possibility that primary infections might occur. The importance of this option is minimal, because the exact outbreak of the primary infections is of little importance. The literature offers different opinions on this

subject, so your decision should be based on the local conditions and experience.

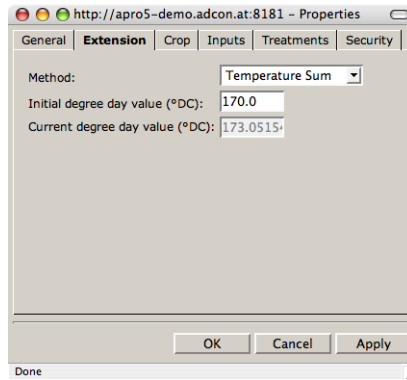
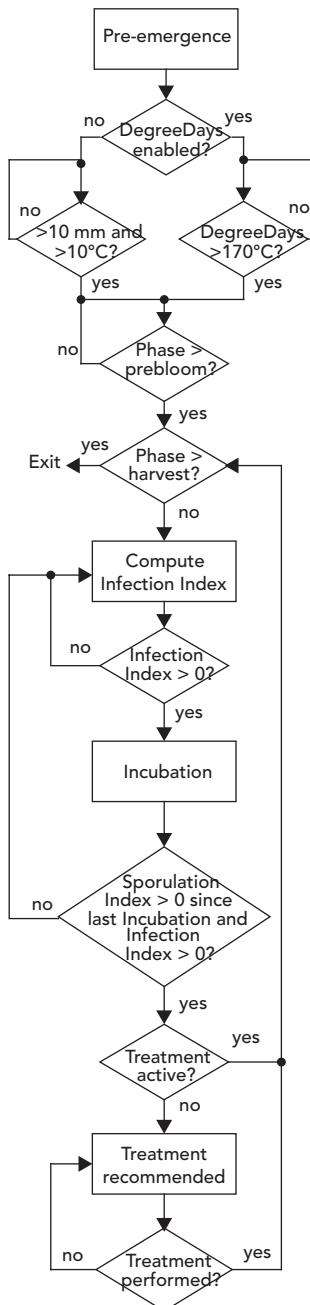


Figure 15. Setting the Grape downy mildew extension starting method

Note: Put the weather station sensors in the canopy, near the fruit zone.

The first information issued by the model is *oospores germination possible*. This occurs if the temperature was constantly over 10°C and the total recorded rain was over 10 mm in the last 72 hours. However, this information is not provided if the option to compute the degree-days is used. Instead you will get the *infections possible* message after the specified degree-days limit was reached.

If the specified conditions are met, the model waits for the primary infection conditions, which are computed based on the equations developed by Dr. Kast and used with permission from his original *PeroDiag* model. To be valid, at least the phenological phase, 3 cm leaves must be reached. If all these parameters are met, either day or night, the *primary infection conditions* message is displayed in the Events list.

The model starts computing the incubation according to the Müller table. You can see its daily evolution by observing the event *incubation xx% done*. In the Events lists, you can see that two different events are reported: the incubation duration and the actual stage of the incubation. The incubation process stops when the temperature is outside the Müller table (less than 10°C or greater than 30°C), but it will resume when the conditions are again favorable.

Note: If the conditions are appropriate, you can have more incubation events running in parallel. All the incubation periods will be shown in the Events list.

From this point forward, the model constantly computes the sporulation and the infection indices according to the *PeroDiag* equations (the indices are also viewable as trends). Figure 16 shows a raw data graph with grape downy mildew information.

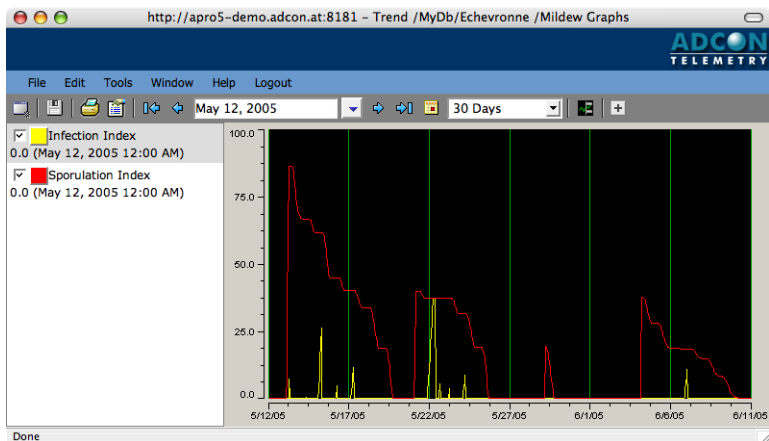


Figure 16. Grape downy mildew indices in a Trend panel

How the Warnings are Generated

Although Kast recommends a strategy based on both climatic parameters and observation of the disease, the Adcon implementation of the model is somewhat simplified in that it does not account for the plant – pathogen interaction. This is due to the difficulties associated with entering subjective data into the program. Therefore, after explaining how the warnings are issued, we’ll cover Kast’s strategy, which Adcon strongly recommends that you follow.

The model issues a warning if all of the following are true:

- At least one incubation ended successfully (no treatments).
- The infection index is greater than 0.
- The sporulation index has always been greater than 0 since the last incubation ended.
- The phenological phase is between prebloom and 3 weeks preharvest.

- No treatment is currently active.

Additionally, preventive warnings are issued for sensitive cultivars when the first secondary infection condition is reported, as well as when reaching the prebloom phenological phase.

This loop continues until the end of the vegetation (3 weeks preharvest). Since this process happens only when the right conditions for the fungi are present at the right time, you might have some opportunities for spray reduction.

Normally the primary infections have a reduced importance, so the model issues only a preventive treatment recommendation for sensitive cultivars. Reports from some researchers, notably in Germany, have stated that treating against primary infections may drastically reduce the initial inoculum and lighten the mildew pressure throughout the season. The model recognizes the primary infections and gives the appropriate message (*primary infection conditions*), so if you find that treatments are necessary at this stage based on your experience, you can apply a treatment.

If no treatment was executed two weeks before bloom time, the model recommends a preventive treatment. You have to weigh the necessity of such a treatment, based upon the conditions in the vineyard, the cultivar sensitivity, and whether the mildew pressure is already high, against the known sensitivity of the vine during the bloom period.

The Kast Strategy

Kast recommends that you periodically check the number of spots on the grape leaves in the field, especially when the infection index is greater than 0. Use Table 1 to determine the appropriate measures to be taken:

- A preventive treatment is executed at the end of the first incubation following the warning.
- A curative treatment is executed in the first three days after the warning.

Table 1. Measures to Take for Grape Downy Mildew

	Spots per leaf	Infection index	Action
Before veraison	none	greater than 0	preventive
	less than 5	less than or equal to 50	preventive
	less than 5	greater than 50	curative
	greater than or equal to 5	greater than 0	curative
After veraison	less than 25	greater than 0	preventive
	greater than or equal to 25	greater than 0	curative

Note: In this context, you must understand that a warning was not issued by the software but was a result of your findings based on the above table.

The Grape Powdery Mildew Extension

The grape powdery mildew (also called *Oidium*) is caused by a fungus that features reproduction of a sexual type, the teleomorphic stage *Uncinula necator* (Schw.) Burr., as well as asexual reproduction, the anamorphic stage *Oidium tuckeri* Bark.

The first appearance of the fungus took place in North America, and it apparently originated in this geographic area. In Europe, the first appearance dates from 1845, in a greenhouse in England, close to the Thames. Later, in 1847, it was also found in a vineyard in France, close to Paris.

Disease Symptoms and Development

The various organs of the vine are affected: leaves, shoots, tendrils, clusters, and berries. The powdery mildew does not produce defoliations to the proportions of that produced by the downy mildew, because, in the case of the first disease, the infections generally have the character of localized foci and do not expand throughout the entire plant, as in the case of *Plasmopara viticola*.

Bud Perennation – Conidial Infections

In the spring, when the shoots have only 3 – 4 leaves, the first symptoms of the attack are recorded. Upon the shoots as well as upon the leaves, mycelia develop from infected buds that generate conidiophores with conidia, which give it the aspect of a gray-whitish growth. Even in this phase of attack, the negative influence upon the growth of the shoots, as well as of the attacked leaves, can be noted. The parts of the plant with powdery mildew infections present a characteristic moldy odor.

Cleisthotecia – Ascospore Infections

In the spring or early summer, when leaves are wet and temperatures are mild for prolonged periods, cleisthotecia that are lodged in the bark release ascospores onto the lower surface of leaves. Isolated infections appear there. Such a phenomenon is still considered to have a lower importance in Europe, but is relatively consistent in the USA.

Following ascospore or conidia infection, a gray-white growth appears. The growth represents the mycelium of the fungus from which the conidiophores with conidia arise. As a consequence to the destruction of the leaf tissues by the fungus' mycelium, distortions of the lamina and

leaves appear curl to upwards. The mycelium may also extend and develop on the petioles of the leaves or fruit.

The fungus easily can cover the entire shoot, from the base to the tip. The mycelium growth, bearing conidiophores, takes the shape of slightly visible patches. With the advance in vegetation and lignification of the shoots, the fructifications become more limited and in the attacked area the surface turns brown. Reddish-brown or reddish-black patches on the shoots become obvious.

The infections may appear, sometimes, before bloom. Therefore, the inflorescence may be entirely covered by the mycelium upon which its fructifications appear. In such situations, the inflorescences turn brown, dry out, and fall off. The infections continue on the berries in various development phases. Regardless of the stage of growth or ripeness of the berries, the negative effects acquire economic importance from the moment they are invaded by the mycelium growth. Therefore, we note:

- The reduction or even cessation of the growth of the berries.
- The growth of the pulp volume, the growth of the seeds and, as a consequence, the splitting of the skin of the berries.
- The draining away of the juice as a consequence of splitting, the tendency of the berries to dry.
- The invasion of the berries by certain saprophytic fungi, and in the rainy years even by the parasite fungus *Botrytis cinerea*.
- The appearance of reddish patches on the ripe berries, which leads to their depreciation.

Using the System Against the Powdery Mildew

Powdery mildew has been studied in detail over a long period of years, as well as various methods to optimize the fight against it. Numerous works have been published on the subject (Toma 1964, 1970; Gadoury et al. 1988, 1990; Chellemi et al. 1991; Gubler et al. 1989, 1994; Kast 1991, 1994).

You can use the models implemented in the Grape powdery mildew extension to better control the disease. Currently, two models are implemented: one after Kast and the second after Gubler et al. The first model is particularly suitable for the European temperate conditions, whereas the second is developed for the dry coastal climatic conditions of California.

As with the grape downy mildew, you have to configure several parameters before starting the model. First, you have to decide which model suits you the best. Proceed as follows:

1. Add the Grape powdery mildew extension to the desired area (see also “Adding Extensions to an Area” on page 9).
2. Select the extension’s properties, click the **Extension** tab (Figure 17), and select the model you decided to run.
3. Configure the remaining parameters appropriately: for the Kast model you must set the last season’s disease severity (on a six points scale) and the winter’s minimum temperature (note that this parameter will be updated by the model if enough climatic data for the year is available). For the Gubler-Thomas model you must decide if you want the model to issue warnings out of *Cleistothecia* infections or not.

Note: If you selected the Kast model and properly set the initial parameters, the system will compute the estimated first disease occurrence date (please allow it several minutes to recalculate the data).

4. Click **Apply** when ready.
5. Click the **Crops** tab and adjust the phenology according to the field conditions, then click the **Apply** button.
6. Click the **Inputs** tab and make sure all input tags are correctly assigned to the extension inputs. If you made any changes, click the **Apply** button.

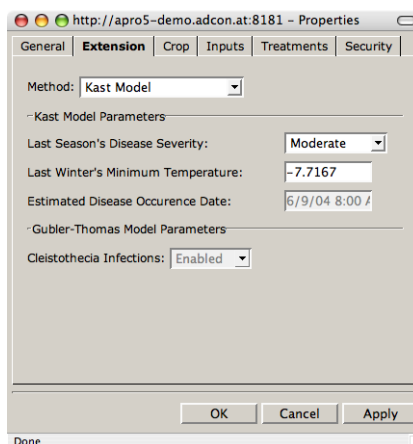


Figure 17. Grape powdery mildew Options dialog box

- Click the **General** tab and make sure that the extension is enabled, then click **OK**.

Basically, both models work through two phases:

- Evaluate the conditions for the first disease outbreak.
- Evaluate the disease pressure and issue the treatment recommendations accordingly by lengthening or shortening the spraying intervals.

The Gubler-Thomas Model

The model starts at bud break and computes the pressure index until harvest. Right after bud break, the first treatment is issued and simultaneously the index computation is started. The indices are computed once per day, and a corresponding message is inserted in the Events list.

The model observes both the ascospores infections (if the appropriate option was activated) and the conidia infections. The conidial infections are observed based on the rule of at least three consecutive days of at least six hours of temperatures between 21°C (70°F) and 30°C (85°F). The recommended spray intervals are shortened if these conditions remain favorable. The model does not observe the relative humidity conditions, as temperature is considered sufficient to predict secondary infections. If temperatures over 35°C (95°F) are reached, the mildew severity is reduced, leading to a lengthening in the spraying intervals (the index is decreased slightly for each day with maximums over 35°C).

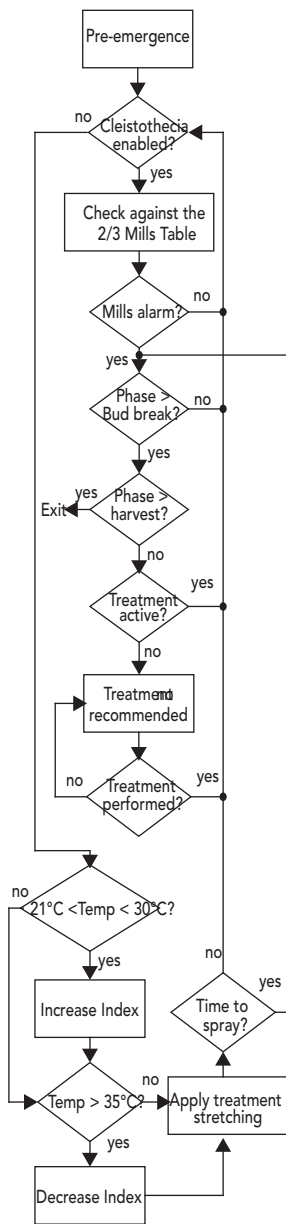
The ascospores infections are observed by using the 2/3 Mills table (used in the apple scab models). If this option is activated, the system will issue warnings for these kinds of infections too. You should determine if such warnings are important for your particular site.

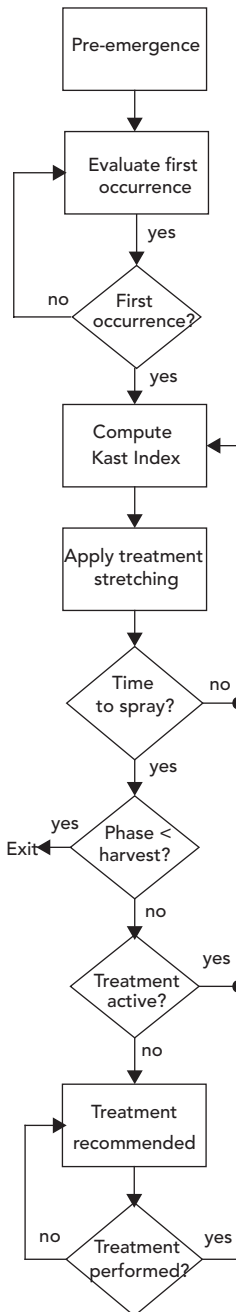
The pressure index can also be displayed and printed graphically, allowing you to observe its evolution over the whole or only part of the season.

The Kast Model

The Kast model (*OiDiag*) was developed and showed good results for the temperate continental regions in Europe. It works in two steps:

- Predicts the first occurrence of the disease





- Computes an index based on temperature, relative humidity, and leaf wetness (rain or non-rain generated) to obtain the distance between two successive sprays

The approximate first disease occurrence is computed using the minimum temperature over the winter preceding the season and the disease intensity during the previous season. These parameters must be set at the beginning of the current season (see page 41). The program issues a preventive warning after the 3 cm leaves phenological phase, but you must determine whether you need to spray at this point.

The pressure index is computed and displayed in the Events list on a daily basis. The index displayed is the average of daily indices calculated for the last seven days. Depending on this index, the coverage of an active treatment is "elongated" or "compressed," taking as normal value the coverage specified in the chemicals list (for example, the normal duration will be used if the index remains at 100 all the time).

No treatment is issued until the index displayed (that is, the average of indices) surpasses the value of 20. The pressure index can also be displayed and printed graphically, for observations on its evolution over the whole or part of the season (Figure 18).

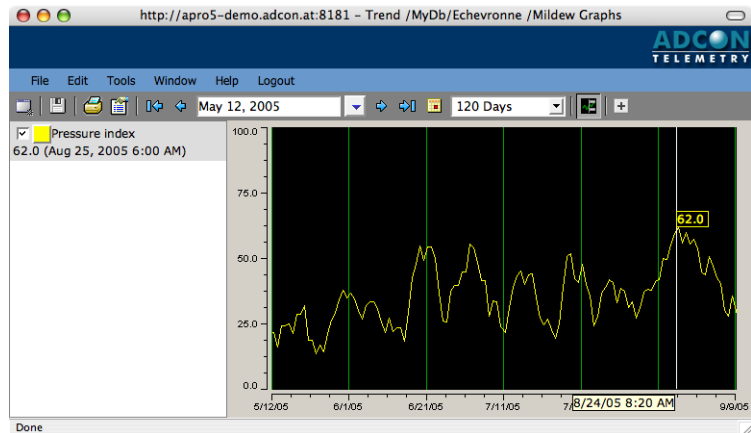


Figure 18. Trend panel showing the Grape powdery mildew index

The Bunch Rot of Grapes Extension

The bunch rot of grapes is caused by the *Botrytis cinerea* fungus. It appears in almost every vineyard.

The infections take place on the young shoots of the growing leaves, but the inflorescences, the flowers, floral peduncles, and developing berries are especially affected. Upon these organs the formed spores constitute a reserve and a source for the secondary infections.

Disease Symptoms and Development

The disease generated by the *Botrytis cinerea* fungus affects the grape production. Also, the pathogen attacks and damages the graft unions of new grafting stock.

The most damaging is the attack on the fruit. The disease develops on the rachis, berry pedicels, skin, and pulp. For the table varieties much greater damages are recorded than for wine grapes. The fungus is able to develop slowly at 1°C; therefore, table grapes stored at temperatures over 0°C are subject to degradation.

The fungus may also develop on the leaves, a phenomenon more rarely found in nature. When the attack is produced, though, they are characterized by the appearance of spots of variable size, which usually start from the edge of the lamina, extending towards the center. The possibility of the infection evolving from the center towards the edges is not excluded. Initially the spots have a yellowish, chlorotic color, afterwards tending to brick-red. In infected areas, the tissues are necrotic and die; a gray growth forms, consisting of the conidiophores and conidia of the fungus. If the conditions are favorable for the pathogen, the fungus may cover most of the leaf; finally the leaf dries up and falls off the shoot. The attack upon the leaves is important only in that it increases the conidia reserve in nature.

The bunch rot of grapes is a so-called *weak* fungus, because of its relatively reduced penetration capabilities. The penetration points of the pathogen in the different organs of the vine are:

- The lesions produced by the grape moths
- The lesions produced by the downy or powdery mildew
- The mechanical injuries produced by the different labors effected in the vineyard
- The injuries produced by hail

- Flowers

Using the System Against the Bunch Rot of Grapes

The extension implements the model developed by Broome et al. (USA). The Broome model uses a regression to compute a disease index, which serves thereafter to issue warnings. Figure 19 shows the bunch rot of grapes index in a Trend panel.

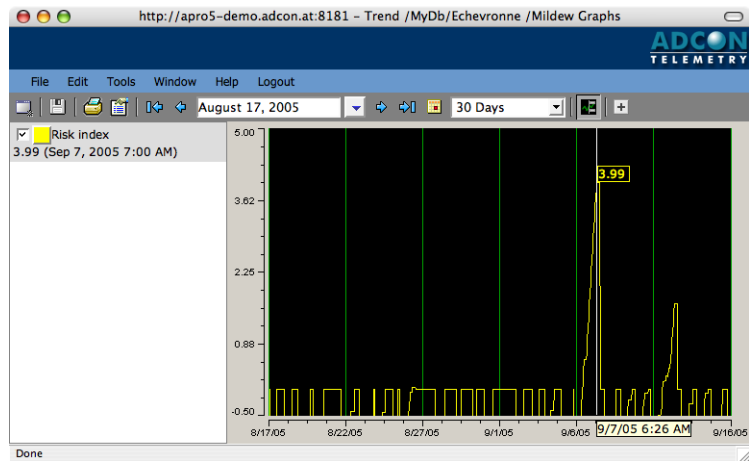
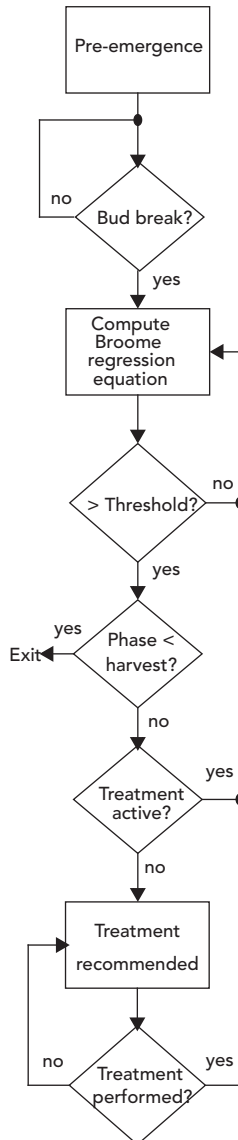


Figure 19. Trend panel showing the Bunch rot of grapes index

The model observes the relationship of the incidence of infection to leaf wetness duration and temperature by means of a multiple regression equation. It initiates the calculation of a disease index whenever leaf wetness is detected. To determine the relative risk of an infection period, the index is compared to some predefined thresholds as follows: under 0.5 – low risk, between 0.5 and 1.0 – moderate risk, and over 1.0 – high risk. Warnings are issued as soon as moderate or heavy risks are recorded. The interruption of the leaf wetness period for more than four hours stops the index calculation.

The model is set by default to trigger an alarm when the index reaches the value 0.55. You can change this value to suit your particular conditions by altering the respective option in the **Extension** tab of the extension's properties dialog box.

References (for all Grape Extensions)

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7. Gadoury D. M. und Pearson R. C., 1988 - "Initiation, Development, Dispersal and Survival of Cleistothecia of *Uncinula necator* in New York Vineyards." *The American Phytopathological Society*, 78, 11, pp.1413 - 1421.
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9. Kast W. K., 1991 - "Oidiumbekämpfung - ein Problem?" *Der deutsche Weinbau* 30, p. 1207 - 1208 und 32, pp. 1277 - 1278.
10. Kast W. K., 1994 - "Erste Erfahrungen mit dem OiDiag-System." *Der deutsche Weinbau* 11, 20 - 22.
11. Toma A., 1980 - "Fainarea vitei de vie *Uncinula necator* (Schw.) Burr." *Metodici de prognoza si avertizare a tratamentelor impotriva bolilor si daunatorilor plantelor de cultura, M.A.I.A. Redactia de propaganda si tehnica agricola*, Bucuresti.
12. Broome et al., 1994 - "Development of an infection model for Botrytis bunch rot of grape based on wetness duration and temperature." *Phytopathology* 1994.
13. Gubler et al., 1991 - "Control of Botrytis bunch rot of grape with canopy management." *Plant Disease* 71: 599 - 601.

14. Thomas C. S., Marois J. J., English J. T., 1988 - "The effects of wind speed, temperature and relative humidity on development of aerial mycelium and conidia of *Botrytis cinerea* on grape." *Phytopathology*, Vol. 78, 3, pp. 260 - 265.
15. Thomas C. S., Gubler W. D., Bettiga L., 1994 - "*Uncinula necator* ascospore release, viability and infection in field conditions in California." *Phytopathology*, 81:1182.

The Heat Units Extension

The growth and development of plants, insects, and many other invertebrate organisms is largely dependent on temperature. This has been known since the mid-seventeenth century. The French scientist René A. F. de Réaumur first studied this concept in 1735. He recognized that physiological development for many organisms was driven primarily by the accumulation of thermal energy rather than by the accumulation of time. In other words, a constant amount of thermal energy is required for the growth and development of many organisms, but the time period over which that thermal energy is accumulated can vary. It was further realized that many organisms slow or stop their growth and development when temperatures are above or below threshold levels.

By the beginning of the twentieth century the accumulation of thermal energy over time became known as *degree-days*. Degree-days and other heat unit measurements have been used for determination of planting dates, prediction of harvest dates, and selection of appropriate crop varieties. More recently, the use of heat units in pest management has increased. Models relating the phenological development of pests to heat units have been developed for many species.

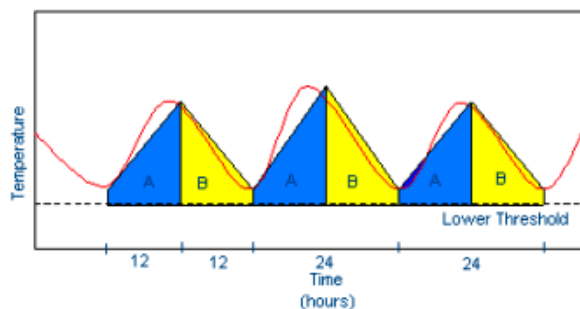


Figure 20. Graphical display of degree-days calculation

Researchers have used various methods of calculating heat units when developing phenological models. Proper use of phenological models for management decisions requires the use of calculation methods similar to those used in developing the models. This extension includes the most commonly used methods for calculating heat units. The user is able to create assessments based on information found in published models. The templates can include the method of heat unit calculation and thresholds levels for alarms. A listing of some web sites that contain

heat unit-based phenological models is included at the end of this section.

Model Operation

You can use the heat unit extension with many previously validated degree-day and heat unit models. The most commonly used methods of calculating heat units are included in this extension. In general, each model requires the user to provide the method of calculation, cutoff thresholds and base (if appropriate), the developmental thresholds at which addVANTAGE will issue warnings, and the messages associated with those warnings. Local agronomic and pest management information sources should be consulted before using any of those models. Once the heat unit model has been enabled, daily heat units calculations will be made and warnings will be issued based upon accumulated totals.

Calculation Methods

Seven basic calculation methods are provided in this extension. Five methods are used to calculate degree-days and the remaining two are used to calculate heat and chilling hours. Each degree-day calculation method estimates the area under the daily temperature curve but above the lower developmental threshold. Each method, however, is different and may yield different values from the same data set. Adcon recommends that you choose the same calculation method as the one being used to validate the model. What follows is a brief description of each calculation method.

Averaging

The Averaging method uses a daily average temperature (historically daily minimum and maximum temperatures). The average is calculated, then the lower threshold value is subtracted from the result. Daily values are accumulated to give a cumulative degree-day value.

A variety of options is available to this method, which accommodates it to many diseases and pests: Computation method, Cut-off method and settings for low and high thresholds (see also “More About Cutoff Methods” on page 54 for more details on these options).

The **Computation method** selects between using all data samples (typically every 15 minutes), or only on the averaged minimum and maximum temperatures resulting out of the samples. If you want to use

the first method select **Discrete**, otherwise **Average** in the respective combo box.

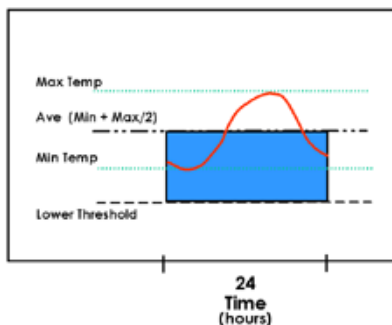


Figure 21. Averaging method set to discrete values

The Average computing method is similar to that used for many agronomic crops in the midwest of the U.S. This method calculates degree-days using the daily minimum and maximum temperatures. Maximum temperatures above the upper threshold are set as being equal to the upper threshold. Minimum temperatures below the lower threshold are set as being equal to the lower threshold. The daily minimum and maximum values are added and then divided by two. The lower threshold value is then subtracted from the result. Daily values are accumulated to give a cumulative degree-day value.

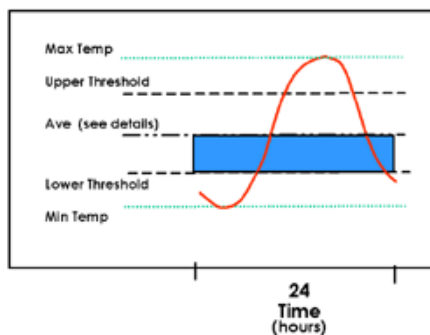


Figure 22. Averaging method set to average values.

Single Triangle

The Single Triangle method calculates degree-days using daily minimum and maximum temperatures to create triangles that estimate the shape

of the daily temperature curve over a 24-hour period. The first side of the triangle consists of a line drawn from a day's minimum temperature to that day's maximum temperature. The second side is drawn using the same minimum temperature as the first side. The area under the triangle and above the lower threshold is used as an estimation of the degree-day value for a 24-hour period. An upper threshold setting is available when a cutoff method is selected. When a cutoff method is selected, the area in the triangle that is used to estimate the degree-day value is reduced according to the rules of the cutoff method.

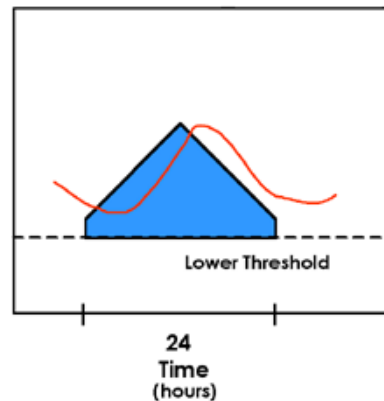


Figure 23. The single triangle method operation

Double Triangle

The Double Triangle method estimates the area under a daily temperature curve by drawing triangles over two 12-hour periods using minimum and maximum temperatures. The first side of the first triangle is drawn between the daily minimum and maximum. The second side is drawn as a vertical line through the maximum temperature. A second triangle is drawn for the second 12-hour period using the same guidelines but using the daily maximum temperature and minimum temperature from the next day. Degree-days are calculated as the sum of the areas under both curves and between any thresholds. An upper threshold setting is available when a cutoff method is selected. When a cutoff method is selected, the areas in the triangles that are used to estimate the heat-unit values are reduced according to the rules of the cutoff method.

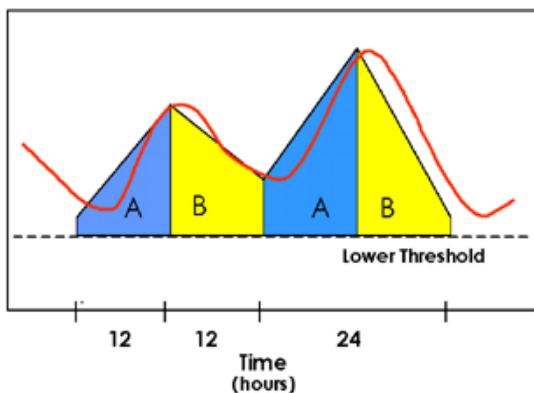


Figure 24. The double triangle method of operation

Single Sine

The Single Sine method estimates the area under a daily temperature curve by drawing a sine curve over a 24-hour period through the daily minimum and maximum temperatures. Degree-day values are estimated as the area within the sine curve that is above the lower threshold. When a cutoff method is selected, the area used for determining degree-day values is reduced according to the rules of the cutoff method. According to UC IPM, the single sine method with a horizontal cutoff has been the most commonly used method of determining degree-day values in California for many years.

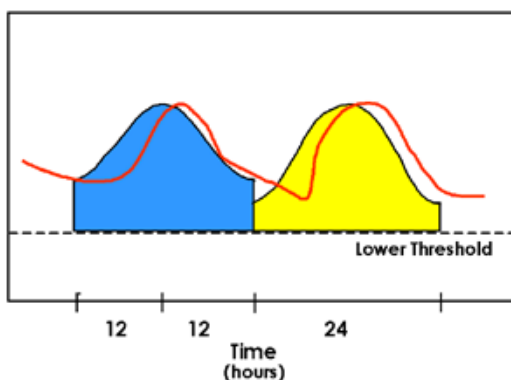


Figure 25. Single sine method of operation

Double Sine

The Double Sine method estimates the area under a daily temperature curve by drawing sine curves over two 12-hour periods. The first curve is drawn using the daily minimum temperature with the first half of the sine curve to represent the first 12 hours. The second curve is drawn from the daily maximum temperature and the minimum temperature of the following day and using the second half of this curve to represent the second 12 hours. An upper threshold setting is available when a cutoff method is selected. When a cutoff method is selected, the area under the curves that is used to estimate the degree-day value is reduced according to the rules of the cutoff method. Degree-days are calculated as the sum of the areas under both curves and between any thresholds.

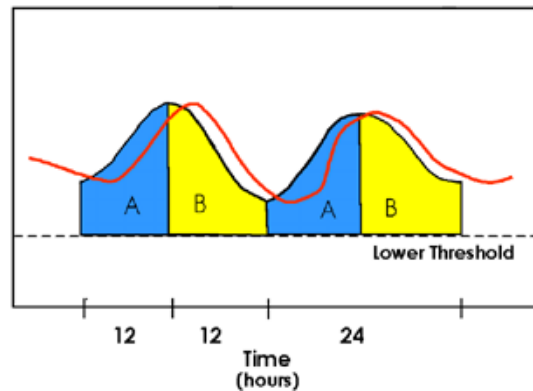


Figure 26. Double sine method of operation

Chill/Heat Hours

The Chill/Heat hours method reports the number of hours with temperatures above or below a user-entered low/high threshold temperature. No cutoff methods are associated with the Chill/Heat method.

For example chilling hour values are used to predict several management factors. Deciduous fruit tree growers are the primary users of chilling hours. Decisions such as varietal selection, pruning, and other management factors related to potential yields can be aided by chilling hour calculations. Chilling hour calculations are based on average hourly temperatures calculated from 15-minute measurements (0, 15, 30, and 45 minute time slots). A user-entered low temperature threshold is used as the point below which chilling hours are accumulated. An

upper threshold serves as a point above which chilling hours are subtracted from the cumulative total. For each hour above the upper threshold, 0.5 hours are subtracted from the cumulative total. An optional base temperature threshold is also available. Temperatures below the base threshold are not added to the cumulative chilling hours.

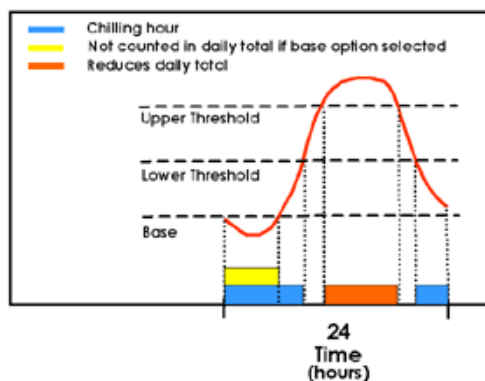


Figure 27. Chilling hours method of operation

Note: The minimum daily chilling hour value is 0; temperatures exceeding the upper threshold are not allowed to cause a negative daily chilling hour value.

Chilling Units, Utah Method

This computation method is similar to the standard Chilling hours method above except that it introduces the concept of relative chilling effectiveness and negative chilling accumulation (or chilling negation). It basically gives different weights to different segments of the temperature spectrum. For additional details on this computation method, you can check the following link:
<http://aggie-horticulture.tamu.edu/stonefruit/chillacc.htm>.

More About Cutoff Methods

The cutoff method is also a key component of a phenological model. It modifies the daily degree-day calculation to more accurately reflect an organism's growth response to high temperatures. Three cutoff methods are included in this extension. They are the Horizontal, Intermediate, and Vertical cutoff methods.

Horizontal Cutoff

The Horizontal cutoff method treats phenological development as continuing at a constant rate above the upper threshold. The area calculated above the upper threshold is subtracted from the area above the lower threshold when this method is used.

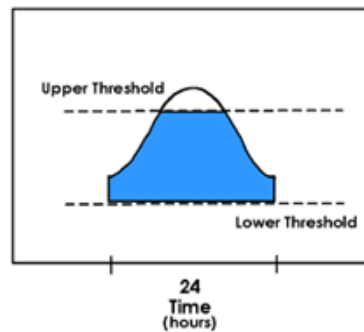


Figure 28. Graphical representation of the Horizontal cutoff

Intermediate Cutoff

The Intermediate cutoff method is used in cases where development slows above the upper threshold. In this case, the area calculated above the upper threshold is subtracted twice from the area above the lower threshold.

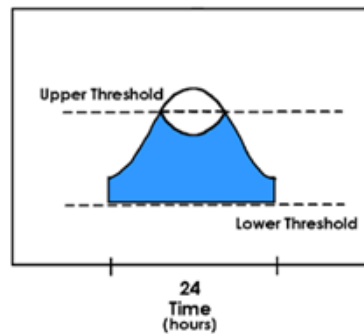


Figure 29. Graphical representation of the Intermediate cutoff

Vertical Cutoff

The Vertical cutoff method is used in cases where no development above the upper threshold exists. Temperatures in the area above the upper threshold are not used in this case.

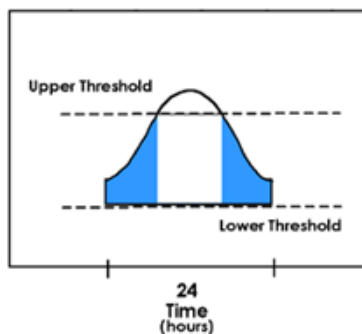


Figure 30. Graphical representation of the Vertical cutoff

Sensor Placement

The heat unit extension uses the temperature sensor for calculations. Different placements of the temperature sensor can yield different measurements based upon temperature gradients, reflective surfaces, wind, etc. Refer to the details of the desired phenology model for the best placement of the sensor. If no information on sensor placement is available in the published model, contact your local pest management advisor/agency for suggestions on the best sensor placement relative to the use of the model in your area.

Configuring Extension Options

The configuration must be done for each area for which the extension is to be used:

1. Add the Heat units extension to the desired area (see also "Adding Extensions to an Area" on page 9).
2. Select the extension's properties, click the **Extension** tab (Figure 31) and select the model you decided to run.
3. Set first the **Start Date** of the extension (you can change this and all other parameters at any time—the extension will recalculate the data).

- Select the appropriate **Degree Days Method** (in our example “Double Triangle”) and enable it using the **Status** combo box.

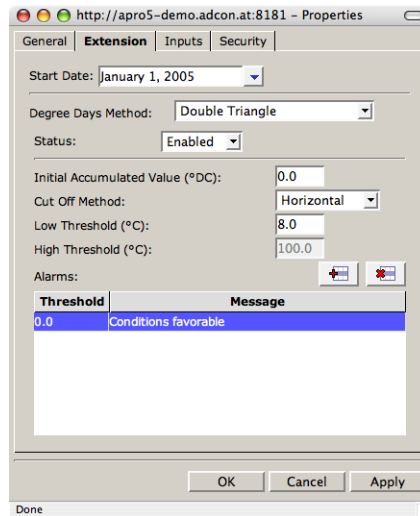


Figure 31. Heat units extension's configuration dialog box

- Depending on the selected method, you might need to set the appropriate options, for example, the **Cut Off Method** or the **Low/High Thresholds**.

Note: If you are uncertain of the appropriate high threshold value to enter, you can enter an extremely high value (example: 140° F or 60° C) to allow for proper functioning of the calculation method without limiting the accumulation of heat units at high temperatures.

- To have the extension generate an alarm in the Events panels, add an alarm by clicking the + icon. Enter the threshold value and the alarm message the extension should issue when the threshold is reached.

Note: Alarms are generated when the threshold value is passed (that is, if a threshold is set at 400, a message will not be generated at 400; it will be generated when the cumulative heat unit value is greater than 400).

- After setting all parameters, click the **Apply** button. You can set another computation for another method repeating the steps 4 to 7, or finish configuring this extension by clicking **OK**.

Daily Operation

Degree-days and other heat units are typically calculated on a daily basis. The daily calculation period for heat units in this extension is considered to be the 12:00 AM through 11:59 PM time slots. As an example, the heat units for day one are calculated at 12:00 AM on day two. The warning messages for thresholds/message combinations entered by the user are posted at the time of calculation. Therefore, a warning message for a threshold that is exceeded on day one will be posted at 12:00 AM on day two. Further, if you are using the Double Sine or Double Triangle methods, the warning messages are not posted until 12:00 AM of day three because the double calculation methods require the minimum temperature from day two.

Use the following steps for daily operation:

- Check the raw data to make sure all the data has been downloaded for each area by opening an appropriately configured Trend panel.
- Check the Events list for each area every day after 12:00 AM. Make sure to thoroughly check and identify any warnings for any area.
- Double-click any alarms to acknowledge that they have been read.

Sources of Phenology Models

The following list is a sample of heat-unit-based phenology models that were available on the Internet at the time this user's guide was written. The content of each web site is subject to change. This list, however, can serve as a starting point in searches for phenology models.

The models contained in the web sites listed here vary in their applicability to crop and pest management and to specific geographic areas. These model lists are presented only as examples of the information available on the Internet. Adcon Telemetry has not validated these models and therefore no recommendation for their use is implied. Locally validate a model before using it to make crop and pest management decisions.

Iowa State University (<http://www.ipm.iastate.edu/ipm/icm/1998/4-6-1998/dd.htm>)

Black cutworm

Alfalfa weevils

Stalk borer moths

Ohio State University (<http://ohioline.ag.ohio-state.edu/hyg-fact/2000/2502.htm>)

Billbugs in turfgrass

Michigan State University

(Models contained in individual pest fact sheets under sections titled "Monitoring")

Codling moth

Oriental fruit moth

Apple maggot

Obliquebanded leafroller

Grounds Maintenance Magazine (<http://www.grounds-mag.com/usedeg.htm>)

Smooth crab grass
emergence

University of Kentucky (<http://www.uky.edu/Agriculture/Entomology/entfacts/fldcrops/ef106.htm>)

European corn borer

University of California (<http://www.ipm.ucdavis.edu/MODELS/index.html>)**Beneficial Insects & Mites***Anagrus epos**Aphytis melinus**Bathyplectis curculionis*

Convergent lady beetle

*Encarsia formosa**Metaseiulus occidentalis*

Sevenspotted lady beetle

Transverse lady beetle

Twospotted lady beetle

*Voria ruralis***Insect & mite pests**

Alfalfa weevil

Apple maggot

Armyworm

Artichoke plume moth

Asparagus beetle

Beet armyworm

Beet leafhopper

Black cutworm

Blackberry leafhopper

Blue alfalfa aphid

Cabbage aphid

Cabbage butterfly

Cabbage looper

Cabbage maggot

California red scale

Calocoris norvegicus

Carrot weevil

Celery looper

Cereal leaf beetle

Citricola scale

Citrus thrips

Nematodes

Columbia root-knot nematode

Stubby root nematode

Weeds

Black nightshade

Bluegrass

Johnsongrass

Smooth crabgrass

Wild oats

Yellow nutsedge

Elm leaf beetle

English grain aphid

European elm scale

European red mite

Fruittree leafroller

Fullers' rose beetle

Green peach aphid

Greenhouse whitefly

Gypsy moth

Hop vine borer

Imported cabbageworm

Indian meal moth

Lilac borer

Lygus bug

Meadow spittlebug

Mediterranean fruit fly

Melon fly

Mexican bean beetle

Nantucket pine tip moth

Navel orangeworm

Northern corn rootworm

Obscure scale

Crops

Alfalfa harvest

Citrus flower model

Common bean

Grapevine

Pistachios-shell hardening

Rose--flowering shoots

Sweet corn

Tepary bean

Peachtree borer

Pear psylla

Pear rust mite

Pink bollworm

Plum fruit moth

Potato leafhopper

Potato tuberworm

Russian wheat aphid

San Jose scale

Seedcorn maggot

Serpentine fruit fly

Sod web worm

Spodoptera litura

Spotted tentiform leafminer

Spruce budworm

Squash bug

Strawberry spider mite

Sunflower beetle

Sunflower moth

Sunflower stem weevil

Sweet potato whitefly

Tobacco budworm

Citrus red mite	Olive scale	Tomato fruitworm
Codling moth	Omnivorous leafroller	Tomato pinworm
Corn earworm	Onion maggot	Twospotted spider mite
Corn leaf aphid	Onion thrips	Variigated cutworm
Cotton aphid	Orange tortrix	Vegetable leafminer
Cotton bollworm	Oriental fruit fly	Western cherry fruit fly
Crucifer flea beetle	Oriental fruit moth	Western grape leafhopper
Cuban laurel thrips	Pacific spider mite	Western grapeleaf skeletonizer
Diamondback moth	Pea aphid	Western pine shoot borer
Egyptian alfalfa weevil	Peach twig borer	

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1. Anderson, J. 1998. Use of Growing Degree Days. Michigan State University Extension, Fruit CAT Alerts 1993-97 – 42093012.
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The Lettuce Downy Mildew Extension

Western Farm Service, in cooperation with the California Lettuce Research Board, developed the lettuce downy mildew extension. The model has been validated in the Central California coastal region and in the Yuma, Arizona area. Environmental and crop management factors affecting disease development have been included in the model. Key among these factors is the role of irrigation in the disease cycle. Users are able to enter the type of irrigation used—sprinkler, furrow, drip, buried drip. The model accounts for the differing effects of these irrigation methods on pathogen and disease development. There is also an option to use soil moisture sensors for detecting irrigation and rain events.

CAUTION The lettuce downy mildew model has been tested only for conditions present in California, USA. Use the model with caution in other areas.

Disease Symptoms and Development

The disease (*Bremia lactucae*) normally appears first on older leaves. Light green to yellow spots appear on the upper surfaces of leaves, while white downy fungal growth appears on the lower surfaces. The lesions are interveinal, giving them an angular appearance as they grow. Affected portions of the leaves turn brown and eventually die. Leaves with numerous lesions may die. Occasionally, the infection may become systemic, resulting in darkening of stem tissue.

Bremia lactucae does not seem to survive in the soil. Disease onset appears to begin following the wetting of soils and/or extended periods of leaf wetness starting at **ten days prethin**. Cultivated lettuce, the main host of the fungus, is the likely source of new infestations. Wild lettuces can, however, also serve as hosts. The disease can be introduced from transplants. Cool damp conditions are conducive to the spread of the disease. Fungal spores are spread by wind. Leaf wetness is required for fungal germination and infection of leaves. Moisture is not required for development of the disease once a plant is infected. Drying winds and hot conditions can slow the development and spread of downy mildew.

Model Operation

The model begins calculating downy mildew disease index points when the phenological phase **ten days prethin** is reached. The software automatically moves the phenological phase to **thinned** once ten days

have passed. Index points start to accumulate when irrigations occur or when more than 0.05 inches of precipitation is detected. The number of points accumulated is based on the crop phenological phase and the type of irrigation. Index points can also be accumulated when leaf wetness is detected during morning hours without concurrent irrigation or precipitation. Nighttime winds over 3 mph and/or high daytime temperatures (greater than 80°F) result in disease index points being subtracted.

Field Setup

This model has been validated using stations placed both within and outside the crop. Placing the station within the crop appears to increase the accuracy of the model somewhat, but this difference has not been critical. If the station is located outside the crop, place it as close as possible to the field and in conditions as similar as possible to those in the field. Place the combined sensor temperature/RH no more than one-foot (1') from the ground. Place the wind speed and direction sensors approximately eight to nine feet (8 - 9') above the seedbed. If you use soil moisture sensors, place them in the seedline at a depth that will permit them to detect soil moisture increases from irrigations. Field studies have been conducted successfully with two Watermark sensors placed horizontally at a depth of two inches (2") and with the third sensor placed vertically with the base of the sensor at six inches (6").

Setup and Operation

Follow these steps to configure each area where you plan to use the extension:

1. Add the Lettuce downy mildew extension to the desired area (see also "Adding Extensions to an Area" on page 9).
2. Select the extension's properties, click the **Extension** tab, select the irrigation system used in the lettuce field and click **Apply**.
3. Click the **Crop** tab and set the correct dates for the plant's phenology. Click the **Apply** button again.
4. Click the **Inputs** tab and make sure all of the extension's inputs are connected to a valid sensor.
5. Click the **General** tab and make sure the extension is enabled, then click **OK**.

The extension will generate an output tag called *Accumulated index* that can be viewed in a Trend panel; in addition, the index will be followed as a daily event.

Daily Operation

Following are things you need to do every day:

- Check the raw data to make sure all the data has been downloaded for each RTU.
- Check the Events list for each station. Make sure to thoroughly check and identify any warnings in the controlled areas.
- If an alarm is displayed, enter a chemical treatment, treatment date, and details.
- Enter all treatments into addVANTAGE within the control duration of the treatment.

If you enter irrigation information manually, be sure you enter irrigations the day they occur so as to reflect the proper point values in the mildew index. Use the extension's Properties dialog box, the **Irrigation** tab, to enter the irrigations.

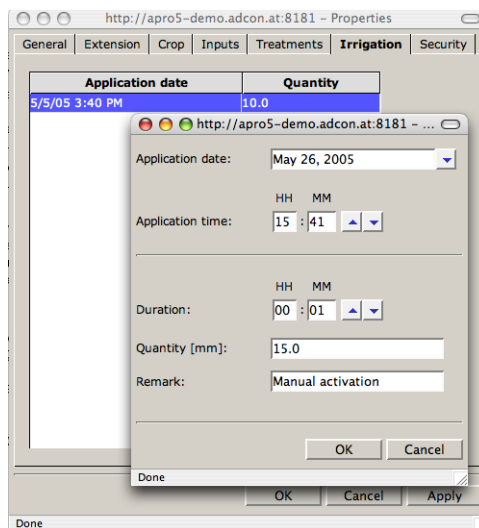


Figure 32. Manually enter an irrigation schedule

Note: You can enter irrigation information into the extension throughout the season. It is critical for proper functioning of the model,

however, that user defined irrigations be entered into the extension with proper application dates, times, and methods before they actually occur. If this is not done, the correlation between the disease index and conditions in the field will be compromised.

References

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2. Scherm, H. and van Bruggen, A.H.C. 1994a. Effects of fluctuating temperatures on the latent period of lettuce downy mildew (*Bremia lactucae*). *Phytopathology* 84: 853-859.
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6. Scherm, H. and van Bruggen, A.H.C. 1995b. Comparative study of microclimate and downy mildew (*Bremia lactucae*) development in subsurface drip and furrow-irrigated lettuce fields in California. *Plant Disease* 79.
7. Iceberg Lettuce Advisory Board Annual Reports 1991-1996.

The Potato Blight Extension

The disease *Phytophthora infestans* (Mont.) deBary originated in South America; its penetration into North America and in Europe apparently took place approximately in the same period, namely, the first half of the 19th century.

Disease Symptoms and Development

The potato blight affects the leaves, shoots, stems, and plant tubers. Nevertheless, two aspects are evident:

- The attack on the aerial parts may cause, in the favorable years and in the absence of an efficient protection, the premature drying up of the foliage, shoots, and stems, causing a drastic reduction of the crop.
- The attack on the tubers leads to losses and difficulties during storage as well as to the supply of the primary infections for the following year.

The disease symptoms are much more obvious and easy to recognize on the leaves. The fungus, by developing its mycelium, destroys the tissues completely. Consequently, the initial spots turn brown and the areas in which the tissues have been destroyed eventually die.

The infections on the shoots and stems develop similarly to the leaf infections. They appear as yellow spots that eventually turn brown.

In the initial phase of the attack, the contaminated tubers are similar in appearance to the healthy ones. Later, though, as the disease advances, the surface of the tubers develops brown or grayish-brown spots of various sizes with slight depressions.

The infection of the tubers takes place in the field, but the healthy potatoes can also be contaminated by the infected potatoes during storage. Storage at a temperature over 4°C and humidity of over 70% favors the development of the blight as well as contamination of various bacteria of the infected potatoes.

Using the System Against the Potato Blight

The performance of the model is conditioned by the data you supply. At the season's start, check all options and parameters. During the season, be sure to update the treatments executed in the field (including those not requested by the system).

After installing the potato extension on all the applicable areas, you have to configure the initial parameters. Depending on the starting date, you have to check the phenological phases.

Note: Place the temperature/RH/leaf wetness sensor at the standard 2 m height in the potato fields.

Following is some general information on the development of potato late blight:

- The disease develops over a considerable temperature range: 6°C to 30°C.
- The fungus needs high relative humidity or leaf wetness to generate infections.
- The incubation period is relatively short, so the disease can reach epidemic proportions in a short time.
- The most important cause of propagation of the fungus from one season to the next is by infected tubers. Eliminate as many of the attacked tubers as possible before planting.

The extension implements two models: the first is based on the Ullrich-Schrödter negative forecast model, with the additions brought by Hansen, and the second is a model developed and validated by Winstel. Both models have their merits and you should use the one that has given best results under your conditions. Alternatively, you can run both models in parallel (e.g. by creating a second area and using the same input tags).

Follow these steps to set up a Potato blight extension on an area:

1. Add the Potato blight extension to the desired area (see also "Adding Extensions to an Area" on page 9).
2. Select the extension's properties and click the **Extension** tab.
3. Choose between Ullrich-Schrödter and Winstel models. For the Ullrich-Schrödter model, set cultivar sensitivity and the irrigation method (if available) and adjust the default thresholds if not appropriate for your site (Figure 33). Click the **Apply** button when you are done.

Note: The cultivar sensitivity and irrigation method are required inputs only for the Ullrich-Schrödter model.

4. Click the **Crop** tab and adjust the dates of the phenological phases, then click **Apply**.

- Click the **Inputs** tab and make sure all input tags are correctly assigned to the extension inputs. If you made any changes, click the **Apply** button.

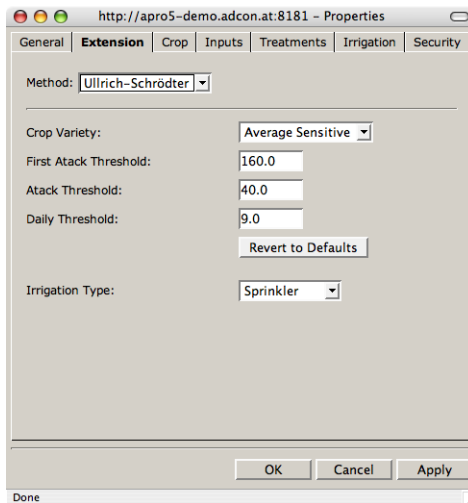
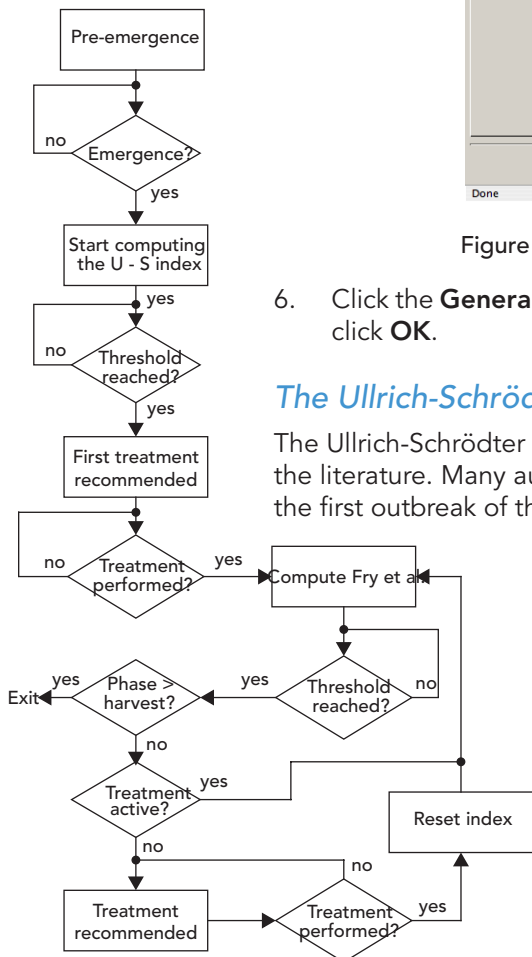


Figure 33. Potato blight settings dialog box

- Click the **General** tab and make sure the extension is enabled, then click **OK**.



The Ullrich-Schrödter Model

The Ullrich-Schrödter method is relatively well known and described in the literature. Many authors report good results in using it to anticipate the first outbreak of the disease (Winstel 1992, Schiessendoppler 1992, Faber 1993, Lücke 1993). An extension to the original model was proposed by Hansen, who tested a combination of the Ullrich-Schrödter model to predict the first outbreak and the Fry et al. model (1983) for the rest of the vegetation period. Basically, the Fry method computes the daily indices using the same table from Ullrich-Schrödter (1957) to assess the short- and long-term evolution of the disease pressure.

The model starts after activating the phenological phase **Emergence**, when it starts to compute the daily index using the Ullrich-Schrödter table. By using this index, the model

assesses the period of time when no infection of economic importance can occur (hence the *negative forecast* term used in conjunction with this model).

After enabling the model, the event *Potato blight – Ullrich-Schrödter index x*, where x is the actual index, is generated daily in the Events list. The index is the result of an elaborate equation based on the relative humidity and temperature. The values are totaled to give the index since emergence. Ullrich and Schrödter stated that significant losses can't occur before the index's sum reaches the value 160.

The model was used with success in many places; however, some users have adapted this limit to the local conditions. The default value in the current implementation is 160, but you can change it by altering in the extension's Properties dialog box as described above.

After the critical value is reached, a warning is issued the very first day when a rise of at least 8 units/day is recorded. If a treatment is applied, the index is reset to zero and the system issues warnings based on the Fry at al. method. The same index using the Ullrich-Schrödter table is computed, giving a daily index. This index is compared against the default limit values, depending on the sensitivity of the cultivar. If the limits are exceeded and the daily index has a value of at least 8, a new warning is issued. If a treatment is applied, the index is again reset and the cycle starts over. You can also change these limits via the extension's Properties dialog box.

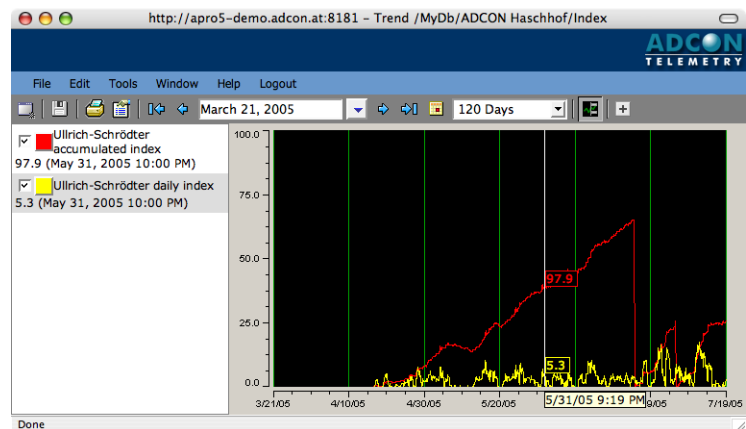


Figure 34. Potato blight indices in a Trend panel (Ullrich-Schrödter)

You can display and print the Ullrich-Schrödter index graphically in a Trend panel (Figure 34), for observations on its evolution over the whole or part of the season.

If the user must enter irrigation information manually, this parameter must be entered the day of the irrigation to reflect the proper point values in the Ullrich-Schrödter index. This is done via the extension's Properties dialog box, the **Irrigation** tab. Depending on the irrigation type, the model might interpret it with its equivalent in natural precipitation and consequently issue a washoff warning. Only the irrigation type **Sprinkler** has such an effect.

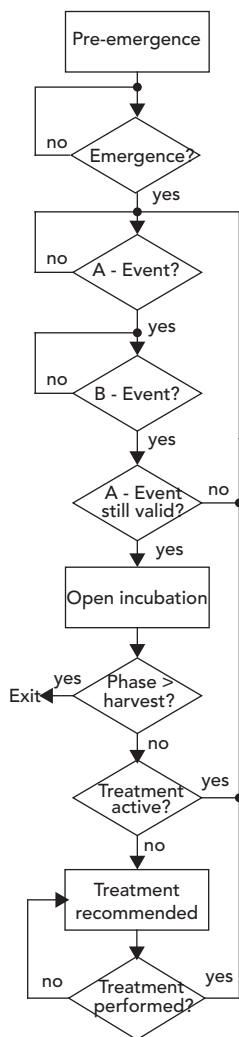
The Winstel Model

Although in general the negative forecast had shown good results, there were some cases where the disease outbreak occurred earlier than this method predicted. Therefore, Winstel (1992) developed an alternative model, based on long-term observations over several seasons, analyzing the correlation between temperature, humidity, leaf wetness, and the first disease manifestation. The current model implementation follows the basic rules to identify the Winstel events (called by the author event A and event B). Moreover, it brings an extension to the model in that it applies the same rules not only to identify the first critical phase of the season, but also to issue warnings throughout the whole growing season.

The model starts after the emergence phase is activated, and it tries to detect the Winstel event A, which is defined as at least 10 hours with temperatures over 10°C and relative humidity over 90%, or leaf wetness. If such an event is detected, the next step is to detect the Winstel event B, defined as at least two successive days with maximum recorded temperatures between 23°C and 30°C. The B event must happen at least 24 hours from the A event, but not later than 10 days after an A event.

The model permanently searches for events of the A type, but the B type is cared for only if there is at least one active A event. After the successful detection of a A event – B event sequence, the model issues a treatment warning.

Thereafter, an incubation is activated and calculated using the standard Ullrich incubation table. The incubation has only an informative value because it generates no change in the algorithm's functionality. If a treatment is applied, the model enters into the controlled phase, but still looks for A and B events. The A events are displayed always, even during the controlled state, for information. In any case, the presence of



such an event, outside the controlled period, signals that an infection could occur in the next several days if the climatic conditions are appropriate.

Note: Do not let a warning go uncared for because the model virtually stops (no more warnings will be issued). You either have to treat or use the "Ignore warning" facility.

References

1. Fry et al., 1983 - "Evaluation of Potato Late Blight Forecasts Modified to Incorporate Host Resistance and Fungicide Weathering." *Phytopathology* 73; 1054-1059.
2. Hansen J. G., 1993 - "The use of meteorological data for potato late blight forecasting in Denmark." Workshop on computer-based DSS on Crop protection; Parma; Italy; In SP report; no. 7; 183 - 192.
3. Lücke W., 1993 - "Die Phyteb-Prognose - Erfahrungen aus Mecklenburg Vorpommern." *Der Kartoffelbau* 44;6; 252 - 254.
4. Minogue K. P. and Fry W. E., 1981 - "Effect of temperature, relative humidity and rehydration rate on germination of dried sporangia of *Phytophthora infestans*." *Phytopathology* 71; 1181 - 1184.
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The Downy Mildew of Hop Extension

The downy mildew of hop is an infectious disease that has the fungus *Pseudoperonospora humuli* (Miy et Tak.) Wilson as the pathogen agent.

The disease is widespread in all the countries in which hops are cultivated. The fungus was observed for the first time in 1905 in Japan, by Miyabe and Takahorhi, and it was later recorded in the USA (Davis, 1908). In Europe the presence of the pathogen was noticed in 1920 (in England).

Disease Symptoms and Development

The first symptoms of the attack are recorded during spring even from the beginning of growth of the hop plants—infected shoots spring out from the stems infected during the autumn. Characteristic are:

- The appearance of the “cereal spike” shaped shoots
- The shortening of the internodes of the canes
- The discoloration of the shoots to grayish-green
- The limiting of the growth of the leaves, their twisting and crowding in bunches at the top end of the cane (hence the name of “cereal spike” shaped)

The following symptoms are a consequence of the aggravation as a result of the succession or even superposition of the infections:

- The growth in length of the infected shoots is limited.
- The attacked shoots turn brown and eventually die.
- The affected canes develop inflorescences slowly and infrequently; such inflorescences have browned bracts and finally dry out.
- The attacked shoots develop few to no cones. The cones that do appear turn brown, dry out, and fall off.
- The attacked cones, even if they do not dry out, lose weight, reduce their contents in alpha acid, which causes a bitter taste of the beer and damages its preservability.
- The stem thickens, hindering and even shortening its ramification.

The infections on the leaf, which during full vegetation of the hop plant primarily ensure the biological reserve of the pathogen, have the following characteristics:

- Certain irregular, angular spots appear in the vein area.

- The hop plant attacked by *Pseudoperonospora humuli* presents spots that have on the underside a violet downy mass and on the upper side a green-yellowish color.
- The tissues in the contaminated area are destroyed and, as a consequence, both sides of the leaf turn brown. Later, in the respective area, the leaves become crumbly and dry up in the end.

The literature mentions (Smith et al. 1988) that the losses due to the downy mildew alone in Germany surpassed 30 million German Marks in 1926. In the USA the damages produced by the fungus led to a change in the strategy of hop growing by moving it from areas with heavy rainfalls to states with a more arid climate like Washington and Idaho.

Using the System Against the Downy Mildew of Hop

The current model implementation is based on a multiple regression analysis equation derived experimentally and published by Royle and Kremheller (1975, 1979). Alternatively, the use of spore traps, where available, may improve the quality of the warnings.

The model observes the leaf wetness caused by rain and the daytime temperature. Dew has no effect on the model. According to Royle and Kremheller (1981), dew is thought to be inefficient for three reasons:

- Dew starts to form in the dark when zoospores do not respond to stomata.
- Inoculum that is splash-dispersed by rain dries after daily release.
- Longevity of dry-deposited inoculum is reduced during the interval between release and wetting by dew, especially in the dry weather commonly associated with dewy nights.

Setup and Operation

Follow these steps to set up the Hop downy mildew extension on an area:

1. Add the Hop downy mildew extension to the desired area (see also "Adding Extensions to an Area" on page 9).
2. Click the **Crop** tab and adjust the dates of the phenological phases, then click **Apply**.
3. Click the **Inputs** tab and make sure all input tags are correctly assigned to the extension inputs. If you made any changes, click the **Apply** button.

4. Click the **General** tab and make sure the extension is enabled, then click **OK**.

The model starts computing an index each day, searching for rain-generated leaf wetness, as soon as the phenological phase **First pair of leaves unfolded** is reached. The index is recorded in the events list every day. As soon as the preset threshold is reached, and if during the last 24 hours the temperature average was over 8°C and no maxima over 29°C were recorded, a treatment warning is issued.

The index may take values between -0.2 and 1.0, where negative values mean virtually no risk while 1 represents an extremely high infection potential. The preset level for issuing a warning is 0.2, but it can be altered in the extension's **Properties** panel (see Figure 35).

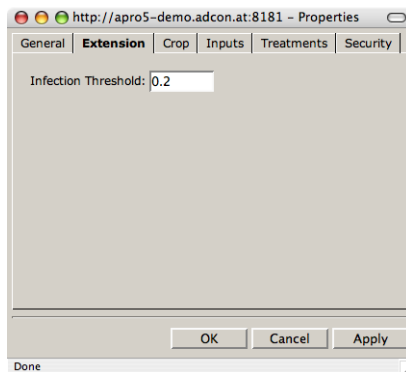


Figure 35. Changing the default infection threshold

If a warning is recorded, a treatment should be performed as soon as possible. When assessing the necessity of a treatment, as previously mentioned, spore traps may be very helpful in evaluating the existing airborne reserve.

You can display and print the index graphically as a trend (see Figure 36), for observations on its evolution over the whole or part of the season.

Note: Install the combination sensor at the standard 2 m height, into the canopy. Pay special attention to the rain gauge, which must remain free of leaves. An atypical solution is to mount an additional 1.5 m aluminum rod when installing the station's mast.

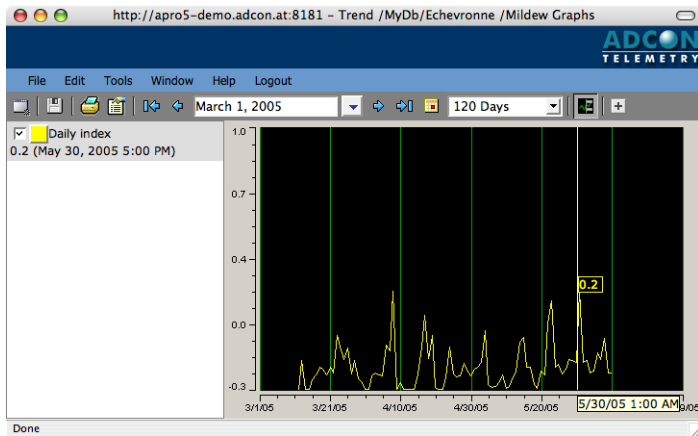


Figure 36. Hop mildew index displayed in a Trend panel

During the season, check the software daily. If a treatment recommendation is issued, assess its necessity. Having spore traps installed in the field can make your decision easier. Do not leave a warning uncared for because the model virtually stops (no more warnings will be issued). You must either treat or use the **Ignore warning** facility (see also “Treatments” on page 14).

References

1. Arens K., 1929 - “Untersuchungen über *Pseudoperonospora humuli* (Miy et Tak.) den Erreger der neuen Hopfenkrankheit.” *Phytopath. Z.*, 1, pp. 169-193.
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4. Royle D.J., 1973 - “Quantitative relationship between infection by the hop downy mildew pathogen, *Pseudoperonospora humuli*, and weather and inoculum factors.” *Annals of Applied Biology*, 73, 1, pp. 19 – 30.
5. Royle D.J. & Thomas G.E., 1972 - “Analysis of relationships between weather factors and concentrations of airborne sporangia

of *Pseudoperonospora humuli*." Transactions of British Mycological Society, 58, Part 1, pp. 79 – 89.

The Tomato Late Blight Extension

The tomato late blight model is based on the Winstel method used for predicting potato late blight. It is an event model that issues treatment warnings based upon a combination of temperature and relative humidity events. The model predicts recurring incidents of the disease throughout the growing season.

CAUTION The tomato late blight model has been tested only for conditions present in California, USA. Use the model with caution in other areas.

Disease Symptoms and Development

Tomato late blight affects leaves, shoots, stems, and fruit. Symptoms on leaves initially appear as irregular water-soaked patches. Those areas enlarge and become brown and papery. A ring of grayish-white mildew may appear on the lower leaf surface under these spots. Entire leaves may die. Infections on shoots have a similar development to those on leaves. Infections on fruit appear as large, irregularly shaped, greenish-brown lesions. Fruit lesions remain firm and have an oily appearance. Secondary infections on fruit, particularly rots, may affect the appearance of the fruit.

Tomato late blight can develop over a wide temperature range, i.e. 6°C to 30°C (43°F to 86°F). Leaf wetness or high humidity is required for infection. The disease has a short incubation time, which allows epidemics to develop rapidly.

Setup and Operation

The model has been used to predict tomato late blight with good results by researchers and growers.

Follow these steps to set up the Tomato late blight extension on an area:

1. Add the Tomato late blight extension to the desired area (see also "Adding Extensions to an Area" on page 9).
2. Click the **Crop** tab and adjust the dates of the phenological phases, then click **Apply**.
3. Click the **Inputs** tab and make sure all input tags are correctly assigned to the extension inputs. If you made any changes, click the **Apply** button.

- Click the **General** tab and make sure the extension is enabled, then click **OK**.

The model operation is based on the correlation between temperature, leaf humidity, leaf wetness, and the first incidence of the disease. The model begins its computation after the emergence stage is reached. It then accumulates data to detect *Sporulation Conditions*, which are defined as at least ten hours with temperatures over 10°C (50°F) and relative humidity over 90%, or leaf wetness.

Next, the model looks for *Infection Conditions*, which occur when at least two successive days with maximum temperatures of 23°C to 30°C (73°F to 86°F). These conditions must be met within a window of 24 hours to ten days after the *Sporulation Conditions* event. Once both event conditions are met, the model issues a treatment recommendation (Figure 37). The same rules are used to issue warnings throughout the season.

#	Begin Date	Duration	Area	Source	Comments
<input type="checkbox"/>	7/1/05 4:00 AM	5h 38m	ADCON Haschhof	Tomato Late Blight	Sporulation conditions
<input type="checkbox"/>	6/30/05 6:00 AM		ADCON Haschhof	Tomato Late Blight	Incubation 2 - 25% done
<input type="checkbox"/>	6/29/05 7:00 AM		ADCON Haschhof	Tomato Late Blight	Infection Conditions
<input type="checkbox"/>	6/29/05 7:00 AM	5d 23h	ADCON Haschhof	Tomato Late Blight	Incubation 2
<input type="checkbox"/>	6/27/05 7:00 AM	54m	ADCON Haschhof	Tomato Late Blight	Sporulation conditions
<input type="checkbox"/>	6/5/05 3:00 AM	4h 43m	ADCON Haschhof	Tomato Late Blight	Sporulation conditions
<input type="checkbox"/>	6/1/05 6:00 AM		ADCON Haschhof	Tomato Late Blight	Incubation 1 - 100% done
<input type="checkbox"/>	5/31/05 6:00 AM		ADCON Haschhof	Tomato Late Blight	Incubation 1 - 96% done
<input type="checkbox"/>	5/30/05 6:00 AM		ADCON Haschhof	Tomato Late Blight	Incubation 1 - 70% done
<input type="checkbox"/>	5/29/05 6:00 AM		ADCON Haschhof	Tomato Late Blight	Incubation 1 - 51% done
<input type="checkbox"/>	5/28/05 6:00 AM		ADCON Haschhof	Tomato Late Blight	Incubation 1 - 28% done
<input type="checkbox"/>	5/27/05 4:00 PM		ADCON Haschhof	Tomato Late Blight	Infection Conditions
<input type="checkbox"/>	5/27/05 4:00 PM	4d 14h	ADCON Haschhof	Tomato Late Blight	Incubation 1
<input type="checkbox"/>	5/27/05 4:00 PM	68d 8h	ADCON Haschhof	Tomato Late Blight	Treatment recommended
<input type="checkbox"/>	5/24/05 6:00 AM	2h 15m	ADCON Haschhof	Tomato Late Blight	Sporulation conditions
<input type="checkbox"/>	5/16/05 9:00 AM	1h	ADCON Haschhof	Tomato Late Blight	Sporulation conditions

Figure 37. Tomato late blight events list

The model requires a combination sensor (temperature, relative humidity, leaf wetness) placed two meters high. In California, where moisture levels are often higher at ground level than at two meters, the model has worked well with the combo sensor placed at canopy height. Consult local recommendations to determine the appropriate placement for specific sites. Be sure that the combination sensor is out of direct sunlight, away from spray strips, and relatively free of the canopy. Do not let leaves lie on top of the leaf wetness sensor. Place the

precipitation sensor so that overhead objects do not interfere with the collection of rainfall.

References

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4. Lücke, W. 1993. Die Phyteb-Prognose – Erfahrungen aus Mecklenburg Vorpommern. *Der Kartoffelbau* 44:6:252-254.
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6. Winstel, K. 1993. Kraut- und knollenfaule der kartoffel eine neue prognosemöglichkeit sowie bekampfungsstrategien. Med. Fac. Landbouww. Univ. Gent, 58/3b.

The Strawberry Powdery Mildew Extension

The strawberry powdery mildew model is based on the Gubler-Thomas model; the model validation work has been conducted in the coastal strawberry growing districts of California. Participants in the validation trials included Western Farm Service staff, under the direction of Carla Thomas and University of California researchers and students, working under the direction of Dr. W.D. Gubler.

CAUTION The strawberry powdery mildew model has been tested only for conditions present in California, USA. Use the model with caution in other areas.

Disease Symptoms and Development

The strawberry powdery mildew (*sphaerotheca macularis*) symptoms first appear as white, powdery-looking patches on the undersides of leaves. As the disease progresses, these patches enlarge to cover the entire bottom of the leaf. Leaf edges commonly roll up at that point. Purple-reddish blotches appear on leaves with older infections. These blotches can appear on either side of the leaves. Infected flowers produce deformed fruit or no fruit at all. Heavily infected flowers can become covered by the fungus and die. Infected green immature fruit can turn bronze, harden, and develop a network of cracks from desiccation as well as have a fine covering of the fungus. Infected ripe fruit look seedy, can develop large cracks, and have powdery, white colonies of the fungus that can produce fungal spores.

The causal organism of powdery mildew can overwinter in the asexual stage on plant refuse. Since the fungal spores are wind dispersed, neighboring fields can be sources of infections. The fungus may also overwinter in the asexual or sexual stage on plants in nurseries. Therefore, new planting material is also a potential source of infection. Dry leaf surfaces, cool to warm temperatures, and high humidity favor infection.

Setup and Operation

Follow these steps to set up the Strawberry powdery mildew extension on an area:

1. Add the Strawberry powdery mildew extension to the desired area (see also “Adding Extensions to an Area” on page 9).

2. Click the **Extension** tab, and if you deem necessary, enable warnings issued by cleistothecia infections (see also below).
3. Click the **Crop** tab and adjust the dates of the phenological phases, then click **Apply**.
4. Click the **Inputs** tab and make sure all input tags are correctly assigned to the extension inputs. If you made any changes, click the **Apply** button.
5. Click the **General** tab and make sure the extension is enabled, then click **OK**.

The Gubler-Thomas strawberry powdery mildew model is a modification of the Gubler-Thomas grape powdery mildew model. The model starts index calculations at the phenological phase dormancy (that is, after being planted). At that point, a preventive treatment warning is issued.

The model issues warnings for ascospore infections if the cleistothecia infections option is selected. Ascospore infection conditions are based on average temperatures during extended periods of leaf wetness. A 2/3 Mills Table is used to determine infection risk. In general, at least 12-15 hours of continuous leaf wetness are required when the average temperature is between 10-15°C.

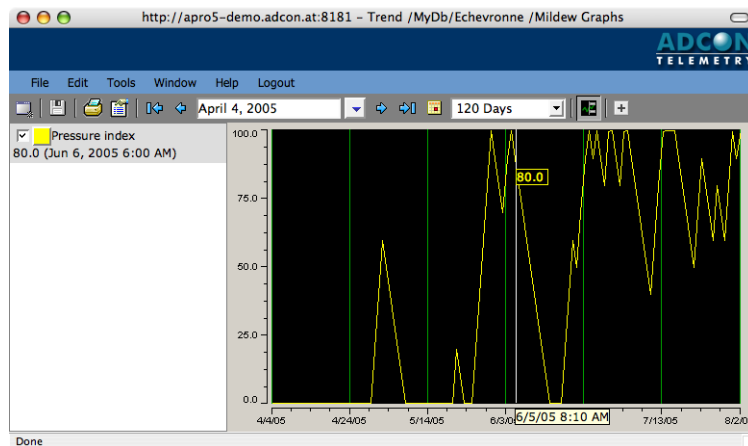


Figure 38. The risk index displayed in a Trend panel

Conidial infection risk is assessed using a risk index that ranges from 0 to 100. Three consecutive days with at least 6 hours at 21-30°C is required to trigger the index. The index increases 20 points each day with at least 6 hours at 21-30°C. The index decreases 10 points on any

day with a maximum temperature above 35°C or fewer than 6 hours at 21-30°C.

You can display and print the risk index graphically as a trend (Figure 38), for observations on its evolution over the whole or part of the season.

Field validation studies have shown that the best results are obtained when the sensors are placed as close to the plants as possible in order to get the most accurate model output.

References

1. Gubler, D. 1998. UC IPM Pest Management Guidelines: Strawberry. UC DANR Publication 3339.
2. Legard, D.E., A.J. Whidden, and C.K. Chandler. 1999. Incidence and occurrence of strawberry disease in Florida. *Citrus & Vegetable Magazine*, 63:5 25-27.
3. Thomas, C.S., W.D. Gubler, L. Bettiga. 1994. *Uncinula necator* ascospore release, viability and infection in field conditions in California. *Phytopathology* 81:1182.

The Strawberry Bunch Rot Extension

The Strawberry bunch rot extension is based on a modified model developed by Broome et, al. grape bunch rot model and was validated for the coastal strawberry growing districts of California.

CAUTION The strawberry bunch rot model has been tested only for conditions present in California, USA. Use the model with caution in other areas.

Disease Symptoms and Development

Botrytis fruit rot symptoms are typically restricted to flowers and fruit. Infected flowers can rot before fruit develops or the infection can remain dormant until fruit sugars and environmental conditions favor disease development. Initial symptoms on fruit typically appear on the calyx end of the fruit or on the sides of fruit touching other infected fruit. These lesions can appear on green or red fruit. Lesions initially appear as small, firm, light-brown spots. Lesions sporulate rapidly when conditions are favorable. A velvety, brown coat of fungus rapidly covers the fruit. The fruit eventually mummifies if humidity is not too high.

The causal organism of Botrytis fruit rot is typically present in most strawberry fields during the growing season. The fungus survives the off-season in the soil and on plant refuse. It is also capable of surviving on the refuse of many other plant species. Spores on plants can remain dormant for a time or cause immediate infection. Spores that remain dormant can resume activity during the growing season or after harvest on stored fruit. Free moisture and cool temperatures favor development of infections.

Setup and Operation

Follow these steps to set up the Strawberry bunch rot extension on an area:

1. Add the Strawberry bunch rot extension to the desired area (see also "Adding Extensions to an Area" on page 9).
2. Click the **Extension** tab, and if you deem necessary, adjust the threshold for issuing warnings (default is 0).
3. Click the **Crop** tab and adjust the dates of the phenological phases, then click **Apply**.

4. Click the **Inputs** tab and make sure all input tags are correctly assigned to the extension inputs. If you made any changes, click the **Apply** button.
5. Click the **General** tab and make sure the extension is enabled, then click **OK**.

The Botrytis fruit rot model is a modification of the Broome, et al. Botrytis grape bunch rot model. This model uses a multiple regression equation to determine the relationship between infection risk, leaf wetness duration, and temperature. The index is calculated whenever leaf wetness is detected. Index calculations cease when a period of greater than 4 hours without leaf wetness occurs.

Predefined index thresholds are used to determine the relative risk of infection as low, moderate, or high. Treatment warnings are issued when the risk level is moderate or high.

You can display and print the risk index graphically as a trend (Figure 39), for observations on its evolution over the whole or part of the season.

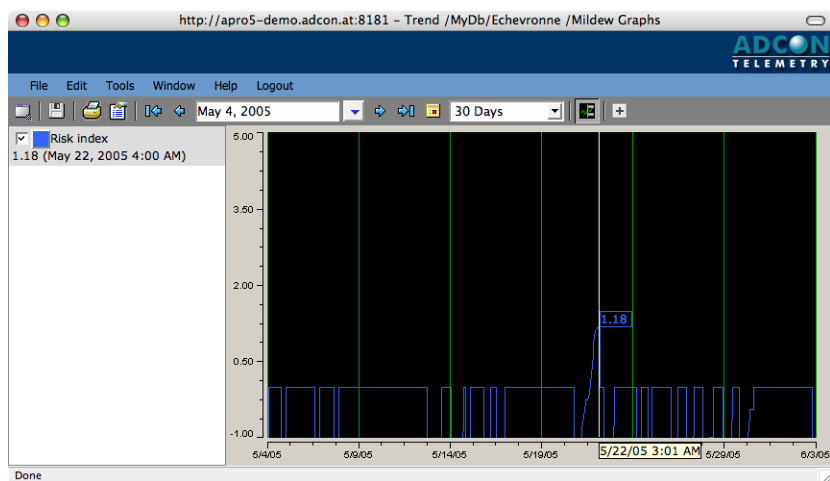


Figure 39. The Botrytis fruit rot index displayed in a Trend panel

Field validation studies have shown that the best results are obtained when the sensors are placed as close to the plants as possible in order to get the most accurate model output.

References

1. Broome, et al. 1994. Development of an infection model for Botrytis bunch rot of grapes based on wetness duration and temperature. *Phytopathology* 1994.
2. Gubler, et al. 1991 Control of Botrytis bunch rot of grape with canopy management. *Plant Disease* 71:599-601.
3. Thomas, C.S., J.J. Marois, T. English. 1988 The effects of wind speed temperature and relative humidity on development of aerial mycelium and conidia Botrytis cinerea on grape. *Phytopathology* 17:3 26-265.

The Pistachio Blight Extension

This model is being developed by George Driver and Themis Michailides at the UC Kearny Agricultural Center in California. The model was first implemented as an Adcon AgroExpert disease risk model in 2002. Research continues on this disease and disease risk model. The model is being used to identify high pressure periods while the final model details are being validated.

CAUTION The pistachio blight model is being developed for the conditions present in California, USA. Use the model with caution in other areas.

Disease Symptoms and Development

Symptoms appear as dark lesions (usually at the base of shoots, rachises, and mid leaves) and are caused by the fungus *Botryosphaeria dothidea* Ces. & De Not. Shoots originating from heavily infested or partially killed buds expand to a short length, become black, and die. Infected flower buds lead to blighted inflorescences. Rachis infections occur at the base or branching points. Infected tissue turns black, and the rachis collapses. Depending on the location of the lesion, these infections can also lead to the collapse of the clusters, with fruit adhering to them.

Conidia released from pycnida present on the previous year's blighted shoots, rachises, cankers, buds, and petioles cause the primary infections in the spring and early summer. Inoculum can also cause in-season infections in late summer and fall. Conidia is usually spread by rain but also by animals and sprinkler irrigation. Infections must occur during the rainy season when temperatures are 10°C or above. Buds become infected when they emerge, even when there has been no rainfall after bud emergence. Early infections of buds are due to spores deposited in leaf axils that develop into active lesions. Latent infections will develop later in the season as temperatures and humidity increase. The pathogen grows best at higher temperatures, increasing the severity in late spring and summer.

Setup and Operation

Follow these steps to set up the Pistachio blight extension on an area:

1. Add the Pistachio blight extension to the desired area (see also "Adding Extensions to an Area" on page 9).

2. Click the **Extension** tab, and if required, enter the initial precipitation value (default is 0).
3. Click the **Crop** tab and adjust the dates of the phenological phases, then click **Apply**.
4. Click the **Inputs** tab and make sure all input tags are correctly assigned to the extension inputs. If you made any changes, click the **Apply** button.
5. Click the **General** tab and make sure the extension is enabled, then click **OK**.

The model starts on January 1, focusing on rainfall events. A rainfall accumulation of at least 5 mm in a five-hour window and five hours of leaf wetness will accumulate one disease risk event. The inoculum pressure is determined by the number of events, as follows:

- 0 to 5 is low
- 6 to 10 is moderate
- over 11 is high

If these conditions occur during bloom, a potential disease severity index at harvest will be generated. Degree hours (DH) greater than 30°C from 12 AM to 12 AM are accumulated over a sliding window of 21 days. You can see the indices generated by the extension as output tags in a trend window (Figure 40).

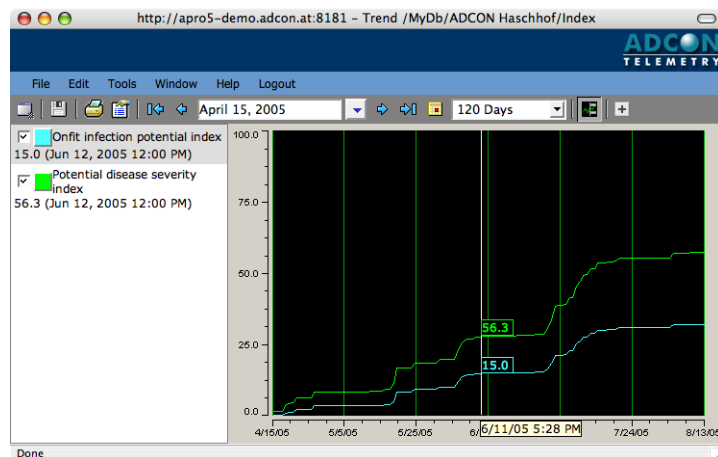


Figure 40. Pistachio blight indices displayed in a Trend panel

The model is currently used to assess potential disease pressure with growers using the model and other factors to determine when to apply a treatment. The model continues to be validated to refine the effects of disease history, temperature threshold, and number of degree hours for generating automated treatment recommendations.

WARNING This extension is not currently issuing treatment recommendations; you should develop a spraying plan based on the model output.

References

1. Themis J. Michailides, David P. Morgan, January 2004, Panicle and Shoot Blight of Pistachio: A Major Threat to the California Pistachio Industry. Department of Plant Pathology, Parlier CA.

For a complete report you can also check the following web site over the Internet: <http://www.apsnet.org/online/feature/pistachio>.

The Evapotranspiration Extension

Evapotranspiration is defined as the loss of water from the soil both by evaporation and by transpiration from the plants growing on it. The Penman-Monteith method of computing the reference evapotranspiration (ET_o) is based on two main equations: an energy equation (global radiation) and an aerodynamic equation (wind and air humidity). Depending on the predominant climatic situation, any of the equations can take a leading role. For instance, during quiet weather conditions, the aerodynamic factors have a lower influence. Consequently, under such conditions, the reference evapotranspiration is valid not only for the cold and humid climates, but also for the warm, semi-arid regions. Due to the day and night climatic differences and their effect upon the evapotranspiration, the Penman-Monteith calculation is based on hourly climatic data.

The model implemented by the Evapotranspiration extension is based on the "FAO Irrigation and drainage paper 56"; for further reading, you can find it at <http://www.fao.org/docrep/X0490E/x0490e00.htm>.

Note: The combo sensor (temperature and RH), the wind speed sensor, and the global radiation sensor must be installed at the 2 m standard height. All of these sensors are essential for the ET_o extension.

Factors Affecting ET_o

Sometimes it is desirable to use climatic data recorded from a distant weather station. This is possible as long as the weather conditions are uniform for a wide area. In regions where this is not obvious (due to the geographical situation, for example, deep valleys and frequent hills), you have to verify that the values recorded from such a distant station are still representative for your area. If in doubt, consult a local weather service.

In arid and semi-arid climates (as well as for the summer months in humid zones), the irrigated fields are often surrounded by large, dry soil surfaces. Under such conditions, massive air displacements such as warm winds lead to the so-called oasis effect, which further leads to a substantially higher evapotranspiration rate, especially towards the fields' boundaries.

The Influence of the Soil Moisture

The evapotranspiration model assumes that the plants' roots have sufficient water. After irrigating, or after a rainfall, the water content will be predominantly influenced by the water needs of the crop. The plants' roots easily absorb this water. Concurrently to the water absorption, the soil water supply diminishes. If a critical threshold is reached, the crop evapotranspiration will sink under the actual computed values.

The effect of the soil moisture on the evapotranspiration varies with crop type and its root system and soil type. Under moderate evapotranspiration conditions (up to 5 mm per day) and high water content, the available water in the soil has practically no effect. However, if the evapotranspiration rate is over 5 mm per day, and the soil moisture in the roots region is reduced, the crop evapotranspiration remains low, especially in heavy and light soils.

Setup and Operation

Follow these steps to set up the ETo extension on an area:

1. Add the ETo extension to the desired area (see also "Adding Extensions to an Area" on page 9).
2. Select the extension's properties, click the **Extension** tab (Figure 41), and set the proper values for Altitude, Latitude, and Wind sensor elevation. Click **Apply** when ready.

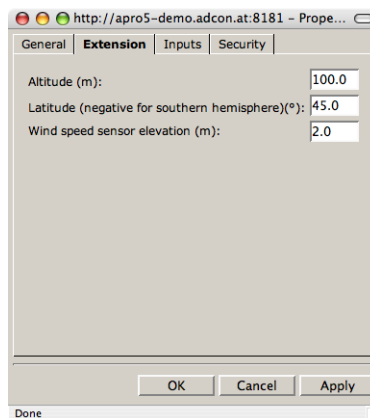


Figure 41. ETo settings dialog box

3. Click the **Inputs** tab and make sure all input tags are correctly assigned to the extension inputs. If you made any changes, click the **Apply** button.
4. Click the **General** tab and make sure the extension is enabled, then click **OK**.

The ETo extension generates a tag (Eto index) that you can display in a trend and/or allow to be used by other extensions as an input tag.

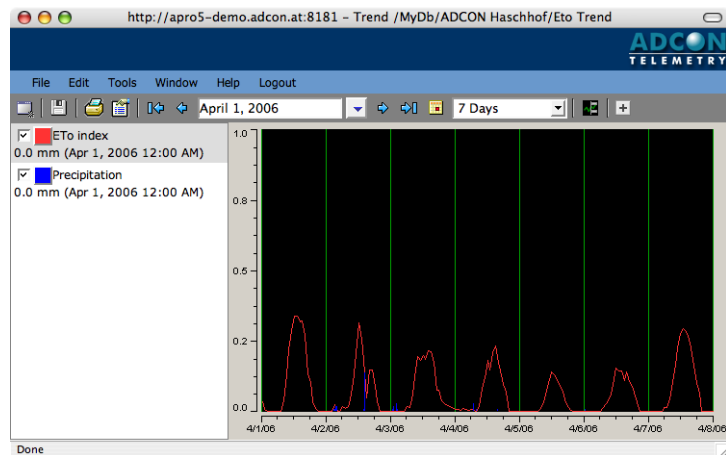


Figure 42. Eto index displayed in a Trend panel

References

1. Doorenbos, J. and Pruitt, W.O., 1977 - "Crop water requirements." FAO Irrigation and drainage paper 24.
2. Doorenbos, J. et al., 1979 - "Yield response to water." FAO Irrigation and drainage paper 33.
3. Anonymous, 1992 - "Cropwat." FAO Irrigation and drainage paper 46.
4. Allen, R.G., Smith, M., Pereira, L.S., Perrier, A., 1994 - "An Update for the Definition of Reference Evapotranspiration." ICID Bulletin, Vol. 43, No. 2, pp. 1 – 92.
5. Paschold, P.J. and Zengerle, K.H., 1993 - "Pfälzer Gemüsebau effektiv und umweltschonend bewässern," Hrsg. SLFA für Landwirtschaft, Weinbau und Gartenbau Neustadt a.d. W., Neustadter Hefte, Heft 61, pp. 73-83.

The Soil Moisture Extension

The Soil moisture extension was devised to operate with capacitive type soil moisture probes. A range of sensors operating on the principle of measuring the dielectric of the soil has been developed lately (Sentek's EasyAG, Agrilink's C-Probe, etc.). However, the output of these sensors expresses values that cannot be used readily with standard irrigation modeling software. Therefore the sensor values—usually expressed in Scaled Frequency Units (SFU)—must be converted to volumetric soil water content (vsw), taking into account the soil type.

You can install the soil moisture probes in a large variety of soil types, from coarse to heavy clay, and their output varies significantly. The output depends on the water-holding capacity of the soils: the heavier the soil, the higher the output of the probe.

Apart from the conversion to volumetric values, the Soil moisture extension offers you the ability to generate compound values, i.e. averages and sums of the probes' outputs. These output tags can be further used as input tags for other extensions, or as such to help you determine the optimum time to irrigate, as well as the amount of water needed by the crop.

Setup and Operation

It is assumed that the soil moisture probes are already installed in the field; for details about installing your probe, see the respective probe's user guide. In addition, it is assumed that the data source (e.g. the Telemetry Gateway) is already properly configured and the soil moisture probe's data has been transferred to addVANTAGE Pro's database. For more details about configuring the soil moisture probes in the Telemetry Gateway, see the respective user guide. Note that the Soil moisture extension is expecting data from input tags of SFU type, which is important when you set up a custom driver.

Follow these steps to set up the Soil moisture extension on an area:

1. Add the Soil moisture extension to the desired area (see also "Adding Extensions to an Area" on page 9).
2. Open the extension's Properties dialog box.
3. Click the **Inputs** tab and make sure all input tags are correctly assigned to the extension inputs. If you made any changes, click the **Apply** button.

4. Click the **Extension** button and set the relevant parameters (Figure 43):
 - a. Verify and, if needed, correct the depth for all the sensors.
 - b. Select the appropriate soil type for each sensor.
 - c. If you need the average and/or sum composite output tags, click the appropriate check boxes. The average tag is computed as an average of all the selected input soil moisture sensors, while the sum tag is the sum value of all the selected input soil moisture sensors (see also the next step).
 - d. Click the appropriate check boxes for the sensors you want to be taken into account by the extension to compute the **Average** and **Sum** composite output tags, if any.
 - e. After having set all the parameters, click **Apply**.
5. Click the **General** tab and make sure the extension is enabled, then click **OK**.

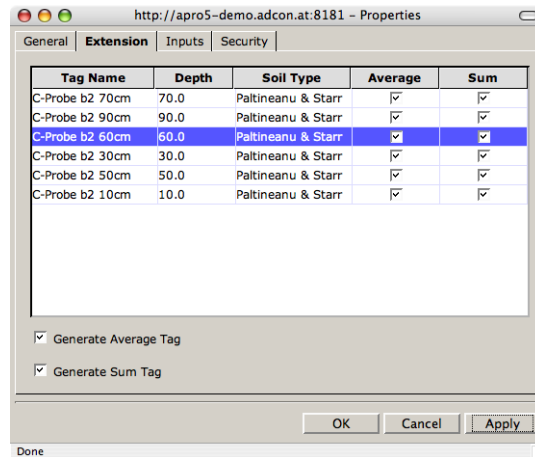


Figure 43. Soil moisture extension setup

The model starts computing the individual output values and the composite values immediately. As with any other tag in the system, you can view the output tags graphically by placing them in a Trend panel (Figure 44). Using the many options offered by the Trend panel, you can set up thresholds for different values of the sensors (e.g. to the refill and full points), change colors, offset the graphs, and so forth.

The output tags can be further used as input tags for other extensions. For example, you can set up the Main extension to issue alarms in the

Events list when specific thresholds have been reached or to send e-mails in extreme cases. You could also use the Statistics extension to generate statistic reports.

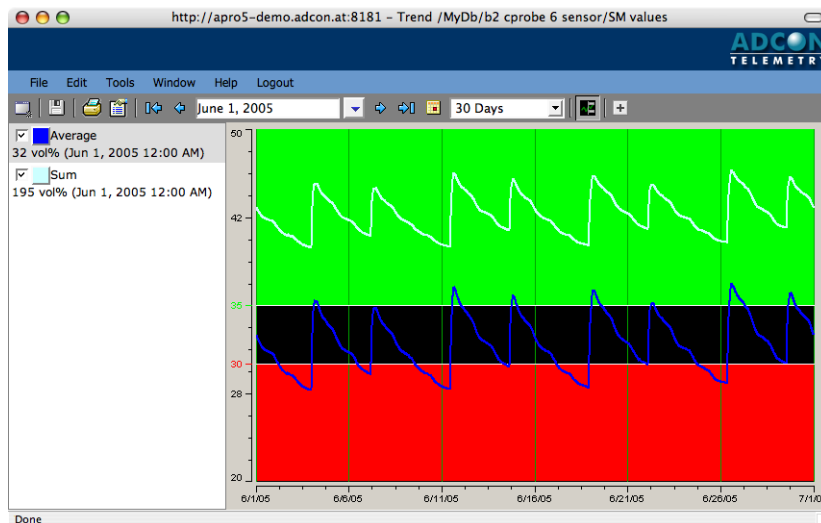


Figure 44. Sum and average tags on a Trend panel

Custom Soil Type Configuration

The conversion between input SFU values and output vsw values is done with a configuration file that stores calibration parameters. The file is called `soilmoisture.cal` and is located in the `\addVANTAGE-Pro\config` directory. You can edit the file with a standard text editor such as Notepad. The file format is 100% compatible with the file format of the `cprobe.cal` file used by the C-Probe extension in the addVANTAGE 3.45 software. Therefore, if you already have configured custom soils, you can use your original file by simply changing its name to `soilmoisture.cal` and placing it in the `\addVANTAGE-Pro\config` directory on your addVANTAGE Pro 5.0 server.

Note: You might want to save the original distribution file under a different name.

For more information on the significance of the parameters in the `cprobe.cal` file, as well as how you can set up your own soil type, refer to the "C-Probe Technical Manual" issued by the C-Probe Corporation (version 3.2, March 2001).

Index

A

- accessing configuration menus, 13
- adding extensions to areas, 9
- administering chemicals, 18
- Algorithms
 - about, 6
 - See also Extensions
- apple powdery mildew
 - introduction, 26
 - pressure index, 27
 - symptoms, 26
 - using system against, 27
- apple scab
 - incubation, 25
 - introduction, 22
 - systems, 22
 - using system against, 23
- automatic properties values recalculation, 11

B

- Botryosphaeria dothidea, 86
- Botrytis cinerea, 44

- Bremia lactucae, 62
- bunch rot of grapes
 - introduction, 44
 - symptoms, 44
 - using system against, 45

C

- calculation methods for heat unit extension, 49
- chemicals
 - administering, 18
 - changing, 19
 - controlled duration, 18
 - listing, 18
 - losing changes, 19
 - overview of service, 18
 - system-defined, 18
 - user-defined, 18
 - waiting time, 19
- common extension properties, 10
- configuration menus, accessing, 13
- configuring
 - custom soil types, 94

- extensions, 10
- contact fungicides, 17
- controlled duration, 18
- crop properties, 11

D

- daily operations
 - heat unit extension, 58
 - lettuce downy mildew, 64
- definitions
 - controlled duration, 18
 - degree days, 48
 - system-defined chemicals, 18
 - user-defined chemicals, 18
 - waiting time, 19
- degree days
 - calculation
 - 15 min. based, 53
 - averaging, 49
 - double sine, 53
 - double triangle, 51
 - GDD, 50
 - single sine, 52
 - single triangle, 50
 - standard, 50
 - Utah method, 54
 - definition, 48
- disease symptoms
 - apple powdery mildew, 26
 - apple scab, 22
 - bunch rot of grapes, 44
 - downy mildew of hop, 72
 - grape downy mildew, 33
 - grape powdery mildew, 39
 - lettuce downy mildew, 62
 - pistachio blight, 86
 - potato blight, 66
 - strawberry bunch rot, 83
 - strawberry powdery mildew, 80
 - tomato late blight, 77
- downy mildew of hop
 - extension setup, 73
 - introduction, 72

- sensor placement, 74
- symptoms, 72
- using system against, 73

- DSV extension
 - and late blight of potato and tomato, 30
 - introduction, 30
 - setup, 31
 - Tom-Cast model, 30

E

- ETo
 - explanation, 89
 - factors affecting, 89
 - influence of soil moisture, 90
 - introduction, 89
 - Penman-Monteith, 89
 - required sensors, 89
 - setup, 90
- evapotranspiration. *See* ETo
- explaining ETo, 89
- extensions
 - adding to areas, 9
 - apple powdery mildew, 26
 - apple scab, 22
 - automatic recalculation, 11
 - bunch rot of grapes, 44
 - common properties, 10
 - configuring, 10
 - crop stages, 11
 - downy mildew of hop, 72
 - DSV, 30
 - evapotranspiration (ETo), 89
 - grape downy mildew, 33
 - grape powdery mildew, 39
 - heat units, 48
 - input tags, 11
 - lettuce downy mildew, 62
 - pistachio blight, 86
 - potato blight, 66
 - soil moisture, 92
 - strawberry bunch rot, 83
 - strawberry powdery mildew, 80
 - tomato late blight, 77

treatments, 11

F

field setup for lettuce downy mildew, 63
forcing properties recalculation, 12

G

grape downy mildew
 incubation, 35
 introduction, 33
 symptoms, 33
 using system against, 34
 warnings, 36
grape powdery mildew
 bud perennation, 39
 cleistothecia, 39
 introduction, 39
 pressure index, 43
 symptoms, 39
 using system against, 40
Gubler-Thomas model, 42

H

Hansen, 67
heat unit extension
 calculation methods
 about, 49
 averaging, 49
 chilling hours 15 min. based, 54
 degree days 15 min. based, 53
 degree days Utah method, 54
 double sine, 53
 double triangle, 51
 GDD, 50
 heat hours 15 min. based, 53
 single sine, 52
 single triangle, 50
 standard, 50
 daily operation, 58
 horizontal cutoff, 55

intermediate cutoff, 55
introduction, 48
model function, 49
phenology model sources, 58
sensor placement, 56
software configuration, 56
vertical cutoff, 56

I

incubation
 apple scab, 25
 grape downy mildew, 35
index
 grape powdery mildew, 43
 hop mildew, 74
 strawberry bunch rot, 84
 strawberry powdery mildew, 82
 Ullrich-Schrödter, 69
Infection
 secondary (downy mildew), 37
infection
 apple scab, 22
 ascospore, 39
 conidial, 39
 grape downy mildew, 36
 grape powdery mildew, 39
 hop, 72
 primary (downy mildew), 35

K

Kast
 model, 27, 35, 42
 strategy, 37
Kremheller, 73

L

lettuce downy mildew
 daily operation, 64
 field setup, 63
 introduction, 62

- model operation, 62
- symptoms, 62
- system configuration, 63
- listing types of chemicals, 18

M

- Mills table, 24, 42
- Mills-Jones index, 25
- model operation
 - heat unit extension, 49
 - lettuce downy mildew extension, 62
- models
 - Gubler-Thomas, 42, 81
 - Kast, 27, 35, 42
 - options, 10
 - Ullrich-Schrödter, 67
 - Winstel, 67, 70
- Müller table, 35

N

- Negative prognosis, 67

O

- Oidium tuckeri*, 39
- oilspots, 33
- other factors, ETo, 89

P

- Penman-Monteith, 89
- PeroDiag, 35
- phenology models, heat unit extension, 58
- pistachio blight
 - introduction, 86
 - setup, 86
 - symptoms, 86
- placing sensors for the heat unit extension, 56
- plant protection properties, 11
- Plasmopara viticola*, 33
- potato blight
 - development, 67
 - introduction, 66

- symptoms, 66
- using system against, 66
- pressure index
 - apple powdery mildew, 27
 - grape powdery mildew, 43

R

- reference evapotranspiration. See ETo
- Royle, 73

S

- sensors
 - DSV extension, 32
 - ETo requirements, 89
 - grape downy mildew extension, 35
 - heat unit extension, 56
- setting input tags for extensions, 11
- setting up
 - downy mildew of hop extension, 73
 - DSV extension, 31
 - ETo extension, 90
 - pistachio blight extension, 86
 - soil moisture extension, 92
 - strawberry bunch rot extension, 83
 - strawberry powdery mildew extension, 80
 - tomato late blight extension, 77
- soil moisture extension
 - custom soil type configuration, 94
 - introduction, 92
 - setup, 92
- soil moisture, influence on ETo, 90
- strawberry bunch rot
 - introduction, 83
 - setup, 83
 - symptoms, 83
- strawberry powdery mildew
 - introduction, 80
 - setup, 80
 - symptoms, 80
- system configuration
 - heat unit extension, 56
 - lettuce downy mildew, 63

system-defined chemicals, 18
systemic products, 17

T

tags, setting in extensions, 11
tomato late blight
 introduction, 77
 setup, 77
 symptoms, 77
Tom-Cast model, 30
Treatments
 curative, 16, 37
 preventive, 16, 37
 recommending, 14
 washoff limit, 17

U

Ullrich-Schrödter model, 67
Uncinula necator, 39
user-defined chemicals, 18
using system against
 apple powdery mildew, 27
 apple scab, 23
 bunch rot of grapes, 45
 downy mildew of hop, 73
 grape downy mildew, 34
 grape powdery mildew, 40
 potato blight, 66
using tools menu to set up chemicals, 18

V

Vine extension
 downy mildew messages, 39
 powdery mildew messages, 44
 setup, 35

W

waiting time, 19
warnings for grape downy mildew, 36
Washoff limit, 17

Winstel model, 67, 70