Powdery mildew of succulent *Euphorbia* species

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The thick waxy cuticle and strong protecting cell walls of highly succulent plants are evolutionary results of the necessity to save water in an arid environment. As a side effect, this solid casing reduces the chance for a potential pathogen to successfully intrude into the well-sheltered plant tissue. Therefore, only a few fungal pathogens are capable of infecting highly succulent plants through the healthy, unharmed epidermis. Moreover, under dry conditions the essential water for germination of spores and growth of the germ tube before entering into the host's cells is often missing on the plants. However, one fungal disease of succulent euphorbias is well known: powdery mildew.

Mycological aspects

Powdery mildews represent the fungi of the order Erysiphales, which consists of approximately 20 genera with about 100 species (the number of genera and species vary depending on the taxonomic concept). A wide range of plants can be infected by these fungi: about ten thousand plant species are known to be hosts of powdery mildews.

Due to their epidemical potential, powdery mildews are of high economic relevance on important crops such as wheat, apples, grapes or roses. Some of the powdery mildew species are able to infect a wider host range; however, most species are specialized to a low number of hosts only, some on only one host genus, such as *Podosphaera (Sphaerotheca) euphorbiae* on euphorbias.

The trivial name reflects the typical visual symptom: a white to grey layer with a powdery appearance on leaves, stems and buds. This white cover consists of hyphae (strands of the fungal organism, making up the mycelium), conidiophores (spore bearing branches of hyphae) and conidia (asexually produced spores).

In contrast to many other fungal plant pathogens, powdery mildews live more or less on their host (ectoparasitically) not within it (endoparasitically). The bigger part of the fungal organism grows on the surface, though, in need to get nutrition, powdery mildews intrude into the cells with so-called haustoria. These root-like structures take up the required substances such as sugars, proteins, minerals and water. This parasitic process depends on living host cells: powdery mildews are obligate biotrophic parasites, depending on the

Fig. 1: E. pentagona *shoot tip with a white cover of powdery mildew*

Fig 2: E. obesa *with light symptoms of powdery mildew at the junctions of the ribs*

Fig 3: Flower bud of E. obesa *with conidiophores of* Podosphaera euphorbiae

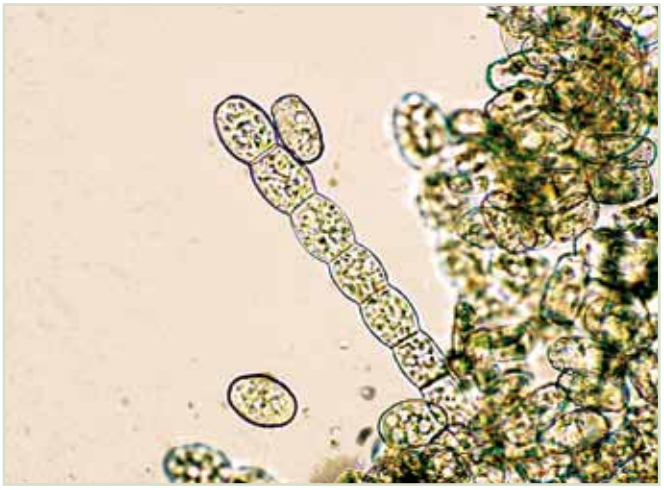

Fig. 4: A conidiophore of Podosphaera euphorbiae. *The conidia are produced in chains.*

survival of the colonized host tissue. Nevertheless, powdery mildew infections may cause early senescence and necrosis of the host tissue, but rot does not occur. For the fungus it is crucial to sporulate before the host tissue dies off. In some cases the time between infection and sporulation is as short as one week.

As mentioned above, conidia are produced on specialized branches of hyphae, so-called conidiophores. The tip of a conidiophore produces single-celled spores one by one. In most species, the conidia cling together and stay in chains until wind or water separates and disperses them. In other species, conidia are released separately. Thousands of conidiophores may stay on the plant's surface, bearing masses of conidia. Macroscopically this – together with the mycelium – gives the impression of the powdery white cover on the plant surface. Most of the conidia are dispersed over a short range only, however, by wind the conidia might be carried over long distances up to many hundred kilometres!

In comparison to spores of most other fungi, conidia of powdery mildews contain much water and fat. Therefore, again unlike other fungi, powdery mildews are not in need of free fluid water for infection. In most situations, high relative humidity of 70 to 100 % is enough. This means, that powdery mildews are well adapted to dry environments.

In contrast, heavy rainfalls are adverse for powdery mildews, as conidia and mycelia are washed from the plant surface. Furthermore, rain also interrupts the long range transport of conidia through the air.

For epidemiology, the sexual stage of powdery mildews is presumably not relevant, at least for the quick population increase during the most active phase of the disease. However, for survival of unfavorable conditions, the small and often dark colored fruiting bodies (so-called chasmothecia, previously "cleistothecia") are of importance. Furthermore, in some species, adapted mycelium with reinforced cell walls may outlast such conditions in buds or on infected tissue.

Powdery mildew on succulent euphorbias

On stem succulent *Euphorbia* species, powdery mildew is generally found on the shoot tips, mainly on freshly grown and soft parts close to the growing point and between the ribs (fig. 1 and 2). Furthermore, buds – both flower and shoot buds – are suitable plant parts for powdery mildew (fig. 3). Leaves, if present, are often colonized by powdery mildew. In particular the upper leaf surface shows whitish spots to begin with and may be totally covered shortly after.

Affected zones often turn brown and corky, especially when the infection is stopped (fig. 5 and 6). These zones of dead epidermis remain on the plants and tell us about a former infection. However, this symptom is not a reliable indication, as it might be caused by other factors.

It is not surprising that different species of Erysiphales are described on *Euphorbia*. As *Euphorbia* is a rather species-rich genus with high diversity, growing in various habitats all over the world, there should be at least some Erysiphales adapted to it. Moreover, the taxonomy of powdery mildews is complex with plenty of synonyms and different concepts. In this manuscript the concept of Braun (1995) is used.

According to this source, species of *Euphorbia* are hosts of at least three different powdery mildews: *Leveillula taurica* (on *E. brittingeri, E. fulgens*), *Oidium*

Fig. 5: E. spec. with a necrotic zone, probably a former infection of powdery mildew

Fig. 6: E. obesa *with zones of corky dead epidermis after an infection of powdery mildew*

cyparissiae (on *E. cyparissias*) and *Podosphaera (Sphaerotheca) euphorbiae* (on many species). However, other sources (Anon. 2008a,b) list different powdery mildew species named after their *Euphorbia* host: *Erysiphe euphorbiae, E. euphorbiicola, Golovinomyces sparsus* var. *euphorbiicola, Podosphaera euphorbiae-hirtae, P. euphorbiae-helioscopiae.* Furthermore*, Golovinomyces andinus* and *Leveillula clavata* are mentioned on *Euphorbia*.

The only powdery mildew species which – to the knowledge of the author – was collected and determined from succulent euphorbias is *Podosphaera euphorbiae*. In the Erysiphales Collection at the University Halle-Wittenberg, Germany, one specimen of *P. euphorbiae* collected from *E. gorgonis* is listed (Anon. 2008c). My own observations suggest, that *P. euphorbiae* is the commonest powdery mildew on succulent euphorbias.

What to do

Powdery mildews are able to infect the healthy, intact epidermis. However, infections occur more frequently under certain conditions, especially when plants are stressed. In order to protect the plants these circumstances should be avoided.

Standing too close, deficiency of light (fig. 7) – resulting in weak cuticle and epidermis – as well as imbalanced supply of nutrients, sharp contrasts of temperature or draft may promote the pathogen. As a prophylactic measure, the environmental conditions should be examined and adjusted to the needs of the succulents. This is of special value as not only the pathogen's chance for infection is reduced by changed conditions, but at the same time, the plant becomes less susceptible due to optimal cultivation. Providing a good position with plenty of fresh air and enough sunlight, a gentle temperature regime and adequate nutrition optimize the plant's defense mechanism.

The same result might be achieved by the application of special preparations which aim to strengthen the plant's defense. Some of these preparations are commercially available; others are "home-made", processed from different plants such as nettle (*Urtica dioica*, Urticaceae), horsetail (*Equisetum arvense*, Equisetaceae) or other locally known herbs. The main draw back of plant strengthening preparations is the need to spray frequently (every 10 to 15 days) to get a sufficient effect. Some of the preparations leave a brownish layer on the plants. Moreover, the efficacy of these preparations is not always stable and depends on different factors. For example, the protection by plant strengtheners is satisfactory if disease pressure is low, but hardly any effect is distinguishable if it is high.

If appropriate, infected plant parts should be eliminated by mechanical means. To cut away a plant part may appear hard, but the unquestionable advantage of extensive removal of the main source of infection might balance it. Leaves or shoot tips of readily branching and quickly growing euphorbias are easy to remove, but no-one wants to cut an infected tip of rare plants.

As the conidia are washed away by rain or overhead irrigation, disease pressure may be reduced by this simple measure. However, one should be aware that the plant surface must dry quickly, otherwise delicate species might rot as a result of infection with other fungi or bacteria!

Fig. 7: E. polygona *etiolated side shoot due to light deficiency and colonized by powdery mildew. The main shoot is apparently not infected.*

Chemical control

Due to the fact that a large part of the fungal organism is within easy reach, powdery mildews are rather susceptible to fungicides. On the other hand, powdery mildews may develop decreased susceptibility, if substances with only one single mode of action are used repeatedly. Therefore, to avoid the development of resistant powdery mildew strains, it is absolutely necessary to vary the fungicide (active compound) during the course of chemical control!

Spraying with fungicides may be necessary as soon as infections are to be expected. Therefore it is advisable to inspect the plants regularly for the typical symptoms. Especially plants close to windows and doors, where draft is likely to occur, should be checked. Experienced *Euphorbia* enthusiasts will know the most susceptible plants and check those with particular attention.

At the latest when the first white powdery spots are visible, spraying with certified fungicides is indicated. Once the white cover becomes more extensive, the effect of fungicides decreases.

Preventive

If contact or preventive fungicides are used, it is crucial to cover the whole plant with the spray in order to get an even fungicide layer. Since these pesticides protect the plants against infections (they prevent or stop the germination and germ tube elongation), they cannot work when the fungus has already entered the plant tissue. In some cases it is not clear, whether there is a fungicidal or a plant strengthening effect. The first two active compounds described below (hydrogen carbonates and lecithin), are often regarded as plant strengtheners. Their effectiveness against powdery mildews is not without controversy. In some trials – especially with low disease pressure – these components performed quite well, in others they failed. Moreover, they have to be applied frequently and in an early stage of the disease. However, as they at least have some effect directly against the fungus, they are listed here.

Hydrogen carbonates

Baking soda (sodium bicarbonate, $NaHCO_3$) and potassium hydrogen carbonate ($KHCO_3$) are recommended as preventive fungicides. The suggested concentration is between 0.5 and 2 %. Often the carbonates act better in mixtures with oils plus emulsifier (surfactant). As plants may be damaged, hydrogen carbonates should be used with care. Also important soil parameters are affected by immoderately applied carbonates (pH, sodium content).

Lecithin

As a ubiquitous component in organisms and a common food additive, lecithin is regarded as a low risk biological fungicide. Frequently applied it affects the elongation of hyphae and spore formation. Therefore, the spread of powdery mildew on the plants is retarded.

Sulphur

Sulphur is one of the oldest active ingredients used for plant protection purposes. For more than 150 years it has been applied world wide in agriculture especially to protect plants against attacks of powdery mildews. As an inorganic compound it is a so-called "multisite inhibitor", which means that sulphur does not bind selectively to a special enzyme, but inhibits or inactivates many different steps of the metabolism at the same time. Therefore, the risk of causing resistance even by frequent application of sulphur is very low. Wettable Sulphur is the most suitable form of sulphur for plant protection purposes. The active ingredient is formulated with surfactants, which makes the sulphur more easily mixed with water.

A traditional alternative to using suspended sulphur is the application of evaporated sulphur. In special devices, pure sulphur is evaporated and distributed in the greenhouse. The sulphur condenses on plants (and elsewhere) and is active against powdery mildew. Although sulphur is a "natural" (which often is wrongly understood as "safe") fungicide, it may cause plant damage when used at temperatures higher than approx. 28 °C.

Strobilurines (Azoxystrobin amongst others)
Fungicidal compounds of the group strobilurines are comparably new in plant protection. They are derivatives of a substance produced by a certain fungus in order to suppress other fungi. The synthetic strobilurines, available since the 1990's are more stable and affect a wide range of fungi. Although strobilurines are absorbed by the cuticle and diffuse into the cells, they do not provide full systemic activity. Therefore they offer the best effect when used as preventive fungicides. The spraying should be executed as early in disease development as possible.

In contrast to preventive fungicides, some active ingredients – often referred to as curative fungicides – might stop the fungus in a later phase of the disease. Though, as stated above, the earlier control measures are taken, the better the chances of success!

Curative and eradicative

Oils
Horticultural oils (formulated mineral or plant oils) are typically used as contact insecticides against scale insects. Although the effect against powdery mildew has been known for many years, it is not widely used in professional horticulture. May be the effect is too low or uncertain, but there are trial reports promising sufficient efficacy to eradicate at least mild infections. Gardeners should be aware of the risk of harm to susceptible plants especially at high temperatures and in some mixtures with other compounds (especially sulphur) with oil applications.

Azoles (Myclobutanil, Tebuconazole amongst others)
In contrast to all other fungicides mentioned above, azole fungicides are systemically active, meaning that they get into the plant tissue and are transported within the plant. However, most of the systemic compounds are mobile in the xylem (water conducting system) only. Therefore the distribution is always from base to top. From this it follows that branches or leaves located lower on the plant are not protected, when application does not cover them. Azoles are a big group of fungicides with different ranges of efficacy. Myclobutanil and Tebuconazole are two azole compounds active against powdery mildew.

Please observe the rules concerning chemical plant protection in your country. In some countries, several of the mentioned substances might not be legally available. ♦

Acknowledgment

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