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The specific abiotic and biotic damage of poppy (*Papaver somniferum*) — a review*

The poppy (*Papaver somniferum*) is a very sensitive crop, suffering from specific types of abiotic and biotic damage. Herbicides, soil conditions, weather and their combination are frequent causes of abiotic damage. Specific type of herbicide deformation is spiral stem. Damage caused by sequence of registered herbicides is also known. Massive solidification of the soil can cause fat growth of root neck or beet deformation of roots. Seedless capsules as a specific poppy damage that is caused by the influence of stress factors (herbicides, soil conditions, high amount of plant chemicals) at elongation growth phase, followed by inappropriate weather at the blossom time. Atypical biotic damage can be caused by diseases Fusarium sp., Sclerotinia sclerotiorum, Botryotinia fuckeliana or bacterial infection. Visual symptoms of fusarial infection (orange colored plant parts or pinkish mycelium) occur only rarely. The often-detected traces of fusariotoxins in the seeds suggest, that the hidden infection of poppy by Fusarium is also possible. Sporadically, Sclerotinia sclerotiorum and Botryotinia fuckeliana can infect stems and capsules too. Lower intensity of bacterial infection (Erwinia carotovora ssp. carotovora) causes the black colored stem basis and root neck. Verticillium sp. causes similar symptoms and so these infections can confused for each other. If the pest damage is unusual, is questionable, because papaver stem midge (Timaspis papaveris) occurs commonly, but this pest is not too well known. The poppy capsule weevil (Neoglocianus maculaalba) is well known in the warmest growth areas and it is now extending to the colder areas too. Hares and roes cause specific biotic damage, when they eat only the buds in the elongation growth stage

Key words: abiotic damage, edible poppy, *Papaver somniferum*, unusual biotic damage

The blue-seeded poppy with low alkaloid content is a popular traditional food in the central Europe. Poppy seeds are used in many traditional dishes and pastry, therefore the taste and overall quality of seeds is very important to the consumers. Poppy as a crop is highly demanding and agrotechnical mistakes can substantially decrease the seed yield and their quality. The poppy is unusually sensitive crop, it can be damaged by influences, that are not too dangerous for other crops, but they can cause heavy damage or liquidation

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of poppy crop. The aim of this work is the presentation of the specific abiotic and biotic damage of poppy, exhibiting the innovative aspects:

— the unknown damage firstly described by the author (root deformation by soil solidification, specific phytotoxicity),
— the known damage with its source identified for the first time (seedless capsules),
— the known damage having specific impact to poppy (lodging, water surplus),
— the known diseases firstly identified at poppy (*Fusarium avenaceum*, *Verticilium* sp.) or having rarely occurring symptoms specific for the poppy (*Sclerotinia sclerotiorum* on the capsules),
— the pests extending to the new area (Neoglocianus maculaalba).

MATERIAL AND METHODS

The main source of knowledge were field trials and farm research since 2000 to the present time. The unusual damage found were recorded and the causes of the damage were identified. Detailed survey of employed growing technology was realized by the affected farmer and by farmers in the neighborhood for comparison. The artificial induction of all damage was tested in the field trials. The weather data were monitored for identification of weather influence to observed damage. The sources of biotic damage were identified on the base of specific symptoms and microscopically, the determination of any diseases was realized in the specialized laboratories. The obtained knowledge originated not from the conventional field trials, therefore the statistical methods were not used here.

Majority of the presented knowledge originated at Opava district. This area has a very good conditions for the poppy cultivation, the poppy yields here are mostly outstanding. The soils in the river valleys are loam-sandy with variable clay component, with occasional appearance of the stony “eyes”. The soils in the hills are sandy-loam with changing stone amount. The soils are fertile and rich with nutrients. The altitude starts at 260 m. Main part of this area is cereal production type, the fields at the higher altitude are potato production type. This area is moderately warm(8,6°C) and moderately moist (567,6 mm). The weather connecting to the specific damage is described in the text.

RESULTS

Unusually long blossom

The renewing blossom (proliferation) is usually an unpleasant complication at crop production resulting in difficult harvest and demanding adjustment of the seeds. On poppy, it is a very dangerous phenomenon leading to a substantial decrease of seed quality (Fig. 1). The renewing blossom is mostly caused by long-term surplus of water in the soil during prolonged rainfalls. The large quantity of late developed capsules causes substantial complications during harvest. The affected crop cannot be desiccated, because no desiccant is registered for poppy at the present time. The residua of glyphosate are strongly monitored contaminants, their detection can lead to return of seed shipment and to sanctions for the seed producers. The harvest must wait to full-ripeness of affected crop.

Fig. 1. The renewing blossom of poppy three weeks after the end of blossom

If the crop is not ripe enough, the soft unripe seeds are crushed during harvest and they quickly become rancid and bitter. Such incorrectly harvested poppy can become unconsumable. If the wet weather prolongs ripening too much, the stems are more fragile, and the capsules fall to the ground. This increases loss of seeds and decreases the seed quality. Such crop supports the weed development, because the soil surface is not sufficiently shaded, and these late weeds cannot be controlled, because no suitable desiccant products are registered.

Lodging

The lodging is a common occurrence in the crop production, dense and over fertilized crops are more sensitive to this condition. The harvested seeds from the lodged crop can be contaminated by sand and soil. To remove such contamination is difficult and special cleaning equipment must be used.

Water surplus in the soil

Long-term wet soil resulting from rainfall surplus can cause large damage, because poppy is very sensitive to it. If anywhere on the flat field water puddles arise, not only the flooded part but the whole field will be usually damaged (Fig. 2, 3). If the poppy vegetates in a too wet soil, the amount of weeds increase as well. Slope fields are less sensitive to water surplus, because the excessive water can flow away. Water surplus in the soil is one of the starting factors for seedless capsules (Havel, 2005). Mahdavi-

Damghani et al. (2010) refer to the water deficit effect on opium poppy, the effect of water surplus is not described in the world literature.

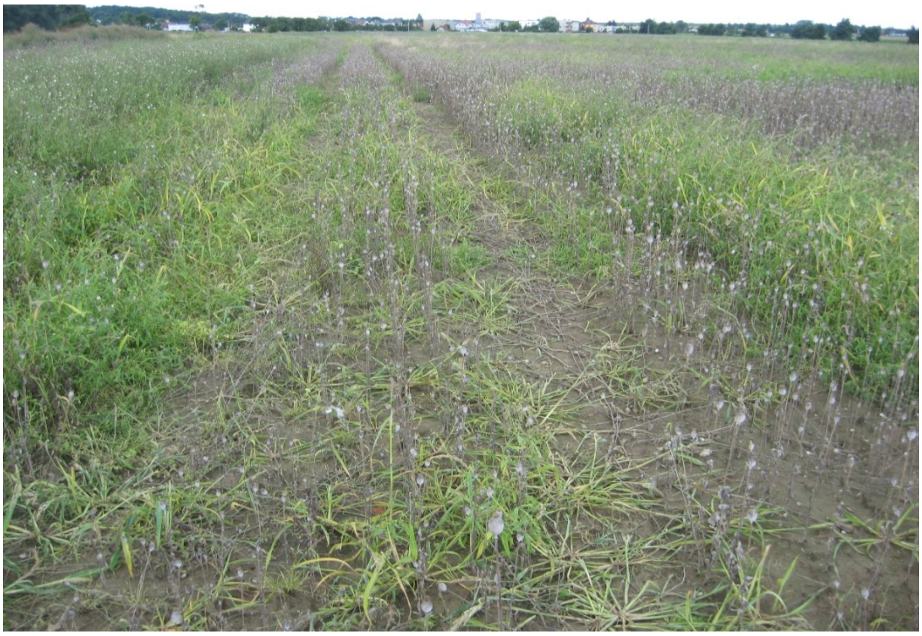

Fig. 2. The crop damaged by water surplus

Fig. 3. Detail of damaged crop

Fig. 4. Fat growth of root neck after sugar beet store (2004)

Fig. 5. Beet like deformation of roots after sugar beet store 2007 (left)

Soil solidification

The massive solidification of the soil causes root deformation of poppy from the fat growth of root neck (Fig. 4) to the beet like deformation of roots (Fig. 5). This damage occurs mainly at headlands, entrances to fields (Havel 2005) and on the localities where sugar beet was previously stored (Havel 2008). The solidification causes plant weakness and can be the starting factor for seedless capsules.

The glued petals

The glued petals are caused mainly by rainy weather. This damage can look quite horrible (Havel 2008), but in reality, it is not too dangerous. Affected capsules ripe mostly normally, only exceptionally this supports development of fungal infection (Fig. 6).

Fig. 6. Petals glued to the capsules

Herbicide damage

The poppy is very sensitive to herbicides, therefore it can be easily damaged. Commonly occurring but not too dangerous is the phytotoxicity caused by registered herbicides. The phytotoxicity caused by mesotrione and tembotrione (Havel, 2008) exhibits large scale of symptoms from minimal, unobservable phytotoxicity over chlorosis to the border necrosis of oldest leaves (Fig. 7). The factors affecting the final phytotoxicity are unfortunately unknown. Pinke G. et al. (2014) describe the typical phytotoxicity caused by combination of mesotrione and tembotrione. The use of clomazone as a post-emergence herbicide (Macleod 1997) is nor realizable in Czech Republic for the too high danger of phytotoxicity.

Fig. 7. Tembotrione phytotoxicity at the oldest leaves

Dangerous phytotoxicity can be caused by the treatment with unregistered herbicides. Mixing of unregistered herbicides together with registered ones is not encountered nowadays (Havel, 2008). This practice seemed to disappear with the registration of new effective herbicides. These mixtures were not much more effective, but they were substantially more dangerous to poppy (Fig. 8). More often, the treatment with unregistered herbicides is encountered as a result of inexpertly recommendation. This is very dangerous too, because such application is insufficiently tested and the effectivity between localities can be substantially different. Such practice is enjoyed too.

Very dangerous mistakes can originate from irresponsible or insufficiently instructed sprayer operators. The common mistake is insufficient cleaning of the sprayer between applications. The formulations of solid matter dispersed into liquid carrier (for example formulation SC and WG) have the tendency to sediment in the sprayer and cleaning by pure water it is not sufficient. These sediments are released by using further product with larger emulgation ability and will damage the treated crop. Special product must be used for the cleaning of sprayer between treatments.

Fig. 8. The spiral stem deformation by the mixture of chlortolurone and small quantity of unregistered 2, 4-D

Fig. 9. The poppy plants destroyed by the rest of 2, 4-D and florasulam in the sprayer

Even worse is the situation, when the operator does not clean the sprayer, because he thinks, that a few residual drops won't cause any damage. In one such case the remaining cereal herbicide (Fig. 9) destroyed the poppy on whole treated area (Havel, 2016).

Severe damage of the crop can occur by using the sequence of registered herbicides. The phytotoxicity of the sequence chlortolurone — isoproturone is known for a long time. The phytotoxicity of herbicide sequences was tested in 2011 in the field trial. The phytotoxicity of sequence chlortolurone — izoproturone was not observed. The possible reason can be, that since the registration of the products containing isoproturone was terminated, a substitute of unregistered product had to be used instead. The unexpected severe phytotoxicity appeared also at the sequences of registered herbicide (besides tembotrione) — tembotrione (Havel, 2016), the sequence tembotrione — tembotrione caused no phytotoxicity. This might have been caused by water surplus in the soil (Fig. 10). In 2012 the trial was repeated and the phytotoxicity did not appear during normal weather course.

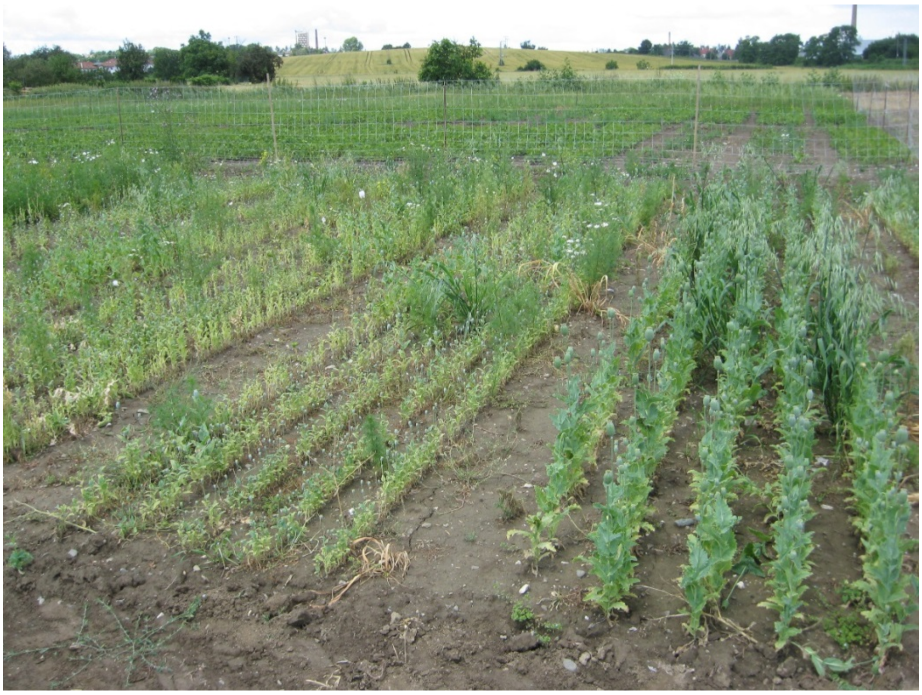

Fig. 10. The phytotoxicity of the sequence registered herbicides — tembotrione

Very specific damage appeared by the treatment with graminicides (Tab. 1). Graminicides are known to be very safe products, exhibiting generally no phytotoxicity at poppy. They were used for a long time generally without problems, but suddenly a fatal phytotoxicity occurred. First damage was observed in 2014 (Fig. 11), the undamaged part of the crop was treated with the identical preparate and the same dose one month earlier.

Table 1

The dependence of chizafop-P-tefuryl influence to poppy on the day/night difference

Application date	The day/night difference oC	Resulting effect	Remarks
06.15.2014	19	destruction of the borders	late treated borders of crop for the seed multiplication
06.15.2015	approx. 15	no phytotoxicity	test of late treatment
05.26.2016	20	60 ha destroyed	crop of local farmer
06.12.2016	10	no phytotoxicity	test at crop without waxy layer after rain with reverberate herbicidal phytotoxicity
05.29.2017	15,5	no phytotoxicity	application at the start of tropical days period
06.20.2017	18,3	no phytotoxicity	application at the start of tropical days period

Fig. 11. Damage caused by chizafop-P-tefuryl

The delayed treatment of graminicides before blossom was tested in 2015 with the aim to identify the cause of this damage, and no phytotoxicity appeared in this test. In 2016 poppy of a local farmer on 60 ha area was destroyed, which gave the impulse to test the graminicide treatment of the crop this year without the leaf waxy layer and with the visual phytotoxicity after the treatment of herbicide mixture. The trial conditions were as similar as possible to those of the affected farmer, but no phytotoxicity appeared. Based on similar problems observed on clover, the large difference of air temperature in the day and night was identified as the potential cause. The analysis of meteorological data at time of treatment showed, that the temperature difference must be about 20°C and maybe combined with the night temperature decreasing under 10°C. In 2017 the graminicide treatments were tested at the start of two periods with high day temperature. However, phytotoxicity didn't occur, because the nights were too temperate, and the temperature differences were insufficient (Havel, unpublished data)

The joint treatment of agrochemicals

The tank-mix treatment of agrochemicals is commonly used in plant production to reduce the cost of application. This treatment is used for poppy too, however if the final mixture contains too many components, it can induce the seedless capsules at poppy (Havel, 2011) or damage the crop by phytotoxicity.

Seedless capsules

Seedless capsules (Fig. 12) are one of the most dangerous abiotic damage of poppy. Although this damage is known for a long time, its symptoms were described only by Benada et al. (1963) with the declaration, that the cause is unknown. The newer literature does not describe this damage at all. This damage can decrease the seed yield to only 20% (Havel, 2011). Fortunately, this damage occurs rarely, because of its complicated origin. The research started at 2004 by discovering a large amount of seedless capsules near Opava. The relevant data from field trials and connecting data provided by the affected farmers were collected and analyzed (Havel, 2004). The initial factor is the damage of poppy in the start of the elongation growth by water surplus, soil solidification, use of herbicides or combination of agrochemicals. The solidification of soil does not cause large damage, because it occurs only on a part of the field. These other factors however probably cause decrease or loss of pollen viability.

Fig. 12. Seedless capsules at poppy

When the pollen of affected plants has low viability or is unviable, the auto-pollination is impossible. Further development of the damage is based on the weather during the blossom (Fig. 13).

Fig. 13. Mixed seedless and normal capsules at one plant — one from the keys for the understanding of the origin of this damage

If the weather is sunny during the blossom and enough bees pollinate the crop, the poppy is easily cross-pollinated by the functional pollen and the seedless capsules do not appear. Only when the poppy blossom during rainy weather, and its own pollen is unviable can the seedless capsules occur. The self-pollination is impossible, and the cross-pollination cannot be realized because bees are not able to fly (Havel, 2006, 2008, 2011, 2016). The latest significant occurrence of the seedless capsules was in 2016 near Svitavy and Opava. Unspecified information showed the occurrence of this damage in 2017 too (Havel, unpublished data).

Unusual biotic damage

Virus infection

The Turnip Mosaic Virus is naturally occurring on poppy, the Beet Western Virus and Beet Yellow Virus occur probably too. The further artificial infections by different viruses were also successful (Kubelková, Špak, 1999). However, the infected plants displaying the visible symptoms are sporadic (Fig. 14). Tang et al. (2016) describe the new opium poppy mosaic virus (OPMV) in New Zealand.

Fig. 14. An unidentified viral infection at the poppy

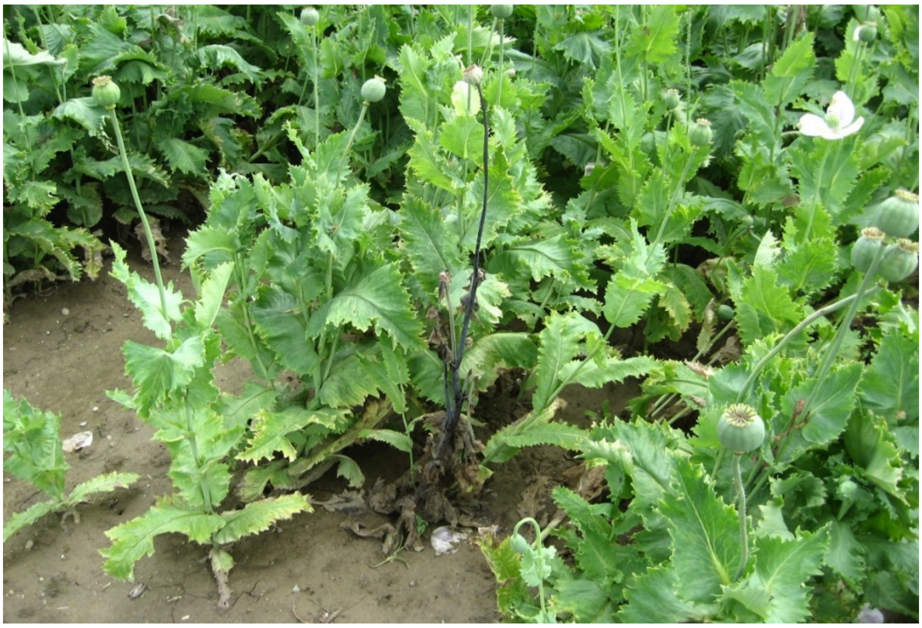

Fig. 15. The typical bacterial infection

Bacterial infection, the stem darkening

Plants with typical symptoms of bacterial infection (dry plant with black-violet stem) occur rarely during wet years (Havel, 2016; Fig. 15). The black spots and black stem bases („black foots“) occur substantially often (Fig. 16). The bacterium Erwinia carotovora ssp. carotovora was identified on parts of infected plants (Havel, 2008, 2016). At different samples the fungal disease Verticilium sp. was found (Prokinova, oral presentation). The infected plants were found in 2017 near Opava, the presence of Verticilium sp. was confirmed by PCR analysis and ELISA test (Havel, Horacek, unpublished data).

Fig. 16. Stem blackening combined by the infection of Fusarium sp. (light spot).

Fusarial infection

The repeated detection of fusariotoxins in the seed samples from farmer production show the presence of Fusarium sp. in the poppy crops. The detected concentrations of mycotoxins are very low, almost on the detection limits. The plants with visible symptoms (pinkish mycelium) are very rare (Havel, 2008, 2016; Fig. 17). Fusarium avenaceum was identified in 2009 as the infection source at the poppy (Havel et al., 2009), the identification on the newer samples was still not successful. Lecomte et al. (2016) describe the plant diseases caused by Fusarium oxysporum at the ornamental plants incl. poppy. The seeds of the Iceland poppy (Papaver nudicaule) were contamined by Fusarium oxysporum (Bertetti et al., 2017), what was identified like Fusarium oxysporum f.sp. papaveris (Ortu et al., 2017). Pastircar and Feier (2014) detected the occurrence of F. equiseti and F. poae on poppy capsules.

Fig. 17. The infection of Fusarium sp. in the stem

White mold (Sclerotinia sclerotiorum)

The fungus Sclerotinia sclerotiorum attacks many plant species, the poppy is infected too. For this disease the whitish part of stem with black sclerotia inside is most typical, the infection of the capsules is extremely rare (in Baranyk et al., 2010; Fig. 18). The infected plants turn yellow, these symptoms can be in the concrete developmental phase similar to viral infection (Havel, 2016). The occurrence of infected plants is sporadic, and the control is not necessary.

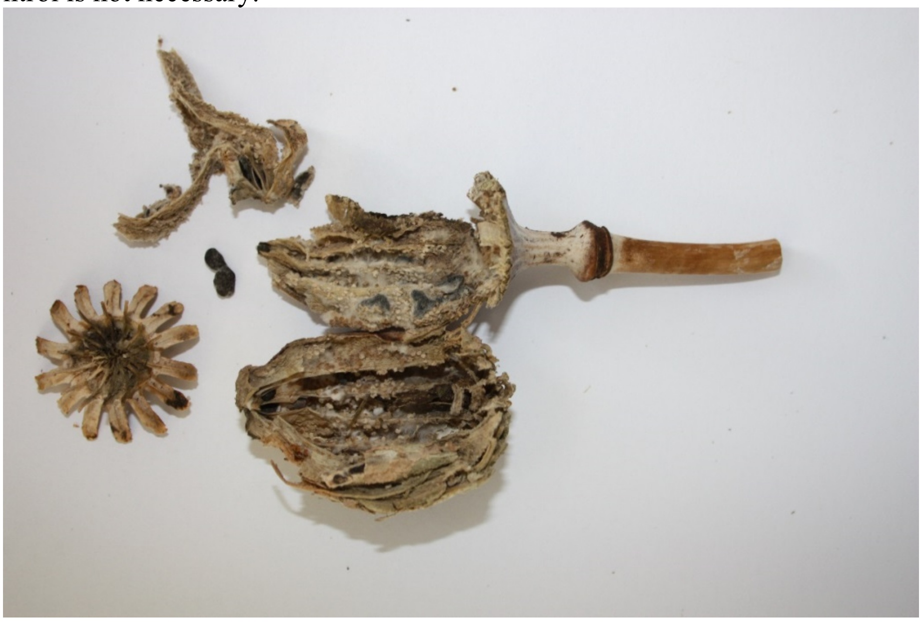

Fig. 18. The capsule infected by Sclerotinia sclerotiorum

Grey mold (Botryotinia fuckeliana)

The typical grey hairy mycelium occurs at all plant parts mainly during wet weather (Fig. 19). The infection symptoms are easily visible on the capsules (in Baranyk et al. 2010). The occurrence of the infected plants is minimal, the protection is not necessary.

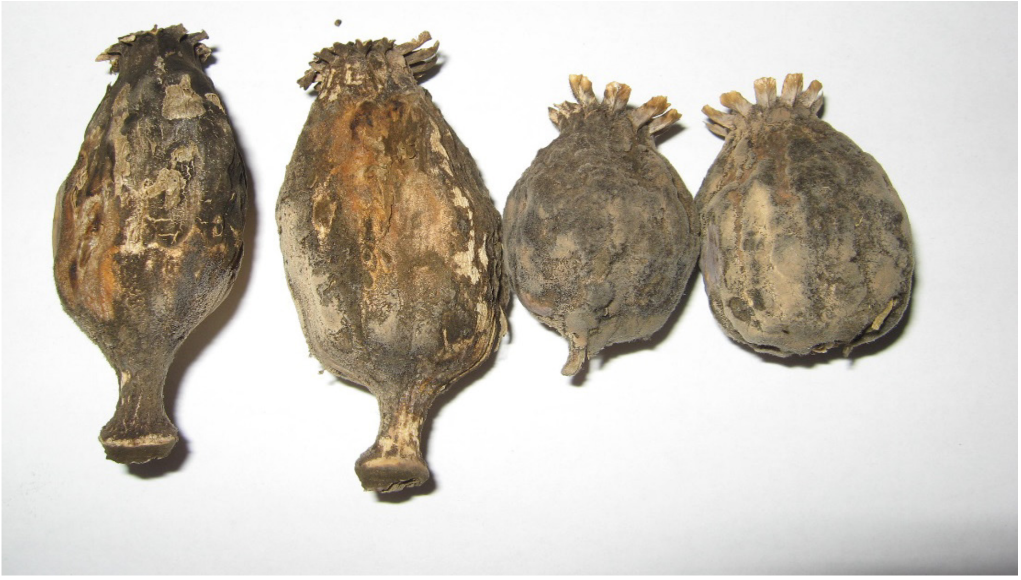

Fig. 19. Grey mold on the capsules

Fig. 20. Stems damaged by Timaspis papaveris

The pests

Poppy stem gall wasp Timaspis papaveris

Timaspis papaveris occurs commonly, but this pest is not too well known for the hidden life style of its larvae and inconspicuous, small imagoes. The larvae damage is hidden in the stems (Fig. 20) and the pests make mostly no visible signs on the plants. The plants wither early at the strong infection. The monitoring is difficult and higher infection occurs rarely, the control is not performed.

Fig. 21. The capsule damaged by the weevil Neoglocianus maculaalba

Poppy capsule weevil (Neoglocianus maculaalba)

This weevil (Fig. 21) is well known in the temperate parts of Czech Republic, the control there is the standard part of the poppy grown technology (Kolařík et al., 2016). The larvae eat the seeds in capsules, the eating can substantially decrease the seed yield and quality. This weevil appeared in the colder areas only recently. This pest started to spread here in the last five years and its presence must be monitored now. The incidence rate is still mostly sporadic, the higher infected fields necessary to be controlled are found seldom (Havel, unpublished data). This weevil is long time known at warmer Europian areas (Saringer, 1991), there the control of this pest must be realized. Poppy capsule midge (Dasineura papaveris) eat seeds too. This midge occur only in the temperate areas of Czech Republic and was not observed in the colder areas. The control targeted to the capsule weevils is effective against the midge too. Poppy gall wasp (Aylax papaveris) and poppy wasp (Aylax minor) create tumors inside the capsules. Their occurrence was not observed in a longer term.

Wild animals

The poppy is not too attractive for wild animals and so this type of damage is rare. The specific damage of this type is the devouring of young buds before blossom by roe deer and hares

Human damage

Besides thefts of mature poppy, it is mainly the cutting of immature capsules (Fig. 22) with the aim to obtain opium. Such activities are doomed in advance to fiasco, because cultivated edible varieties of poppy contain only a small quantity of alkaloids and obtaining opium by the traditional way is extremely ineffective. Moreover, the drug abusers cut the capsules mostly incorrectly (Fig. 22). The total absence of local news about the poppy abuse is the best testimony to the unsuccessfulness of such activities, the abuse of medicaments is substantially easier. The growing of pharmaceutical morphine-rich poppies increases the danger of the abuse. Martinez et al. (2016) describe the death of a 32-year-old male in the legal pharmauceutical poppy field in Spain. Authors however stated, that other similar cases are not known.

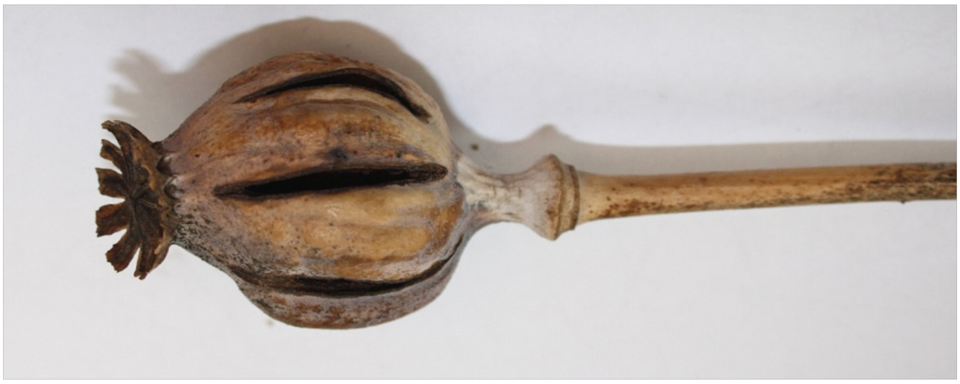

Fig. 22. The capsule damaged by drug abuser

CONCLUSION

This work contains the knowledge obtained in the last 15 years of author´s poppy research. The neighborhood of Opava has excellent conditions for poppy growing, almost all farmers cultivate poppy and this allowed the collection of so much new information. The author is grateful to the farmers for the support of initial data connecting to the poppy growing and to the coworkers for the assistance and understanding. Without these supports this work could not be created.

REMARK

The web of knowledge contains to the present time 2489 bibliographic references connecting to the word poppy. Three quarters of this references are totally out of topic, and the main part of the rest is orientated to the drug abuse and toxicology. Citations connecting to this article are rare and references to abiotical damage are none. The discussion cannot be more extended therefore.

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