SEED-BORNE PESTS AND DISEASES OF FABA BEANS (*Vicia faba*)

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Introduction

Faba beans (*Vicia faba* L.) originated in the area between Afghanistan and the Eastern Mediterranean (Lawes *et al.*, 1983). Hawtin & Hebblethwaite (1983) reviewed the ancient literature and found that the crop was mentioned in Sumerian, Egyptian, Hittite, Greek and Roman sources. The world production has slightly increased since 1979 and was 4.5 million tonnes in 1987. Countries with high production are China, Egypt, Ethiopia, France, Germany, Italy and Morocco (FAO, 1988). The crop may be used as animal feed, human food (either as dry beans or fresh vegetable), as green manure, or as green fodder (Hawtin & Hebblethwaite, 1983).

The crop is grown under widely ranging climatic conditions, as far north as in Scandiniavia, as well as in the highlands of Ethiopia, at high altitudes in the northern part of the Indian subcontinent, and in the Andean region of Latin America (Hawtin & Hebblethwaite, 1983).

There is some confusion as to the nomenclature of *Vicia faba*. In older literature the common name "broadbean" is given, with "horsebean" for ssp. *equina* and "small horsebean" for ssp. *minor* (Kelsey & Dayton, 1942). Occasionally the name "tick bean" can be found. Hawtin & Hebblethwaite (1983) reported that the species *faba* is subdivided into the two subspecies *paucijuga* and *eu-fabae*, the latter with the varieties *major* (large-seeded), *equina* (intermediate) and *minor* (small-seeded). The term "field bean", which is frequently used in Europe for small and intermediate types, describes *Phaseolus vulgaris* in many other parts of the world. The name "faba bean" seems to be widely accepted for the entire species, and therefore is used in this paper.

As with many other crops, pests and diseases are among the factors limiting production of high yields. Their distribution depends largely on climatic factors. In moist environments, the fungal pathogens are particularly abundant, e.g., in the coastal areas of Morocco and Syria, in areas with a high rainfall (Germany, UK) or under sprinkler irrigation. Besides climatic factors, the distribution of a crop in an area and the varieties grown determine the relative importance of a pest or pathogen. Probably the most devastating pathogen is *Orobanche crenata*, which forced farmers in some areas of Morocco to give up faba bean cultivation in infested fields (Schlüter & Aber, 1980). Rust, *Ascochyta* blight and chocolate spot cause severe yield losses under conditions conducive to disease development. Viruses, although sometimes not easily identified, also can reduce yields significantly.

Under the heading "control measures", one method is common to each disease/pest: the use of resistant varieties. Although there are numerous reports about breeding for resistance and work is underway to achieve multiple-disease resistance (Nene, 1988), there seem to be few commercial varieties that prove resistant under different conditions. Moreover, few varieties show a stable resistance: "unfortunately pathogens change and resistance melts like snow in summer" (Griffiths, 1978). This aspect is consequently omitted from the text.

Chapter 1
Inspection and Seed Testing

Field inspection and seed health testing can help to ensure production of healthy seeds. Low disease or pest incidence is generally difficult to detect in either the field or the laboratory. The combination of field inspection and laboratory seed health testing proves particularly useful in such cases. The two approaches are also complementary in the sense that a laboratory test may be necessary for proper identification of a disease found in the field. On the other hand, viruses may be latent, i.e., the affected plants may not show any symptoms, although the virus is transmitted to the seeds. In this instance a laboratory test is the only way to assess the health status of the seeds. Specific points concerning laboratory test methods in particular are addressed in each following chapter. Some general comments follow.

Field Inspection

Successful seed production programs always include a field inspection component (Fig. 1). However, the emphasis is clearly on trueness to cultivar (Kelly, 1988). Inspectors trained in cultivar identification may lack the experience to recognize locally uncommon seed-borne diseases. It is, therefore, of utmost importance that field inspectors receive training in aspects of plant pathology, to the extent that they can then advise growers on possible plant protection measures. Naturally, their knowledge must be kept up to date.

Inspection for plant diseases needs to follow a sampling procedure such as that used for the inspection for genetic purity. Sample areas should be randomly

Fig. 1. Field inspection in a faba bean crop

selected and carefully inspected. Size and quantity of sample areas depend on the crop and the field size. Also, timing may be crucial; inspection for trueness to cultivar is generally conducted at, or just after, flowering (Kelly, 1988). However, earlier timing may be desirable for plant disease inspection in order to rogue virus-infected plants before the virus can spread, or to apply pesticides at the right time.

Seed Health Testing

Neergaard (1977) provided a comprehensive description of techniques for seed health testing. For some crops and pathogens, standardized methods are prescribed in the International Rules for Seed Testing (ISTA, 1985a, 1985b). The appropriate method to use largely depends on the pathogen in question. Very few pathogens can be detected by direct examination, even with the help of a hand lens or a stereoscopic microscope (Fig. 2). Whereas some pathogens, e.g., *Ascochyta fabae*, cause discolouration of the seeds, the lack of such symptoms can not guarantee absence of the pathogen. Insect infestation can be readily detected by visual inspection (Fig. 3).

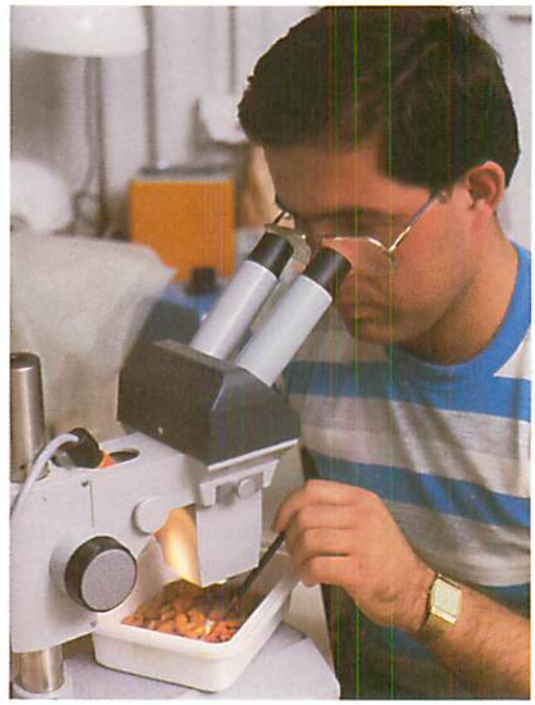


Fig. 2. Direct inspection of faba bean seeds by stereoscopic microscope

Fig. 3. Faba bean seeds in direct inspection, showing symptoms of bruchid infestation (bottom right), broad bean stain virus (top right), *Ascochyta fabae* (center), and unknown etiology (others)

Fig. 4. Washing of seeds to remove surface-borne contamination with fungal spores. The detergent is added to reduce the surface tension

Pathogens borne on the seed surface, such as fungal spores or bacteria, can be removed by washing the seeds (Fig. 4). The liquid can be checked microscopically or can be plated on a suitable medium, either directly or after concentrating, e.g., by centrifugation. However, many fungi are carried internally, in the seed coat, or in the cotyledons. These infections can best be detected by incubating the seeds on a suitable medium such as blotter paper or agar plates. The blotter paper could be replaced by other absorbent material like cotton wool, tissue paper, etc. (Fig. 5).

Pleated strips (Fig. 6), which are useful in testing small seeds, are not practical for faba beans. If seeds are incubated without surface sterilization (pretreatment), common saprophytes may develop and overgrow seeds as well as slow-growing pathogens (Fig. 7). Therefore the International Seed Testing Association (ISTA, 1985b) recommends soaking the seeds for 10 min in a solution containing 1% w/w available chlorine. Care must be taken that the seeds are kept moist throughout the incubation. Excess water, however, could cause contamination of healthy seeds by disseminating spores.

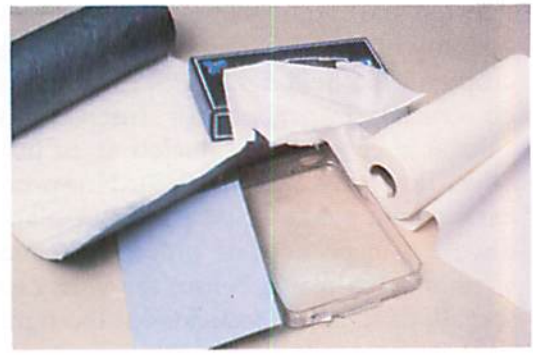


Fig. 5. Suitable media for a blotter test

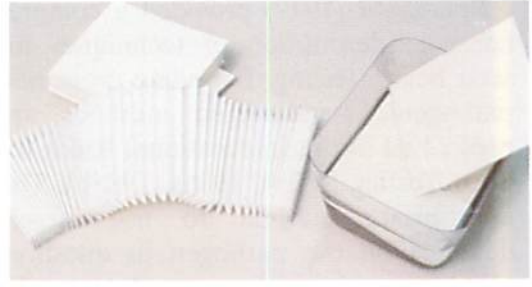


Fig. 6. Pleated filter paper strips for small seeds

Fig. 7. Faba bean seeds overgrown with saprophytes

While petri dishes are suitable for small seeds like rapeseed, larger containers with a lid are appropriate for faba beans (Fig. 8). Containers can be sealed with masking tape in order to retain sufficient moisture during incubation. The standard incubation time is 7 days, and the standard temperature is 20°C; deviations may be advisable. A 12/12-hour light cycle, either artificial white or near-UV light, stimulates the sporulation of some pathogens. The developing colonies are evaluated by stereomicroscope; identification of spores by compound microscope may be necessary. The blotter test is simple and does not require sophisticated equipment.

In the agar plate test, generally only surface-sterilized seeds will be plated (Fig. 9). Sterilization of containers, media, tools, and work area is essential (Fig. 10), and care must be taken not to contaminate the plates (Fig. 11). Incubation and evaluation are the same as for the blotter test.

Fig. 8. Plastic containers sealed with masking tape being arranged for incubation

Fig. 10. Sterilizing a pair of tweezers over a flame after dipping them in alcohol

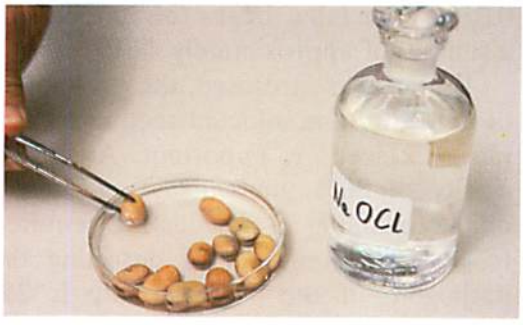


Fig. 9. Pretreatment of seeds by soaking in sodium hypochlorite

Fig. 11. Plating seeds in a petri dish with faba bean dextrose agar

Viruses can be detected in a "growing-on test": planting the seeds and observing the seedlings for symptoms of virus infection. However, the symptoms may not be expressed under all conditions, or not at all if the virus is latent. Viruses can be seen by electron microscope after adequate preparation of sap samples. Most other detection methods in virology, i.e., latex agglutination and passive hemagglutination assays, enzyme-linked immunosorbent assay (ELISA, Fig. 12), radioimmunoassay (RIA), and immunoelectron microscopy (IEM), depend on the detection of virus antigens (coat protein), whereas various "blot tests" permit the detection of specific viral nucleic acids by the use of isotope-labelled complementary DNA.

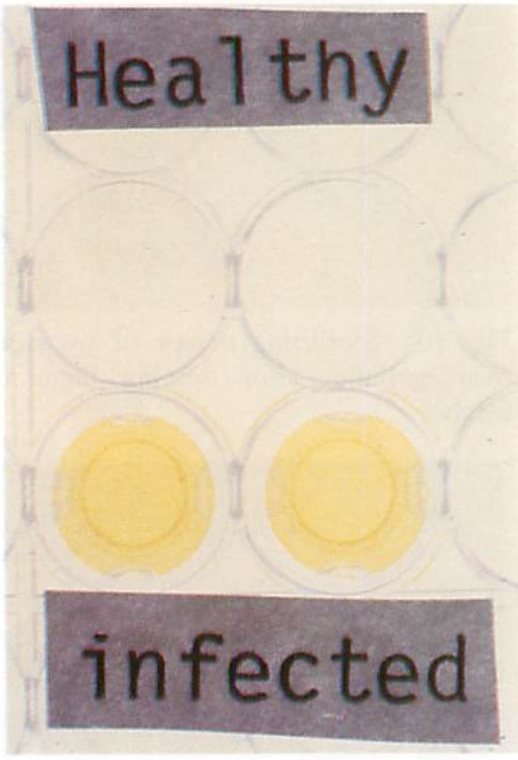


Fig. 12. A plate ready for reading an ELISA test. The yellow spots are positive for the virus

With immunosorbent assays the detection of 1-2% seed infection is possible. A clear disadvantage for the interpretation of the tests is the fact that there is no discrimination between infective and noninfective virus particles. Furthermore, it is important to distinguish between viruses located in the embryo, which may cause seedling infection, and those in or on the seed coat, which most likely will not infect the seedling. Thus serological tests should be conducted on germinated seedlings rather than on seeds (Hamilton, 1983).

Occasionally quarantine authorities request that seed lots be free from a certain pathogen. However, all that can be reasonably testified is that the level of infection or infestation is less than a specified percentage. Sensitivity of the method used in seed health testing and the sample size are very important factors. Geng *et al.* (1983) elaborated on the sample size necessary for testing a seed sample directly or indirectly by bioassays. In one example they established that a sample size of 48,000 seeds is required to be 99% sure that a seed lot will be rejected if its disease rate is greater than an established standard of 0.1%, and to have 95% confidence that a seed lot will not be rejected if its disease rate is less than 0.05%. For faba beans this amounts to a sample of approximately 48 kg!

If bioassays are used, the probability of detecting one infected seed in a sample of x seeds is important. At a sensitivity of 80%, nine assays of sample units containing 347 seeds are required to be 99% confident of detecting the pathogen if the disease rate is 2% (Geng *et al.*, 1983).

The sampling method of a seed lot is of utmost importance. If the sample does

not adequately represent the lot, the results of even the most sophisticated tests will not be meaningful. ISTA has developed detailed rules for sampling, which, when followed, assure that the sample accurately represents the seed lot in question (ISTA, 1985a, 1985b).

Although the importance of quantifying the inoculum per seed and the relation of inoculum to disease expression has been recognized (Colhoun, 1983), there are still considerable difficulties for many pathogens. No problems are encountered with pathogens that are exclusively surface-borne, such as *Tilletia* spp. on wheat. The spores can be washed off the seeds and counted. A similar method can be employed for bacteria such as *Xanthomonas campestris*, where internally seed-borne bacteria ooze into sterile saline that can be plated on a selective medium in dilutions so that colonies can be counted after incubation (Schaad, 1982). With other pathogens, e.g., *Fusarium* spp. and *Ascochyta* spp., only a differentiation between superficial and deep-seated inoculum can be made by sterilizing the seed surface before the test.

Little is known about the importance of surface-borne inoculum in disease epidemiology. The differences found by various authors in the relation between seed infection and disease incidence of the emerging plants could be due to the lack of quantifying a mild or severe infection. Such considerations are also important when it comes to the establishment of tolerances in quarantine regulations.

Chapter 2
Viral Diseases

Cockbain (1983) described in detail 57 virus and virus-like diseases of faba bean, including diseases caused by mycoplasma-like organisms. Many of the pathogens infect mainly or also other crops such as pea, alfalfa and *Phaseolus* bean. Bos *et al.* (1988) reported that seven of the viruses discovered in faba beans are seed-transmitted, with the transmission rate depending greatly on the virus, virus strain, host species and host cultivar. Only three of them seem to be important: broad bean stain virus (BBSV), broad bean true mosaic virus (BBTMV), and bean yellow mosaic virus (BYMV). For others, seed transmission is doubtful, or apparently does not play an important role. However, because many viruses have a wide host range, introduction into a new area with seeds of one of the less important hosts could be disastrous for other crops.

Some facts apply to all seed-borne viruses, e.g., that infection of the mother plant after flowering rarely leads to seed infection, or that infected seeds and seedlings may appear healthy and that symptoms on the seed coat do not prove embryo infection (Bos *et al.*, 1988). All seed-borne viruses also have other means of transmission such as contact, nematodes, insects, fungi, or pollen. However, survival is longer in seeds than in pollen or in vectors, and the spread is more efficient with seed than with the other means (Thresh, 1978). Several viruses described long ago were recently for the first time reported to be seed-transmitted. Reasons for not recognizing the seed transmission earlier are given by Mathur *et al.* (1988): lack of epidemiological investigation, low seed transmission frequencies, seed-borne but symptomless infection in certain hosts, and deficiency in suitable and sensitive detection methods. It is quite likely in the future that more faba bean viruses will be reported to be seed-transmitted, e.g., those reported to be seed-transmitted in other crops, such as cowpea mosaic virus, tomato spotted wilt virus, or bean common mosaic virus.

There is no way to eradicate a virus from embryo-infected seeds, or to cure plants from virus infection. Therefore, control is limited to the application of certification schemes, production of seed from virus-free stocks under vector-free conditions, and/or vector control and use of resistant cultivars where feasible. Hamilton (1983) stressed the need to start programs against seed-borne viruses at the basic level of the germplasm collection available to the plant breeder.

To prevent the spread of virus-infected seeds to areas where the virus did not previously occur, quarantine measures such as seed health testing, planting of imported seeds in containment, or third-country quarantine may have to be imposed.

Broad Bean Stain Virus (BBSV)

Geographical distribution

Gibbs *et al.* (1968) isolated BBSV in England for the first time in 1960 from plants grown from seeds from North Africa, mainly Morocco. Russo *et al.* (1982) described BBSV for the first time

in southern Italy and assumed that the virus had been introduced with infected seeds from North Africa. BBSV was reported for the first time in China in 1985 (Liang Xun Yi, 1986). In addition, Cockbain (1983) quoted reports of BBSV from Australia, Czechoslovakia, Egypt, France, Germany and Sweden. Makkouk *et al.* (1987) reported BBSV for the first time from Lebanon, Sudan, Syria and Tunisia.

Economic importance

Fischer & Lockhart (1976) suspected a yield loss of about 70% if infection with BBSV occurred before flowering, whereas in Scotland Jones (1978) could not find a significant yield loss in plants inoculated 11 weeks after sowing. Cockbain (1983) quoted 44% yield loss in plants inoculated 3 weeks before flowering with BBSV, and 62% loss if plants were inoculated with BBSV and BBTMV. In England some crops were found to be infected with these viruses at 60-90%, and many at 20-40% (Cockbain, 1980). Makkouk *et al.* (1988a) recorded 84% yield loss in plants inoculated with BBSV 11 weeks after sowing.

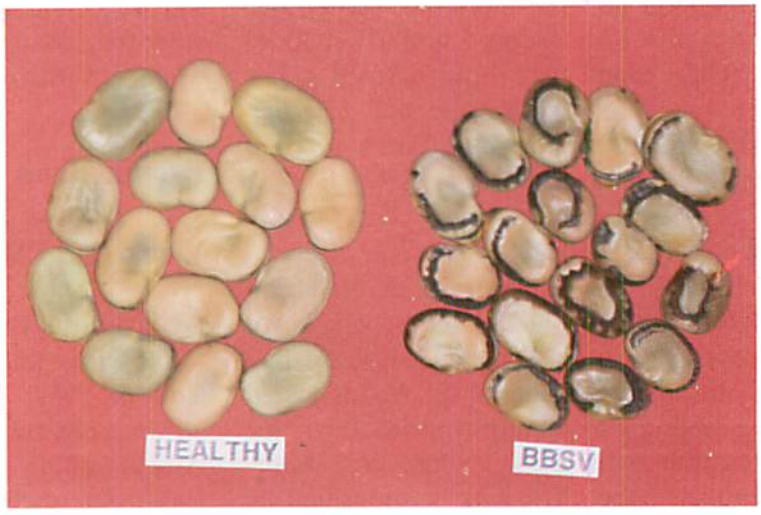
Symptoms

Gibbs & Smith (1970) described chlorotic mottling and mosaic of the leaves (Fig. 13a). In addition, Russo *et al.* (1982) found reduced growth, poor fruit setting, deformation of pods and brown discolouration of the seeds (Fig. 13b). Symptoms are worse in cold weather than in hot (Dixon, 1981a).

Pathogen

BBSV belongs to the comovirus group. The particles, about 25 nm in diameter, are angular isometric, and, when centrifuged, sediment as three components (Gibbs & Smith, 1970).

a



b

Fig. 13. (a) Symptoms of broad bean stain virus on faba bean leaves; (b) symptoms of broad bean stain virus on faba bean seeds

Epidemiology

The hosts of BBSV are restricted to the Leguminosae (Gibbs & Smith, 1970). Makkouk *et al.* (1987) found latent infection in 12 wild species, as well as in chickpea, lentil, vetches and subterranean clover. Symptoms were produced in faba bean (mild mottle), pea (diffuse mottle), *Medicago arabica* (L.) Huds. and *Trifolium spumosum* L. The virus is transmitted by the curculionids *Apion* spp., particularly *A. vorax*, and *Sitona* spp.; *A. vorax* is the most efficient vector (Cockbain *et al.*, 1975). Jones (1978) found that the virus did not spread in commercial crops containing seed-borne infection, although *Sitona* spp. were abundant in many fields. Vorra-Urai & Cockbain (1977) found that virus-infected seeds produced infected seedlings after storage up to 4 years. The highest transmission rate through seeds was 16%. However, plants remaining uninfected until after flowering failed to transmit the virus to the seeds. Jones (1978) found the same effect of time of plant infection, but detected a maximum of only 2.7% infected seedlings. Transmission through seeds is reported to be up to 40% (Russo *et al.*, 1982). Hamilton (1983) reported a seed transmission rate between 1 and 10%. Jones (1980b) found that most infected plants produced few seeds. Infected wild legume species may be important sources of infection (Makkouk *et al.*, 1987).

Detection in seed

The procedure used in Scotland involves sowing 100-200 seeds, which are kept in cool, frost-free glasshouses. Sap from symptom-bearing plants is tested by the agar gel-diffusion method for reaction with BBSV antiserum. Alternatively, the virus may be identified by its reaction to different test plants (Jones, 1980a). In contrast, Russo *et al.* (1982) found that in a growing-on test symptoms showed up clearly only in full summer, whereas in other seasons infection was almost latent. Immunosorbent electron microscopy (ISEM) of separated embryo axes proved to be very reliable (Russo *et al.*, 1982). Lester (1982) also detected the virus in seed by ISEM. Makkouk *et al.* (1986) discovered the virus by ELISA in germinated seedlings. Makkouk *et al.* (1987) could detect BBSV in ground faba bean seeds in mixtures of infected and healthy seeds of up to 1:400 by ELISA. The virus was detected in embryo axes and cotyledons of seeds with and without symptoms of virus infection. No virus could be found in the seed coats.

Control

Fischer & Lockhart (1976) recommended the use of healthy seeds and avoidance of the proximity of garden peas, which are also susceptible to the disease. According to Cockbain (1980), the spread of the virus can be suppressed by vector control with insecticides, but better results can be expected with virus-free seed. He also found that achieving virus-free seed by roguing was difficult when *A. vorax* was common.

Broad Bean True Mosaic Virus syn. Echtes Ackerbohnenmosaik-Virus (BBTMV)

Geographical distribution

The virus was first recorded in England in 1959, isolated from plants grown from seeds imported from North Africa, mainly Morocco (Gibbs *et al.*, 1968). Thereafter, it was introduced into

Australia with seeds from the UK (Randles & Dube, 1977). The first record in Italy is from Gallitelli *et al.* (1978). In China, the virus was first found in 1985 (Liang Xun Yi, 1986). In addition, Cockbain (1983) quoted reports from Egypt, Germany, Lebanon, Poland, Romania, Sweden and USSR.

Economic importance

In a field experiment in Scotland, Jones (1978) found a yield reduction of about 20% in plants inoculated 11 weeks after sowing, and 62% in plants grown from seed infected with either BBTMV or BBSV. Cockbain (1983) quoted 30-59% yield losses with inoculation at the seedling stage in Poland, 38% for the same inoculation time in Egypt, and 41% with inoculation 3 weeks before flowering in England. Bailiss & Senananyake (1984) found that the virus reduced yield by 80% in glasshouse-grown plants and by 89% in field-grown plants.

Symptoms

Gibbs & Paul (1970) described a mosaic and malformation of the leaves, and stunting of the whole plant. Severity of symptoms and virus concentration in the youngest leaves vary cyclically throughout the growth of the plant. Gallitelli *et al.* (1978) also reported severe deformation accompanied by necrosis of seeds. In addition, Smith *et al.* (1988) mentioned a systemic leaf mottling, which was indistinguishable from that induced by broad bean stain virus. According to the same source, infected seedlings are severely stunted and produce few seeds.

Pathogen

The isometric virus of 28 nm diameter is serologically related to BBSV (Cockbain, 1983). Gibbs & Paul (1970) suggested the fact that BBSV infects some varieties of *Phaseolus vulgaris* is a means of distinguishing between the two viruses.

Epidemiology

Like BBSV, this virus is transmitted by seed and the weevils *Apion* spp. and *Sitona* spp. (Cockbain *et al.*, 1975). *Sitona* is an inefficient vector (Cockbain *et al.*, 1975; Jones, 1978). According to Gibbs & Paul (1970), the seed transmission rate may be up to 15%. In a 3-year experiment, Cockbain *et al.* (1976) found an average of 0.44%, and a maximum of 1.8% infected seedlings, the latter resulting from a crop with 87% of the plants showing symptoms. Vorra-Urai & Cockbain (1977) reported a maximum seed transmission rate of 5%, and Jones (1978) 2.1%, both in plants infected before flowering. As with BBSV, Jones (1980b) found that infected plants produced few seeds. Despite an apparently low seed transmission rate, infected seed was the main source of infection at Rothamsted Experiment Station, UK (Cockbain, 1980).

Detection in seed

In Scotland, 100-200 seeds are sown and kept in cool, frost-free glasshouses. Sap from symptom-bearing plants is tested by the agar gel-diffusion method for reaction with BBTMV antiserum. Alternatively, the virus may be identified by its reaction to different test plants (Jones, 1980a). The virus was detected in seed by ISEM (Lester, 1982).

Control

According to Cockbain (1980), the spread of the virus can be suppressed, like that of BBSV, by vector control

with insecticides, but better results can be expected with virus-free seed. He also found that achieving virus-free seed by roguing was difficult when *A. vorax* was common.

Bean Yellow Mosaic Virus (BYMV)

Geographical distribution

Sjödin (1980) reported that BYMV, as well as other viruses, was first observed in Sweden at breeding and research stations and was probably imported in foreign breeding material. Cockbain (1983) listed 31 countries in which the virus has been reported.

Economic importance

Inoculation with BYMV at the pre-bloom stage reduced the yield of faba beans in Iran by 44% (Kaiser, 1973). Hampton (1975) found a yield reduction of 41% in BYMV-infected *Phaseolus* plants compared with healthy plants. The yield loss was mostly due to the reduced number of pods per plant (33% compared with healthy plants). Also, there were fewer seeds per pod and lower seed weight in infected plants. Frowd & Bernier (1977) described a clear relation between time of inoculation and yield reduction. They found a yield loss of 96% with the "severe" isolate and an early infection, whereas the yield loss was only 17% with a late infection (61 days after seeding) in both isolates. They also reported up to 75% reduction of root nodulation with an early virus infection. Bailiss & Senanayake (1984) found a yield reduction of 62% in glasshouse-grown plants and 85% in field-grown plants. Makkouk *et al.* (1988a) reported an 81% yield loss in plots inoculated 11 weeks after sowing. They described an almost complete crop failure due to a mixed infection of broad bean mottle virus (BBMV) and BYMV before or during flowering. In contrast, Cockbain (1983) quoted reports from New Zealand that BYMV infection had little effect on yield, and from the USSR of only 11% yield reduction due to the pea mosaic strain.

Omar *et al.* (1986) reported that infection with BYMV increases plant susceptibility to *Botrytis* spp. Virus-infected plants, however, showed a decreased density of pustules of *Uromyces viciae-fabae* (Omar *et al.*, 1986).

Symptoms

The virus causes a mild chlorosis with dark green spots (Fig. 14). In addition, the leaves become slightly deformed and the plants stunted (Smith *et al.*, 1988). Bos *et al.* (1974) found that different isolates caused different symptoms, ranging from chlorotic or necrotic local lesions to systemic green or bright yellow green mosaic, systemic vein chlorosis and curling of top leaves followed by top and stem necrosis, leaf wilting and premature death. In addition to a "mild" isolate causing mosaic only, Frowd & Bernier (1977) described a "severe" isolate that also caused leaf and stem necrosis. Vovlas & Russo (1978) described stunting as well as a strong mosaic of the leaves, followed by necrosis and death of the plants.

Pathogen

BYMV has filamentous particles of 750 × 15 nm (Smith *et al.*, 1988) and a very wide host range of more than 150 different species (Rohloff, 1980). It belongs to the potyvirus group.

Fig. 14. Symptoms of bean yellow mosaic virus on faba bean leaves

Epidemiology

According to Rohloff (1980), the virus is transmitted in a non-persistent manner mainly by the aphids *Acyrthosiphum pisum*, *Macrosiphum euphorbiae* and *Myzus persicae*, and, to a lesser extent, by *Aphis fabae*. Kaiser (1973) reported a rapid spread of BYMV by aphids in a trial in Iran. Starting from less than 1% infected seeds, up to 100% of the plants were infected after 22 weeks.

Bos (1970) reported that transmission through seed is not common in faba bean, but may reach 6% in lupins. Only 0.2% of seeds originating from plants infected with BYMV gave infected seedlings (Fiedorow, 1978). Hamilton (1983) reported a seed transmission rate between 0.1 and 2%. Frowd & Bernier (1977) could not detect the virus in seeds from infected plants. No seed-borne infection was detected in 6 years of field experiments at Rothamsted, and only slight infection in a few samples in a greenhouse growing-on test Cockbain, 1980).

Detection in seed

Fiedorow (1978) isolated the virus mostly from young unripe seeds. It usually occurred in the seed coat, and less frequently in the embryo. In Scotland, 100-200 seeds are sown and kept in cool, frost-free glasshouses. Sap from symptom-bearing plants is examined by electron microscopy for BYMV particles. Alternatively, the virus may be identified by its reaction to different test plants (Jones, 1980a).

Control

According to Smith *et al.* (1988), clover and gladioli are the most important sources of infection; therefore, faba beans should not be planted near these crops. Roguing is only considered feasible when the number of infected plants is low, e.g., early in the season. According to Rohloff (1980), control of aphid vectors by insecticides is ineffective in controlling the virus. The use of healthy seeds is also ineffective because of the more than 150 natural hosts. Cockbain (1983), however, quoted several reports on the effectiveness of insecticide treatments in reducing the disease incidence. The situation may be similar to that in potato where Zitter &

Simons (1980) reported a reduced incidence of potato leaf roll virus (PLRV) and an increased spread of potato virus Y (PVY) after application of aldicarb. Moreover, the activity of aphids is often increased after feeding on plants treated with systemic insecticides, which enhances the virus spread (Fritzsche *et al.*, 1972).

Other Viruses

Pea Seed-borne Mosaic Virus (PSbMV)

In faba beans the virus causes systemic leaf mottling (Fig. 15) and downward rolling of leaf margins (Harrison, 1973). Dixon (1981a) reported that the rolled leaves are thickened and brittle. According to Smith *et al.* (1988), the symptoms in faba bean are more severe than in pea and include stunting of plants as well as necrosis of many growing points. Hampton & Mink (1975) theorized that the virus is distributed worldwide because of the international exchange of infected seed.

PSbMV belongs to the potyvirus group and has elongated particles of 770 × 12 nm (Hampton & Mink, 1975). The virus is transmissible by sap, in a nonpersistent manner by aphids, and through seed (Hampton & Mink, 1975). PSbMV is among the viruses with the highest seed transmission rate, reaching up to 90% in pea. According to Cockbain (1983), there are no reports of natural seed-borne infection in faba bean and only one report from East Germany about experimental seed-borne infection.

Pea Early Browning Virus (PEBV)

Cockbain *et al.* (1983) described various symptoms that, depending on the isolate, ranged from a very mild systemic mottle to diffuse reddish-brown necrotic local lesions. Some isolates in some varieties failed to induce any symptoms. A mixed infection with PEBV and bean leaf roll virus (BLRV) often resulted in a systemic stem necrosis that killed the plants in a few weeks. Plants also were usually very stunted or spindly and showed distortion of some of the younger leaves.

Fig. 15. Symptoms of pea seed-borne mosaic virus on faba bean leaves

PEBV occurs in Europe, especially Holland and England (Dixon, 1981a), and North Africa (Smith *et al.*, 1988). The pathogen belongs to the tobravirus group. Particles are short, thick rods of 100 and 200 nm (Dixon, 1981a).

The virus has a wide host range consisting of more than 30 dicotyledonous species (Harrison, 1973). It is transmitted by trichodorid nematodes and seed-borne in pea up to 37% (Harrison, 1973) and up to 5% in faba bean (Cockbain, 1983). According to Hamilton (1983), the seed transmission rate may vary between 1 and 15%. Lester (1982) found that infected seedlings were symptomless.

Vicia Cryptic Virus (VCV)

Jones (1980b) detected this virus by centrifuging the sap from seedlings at high speed and by examination in the electron microscope for isometric particles. According to Cockbain (1983), this virus is seed- and pollen-borne. It has been found at low concentration in symptomless plants, and could not be transmitted by aphids, mechanical inoculation or grafting. Its effect on yield seems to be low. The virus was transmitted through about 75% of the seeds set by self-pollinated plants (Cockbain, 1980). Hamilton (1983) reported a seed transmission rate between 1 and 10%. Jones (1980a) found the virus in 7 of 14 seed stocks in Scotland by extracting the virus from symptomless seedlings and examination with the electron microscope.

Broad Bean Yellow Band Virus (BBYBV)

Russo *et al.* (1984) described yellow discolourations of the leaves in the form of rings and line patterns or, more frequently, yellow vein banding. In addition, many pods were deformed and showed brown necrotic rings 0.5 to 3 cm in diameter. Infected plants sometimes occurred at random in the field, but more often in patches. This disease had been recorded every spring since 1980 in the coastal Ionian plain. The virus was readily transmitted from diseased broad bean leaves and from deformed pods and seeds.

The virus particles are straight rods occurring as two populations with modal lengths of 77 and 202 nm. BBYBV infects and systemically invades *Pisum sativum*, but induces in this host, unlike PEBV, a very mild disease. Whereas Russo *et al.* (1984) found that the virus was serologically unrelated to two isolates of PEBV, Conti (1984) suspected that the virus may be a new serotype of PEBV.

Broad Bean Mild Mosaic Virus (BBMMV)

Smith *et al.* (1988) described BBMMV as causing "shortened internodes, stunting of the plant, small curled leaves, and necrosis." Cockbain (1984) reported that the virus occurred in China. BBMMV has isometric particles 25 nm in diameter. In addition to faba bean, the virus infects pea, lucerne and clover (Cockbain, 1983). According to Smith *et al.* (1988), transmission is mechanical and through seed, whereas Cockbain (1983) stated that the virus does not seem to be seed-borne.

Broad Bean Mottle Virus (BBMV)

The symptoms include a yellow mottle as well as leaf necrosis and crinkling (Fig. 16, Cockbain, 1983). Makkouk *et al.* (1988b) reported a severe systemic vein chlorosis and chlorotic vein banding

Fig. 16. Symptoms of broad bean mottle virus on faba bean leaves

developing into overall leaf chlorosis. BBMV is reported to occur in China (Cockbain, 1984), and Europe and Africa (Smith *et al.*, 1988). Significant yield losses were described by Makkouk *et al.* (1988a), particularly in mixed infection with BYMV. The virus belongs to the Bromovirus group with isometric particles of 26 nm diameter. According to Murant *et al.* (1974), combined infection with bean yellow mosaic virus may cause broad bean mottle virus to be seed-transmitted. Hussein (1979) also reported the seed-borne nature of BBMV in Sudan, whereas Jones (1980a) could not detect the virus in seed stocks in Scotland. Makkouk *et al.* (1988b) found BBMV in 1.3% of the embryo axes tested by ELISA.

Broad Bean Wilt Virus (BBWV)

Depending on the strain, the virus causes retarded growth, leaf deformations, mottle, occasionally a ring-like pattern and, synergistically with fungal disease agents, wilting (Fig. 17, Cockbain, 1983). It is known to occur in several European countries, Australia, America, Japan, Africa (Smith *et al.*, 1988) and China (Cockbain, 1984). BBWV has isometric particles ca. 25 nm in diameter (Cockbain, 1983). Although there is one report of seed transmission of BBWV at a low rate in France (Putz & Kuszala, 1973), Cockbain (1983) declared that there is no evidence to support this.

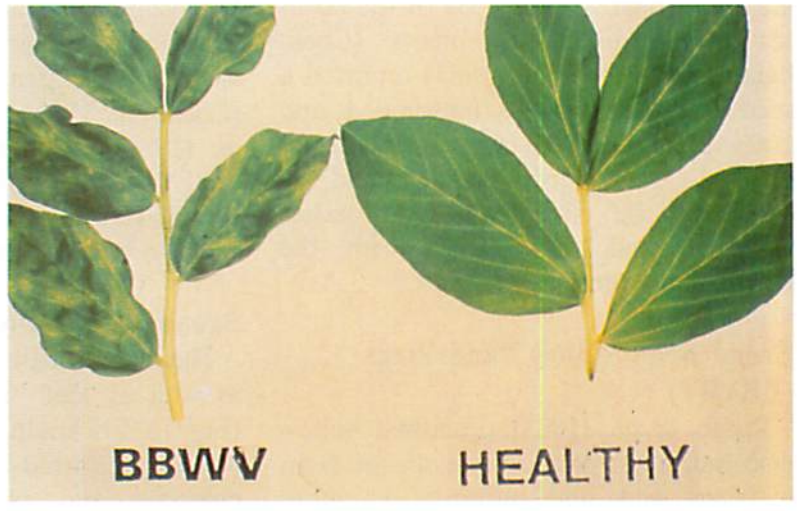


Fig. 17. Symptoms of broad bean wilt virus on faba bean leaves

Chapter 3
Bacterial Diseases

Geographical distribution

According to Stapp (1956), faba beans are hosts to a number of bacteria. However, only *Corynebacterium fascians* (Australia, Canada, England, Germany, Sweden and USA), *Pseudomonas fabae* (China) and *P. aptata* (Australia, England, Korea and USA) are listed as potentially seed-borne. Salt (1983) listed the distribution of *P. fabae* in USSR and Germany, and reported a seed-borne *Erwinia* sp. from Russia and Germany, and a seed-borne *Bacillus* sp. from Germany.

Economic importance

Bacterial diseases of faba beans are restricted in distribution, but could be very damaging when climatic conditions favour their spread.

Symptoms

Pseudomonas fabae causes a soft rot of roots and stem base and also attacks leaves and pods, which results in a characteristic blackening (Stapp, 1956). Similar symptoms are caused by *Erwinia* (Salt, 1983). *Pseudomonas aptata* infection results in leaf spots of several hosts, whereas *C. fascians* mainly attacks vetches where it causes a tumor growth at the stem base (Stapp, 1956).

Pathogens

The pathogens were described by Stapp (1956) and their characteristics are summarized in Table 1.

Epidemiology

Stapp (1956) described *Pseudomonas fabae* as a wound parasite. According to Salt (1983), the pathogens are mainly propagated through infected seeds.

Control

Salt (1983) listed the use of healthy seed as being of prime importance in control, along with roguing of infected seedlings and other infected material, sound crop rotation and the liberal use of potassium fertilizer.

Table 1. Characteristics of bacterial pathogens of faba beans (after Stapp, 1956).

Bacterium	Size	Colony character
Pseudomonas fabae	1.1-2.8 x 0.8-1.1 μ	white in the beginning, then salmon, round, shiny
Pseudomonas aptata	2.1 x 0.7 μ	smooth, whitish with "fish-bone pattern"
Corynebacterium fascians	1.5-4.0 x 0.5-0.9 μ	small, round; on PDA cream coloured, then yellow-orange

Chapter 4
Fungal Diseases

Leaf, Stem and Pod Spot (*Ascochyta fabae* Speg.)

Geographical distribution

Randles & Dube (1977) isolated the pathogen for the first time in South Australia from seedlings grown from seed imported from the UK. Omar (1986) reported a recent introduction to Egypt with imported germplasm. The CMI Distribution Maps of Plant Diseases (Commonwealth Agricultural Bureaux, 1976) list a record for Egypt in 1958; however, it is mentioned that the disease is not included in a 1963 general survey of plant diseases in Egypt. In addition, 15 other countries are listed by CMI. Dixon (1981a) assumed that the pathogen is distributed worldwide through seed infection.

Economic importance

In New Zealand, Hampton (1980) found a 34% yield loss due to *Ascochyta*, which was associated with an infected leaf area of 5.9% and an infected pod area of 14.1%. Madeira *et al.* (1988) compared plots infected with *Ascochyta fabae* with healthy plots. Although plants were infected at a late stage (73 and 88 days after sowing), the leaf area index, seed yield and dry matter production of the crop were reduced significantly. Moreover, the germination of seeds from diseased plots was 84% compared with 100% in those from fungicide-treated plots. The authors compared the effects of *Ascochyta* to those of water stress and nitrogen supply. All of them induced premature senescence and increased the rate of leaf death. Gaunt & Liew (1981) found yield losses of up to 44% in a crop with an initial seed infection of 12%. In contrast, Wallen & Galway (1977) reported that infection levels of 4-10% in field plots did not reduce yield significantly.

Symptoms

The first symptoms are elongated lesions, up to 10 mm long, on the primary foliage leaves of seedlings developing from infected seed, with characteristic chestnut-brown margins and greyish centers. Lesions develop first on the tips and margins of leaves, gradually spreading toward the main veins of the compound leaves and petioles (Fig. 18a). Pycnidia are easily seen in older lesions (Fig. 18b). In severe attacks, foliage is totally destroyed. Elongated red-brown stem lesions develop, which weaken the stem and may cause lodging. Pod and stem lesions are usually darker and more deeply sunken than those on leaves (Fig. 18c). Infected seeds may be covered with circular dark brown lesions (Smith *et al.*, 1988).

Pathogen

Ascochyta fabae is an imperfect fungus belonging to the order Sphaeropsidales. The conidia are hyaline, straight or slightly curved, mono- to triseptate and measure 16-24 x 3.5-6 μ. They are formed in yellow-brown pycnidia of 200-250 μ with a papillate ostiole (Fig. 19; Punithalingam & Holliday, 1975).

a

b

Fig. 18. (a) Lesions caused by *Ascochyta fabae* on a faba bean leaf; (b) lesion of *Ascochyta fabae* with pycnidia; (c) pod and stem lesions of *Ascochyta fabae*

c

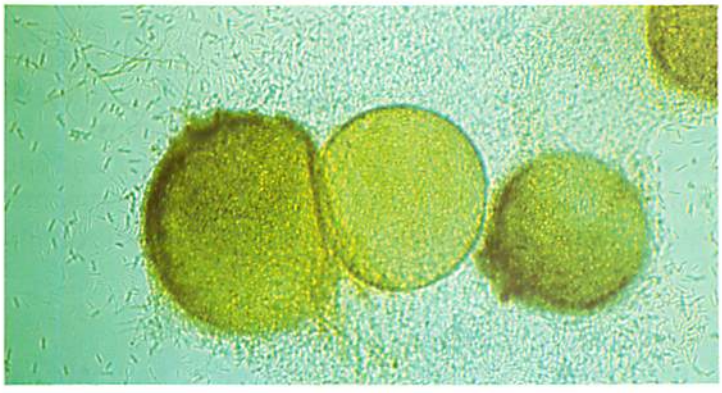


Fig. 19. Pycnidia and conidia of *Ascochyta fabae*

Epidemiology

This pathogen can remain viable on seed for up to 3 years and for 4-5 months on infected crop residue (Dixon, 1981a). By testing infected seeds, Michail *et al.* (1983) isolated the pathogen from all seed coats, from 46% of the cotyledons and from 27% of the embryo axes. Kharbanda & Bernier (1979) observed that survival on crop debris is 3-4 years; if faba beans are not grown in a field for that period of time, infected seeds serve as the source of primary inoculum. Short-range spread occurs by rain splash transmitting the pycnospores which ooze from pycnidia in wet weather. Bond & Pope (1980) found that, in contrast to earlier results, the disease can spread at least 120 m. The UK Seed Certification Scheme therefore recommends that seed crops should be isolated by at least 50 m from other bean crops and from fields that carried a faba bean crop the previous year.

In a greenhouse study, van Breukelen (1985) found that more than 2 days of high humidity following inoculation are required for a significant infection. In that study, older leaves seemed to be more resistant than younger leaves, which is in contrast to the results reported by Hanounik (1980). For successful infection of seed there must be rain early in the development of a crop so that the pathogen is carried sufficiently high in the leaf canopy to reinfect the pods and seeds as they develop (Hewett, 1973). According to Dixon (1981a) one disease cycle from infection to pycnidia formation takes 12-18 days. Jellis *et al.* (1985) reported that short-strawed cultivars showed a higher incidence of pod infection. Hewett (1973) found that infected seed produced between 2 and 15% seedlings with primary infection, which is a relatively low transmission rate. Similar results were reported by Wallen & Galway (1977) who found that less than 3% infected seedlings resulted from a seed-borne infection of 13%. According to Hewett (1973), the infection of new seed depends largely on weather conditions, particularly rainfall. The time of harvesting also may be important, with an early harvest preventing high seed infection rates. The maximum increase in the rate of infected seed sown to infected seed harvested was eight times (Hewett, 1973). In New Zealand, Gaunt & Liew (1981) found a particularly high multiplication rate (15% diseased plants) if the initial inoculum percentage was small (0.2%).

Lamprecht & Steiner (1984) found that, in over 400 German seed samples tested, 8% were infected with *Ascochyta*, which was down from 43% the previous year (Steiner & Lamprecht, 1983). Samples from areas with consistently dry climatic conditions showed a lower infection rate. Lockwood *et al.* (1985) reported a strong correlation of seed infection with both foliar and pod infection. They also found that *ti-1* types, i.e., those with a determinate growth habit, were relatively more susceptible to *Ascochyta*.

As with many fungi, the rate of epidemic development from infected seed and re-establishment of seed infection from diseased plants varies considerably from year to year and site to site depending on environmental conditions, particularly moisture (Smith *et al.*, 1988).

Detection in seed

Hewett (1979) tested a pretreatment with sodium hypochlorite (1% available

chlorine), from 30 sec up to 40 min, and found no effect on the recovery of *Ascochyta* on agar medium. For the detection of *Ascochyta pisi* in pea, the International Rules for Seed Testing (ISTA, 1985b) recommend plating 400 seeds after pretreatment with sodium hypochlorite (1% w/w available chlorine) for 10 min on malt or potato dextrose agar. After 7 days incubation at 20°C in darkness, the plates can be checked for white mycelia covering infected seeds. Alternatively, Hewett (1987) suggested incubation under alternating light and darkness in a 12/12-hour cycle, which results in less mycelial growth and an increased pycnidial production. In that case, colonies may be easier to identify by less experienced personnel. Although, according to Hewett (1987), approximately 50% more *Ascochyta* spp. can be detected in agar tests than in blotter tests, Mathur (1981) recommended the blotter test for the detection of *A. rabiei* in chickpea seeds. For the detection of *A. fabae* in seeds, more pathogens were isolated on faba bean dextrose agar (Fig. 20) than in a blotter or freezing blotter test (Diekmann, unpublished data).

Control

According to Dixon (1981a), the introduction of a seed certification scheme in the UK considerably reduced the incidence of *A. fabae*. The cultivar 'Minor' was even freed from the disease. Seed treatment with benomyl and thiram slurries reduced the infection to less than 0.1%, but affected seed germination.

Gaunt & Liew (1981) and Jellis *et al.* (1984) recommended the application of chlorothalonil (Bravo 500 with 50% a.i.) at 0.1% a.i. in water, using 2.5 kg a.i./ha. Michail *et al.* (1983) found that five sprays with Benlate 50 (0.1%) or Dithane M-45 (0.25%) reduced the disease incidence on pods and increased yield; however, the seed harvested had an infection rate of 7-15%. According to Smith *et al.* (1988), the spraying of a standing crop (e.g., with maneb) had only limited success compared with seed treatment.

Wallen & Galway (1977) found that seed treatment with captan, benomyl and thiram did not significantly affect the amount of seedling or adult plant infection. Kharbanda & Bernier (1979) compared seed treatment fungicides and found that thiram is ineffective on

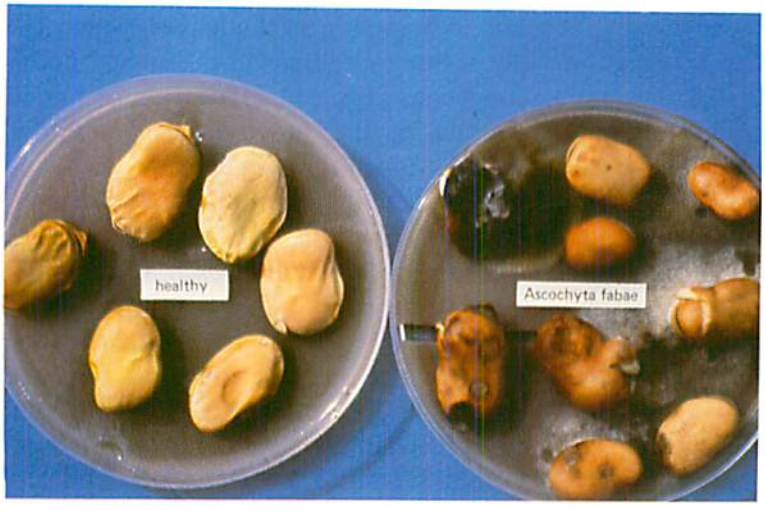


Fig. 20. Colonies of *Ascochyta fabae* on faba bean dextrose agar; left: healthy seeds

Ascochyta beneath the seed coat. Also, benomyl, captafol, captan, chlorothalonil, metiram and thiabendazole failed to eradicate the fungus. Although soaking of the seeds in a 0.2% a.i. suspension of benomylthiram for 8 hours and subsequent air-drying of 48 hours gave complete control in laboratory tests, up to 2.9% infected seedlings emerged in the field. Hampton (1980) also found that various seed treatments were effective in the laboratory, but did not provide complete control in the field.

Gaunt & Liew (1981) recommended a benomyl + captan (63 + 81 g a.i./100 kg seed) seed treatment to reduce the establishment of the disease on seedlings.

Chocolate Spot (*Botrytis* spp.)

1. *Botrytis fabae* Sardina

Geographical distribution. The CMI Distribution Map of Plant Diseases (Commonwealth Agricultural Bureaux, 1981) shows that the disease is prevalent in 31 countries. The first record for North America was 1970 in Nova Scotia, on plants probably grown from seed imported from England (Gourley & Delbridge, 1973).

Economic importance. Crops may be destroyed if the aggressive stage appears early in the season. In moderately cool and moist climates, severe yield losses may occur. Kaiser *et al.* (1967) described yield losses of about 50% in Iran due to chocolate spot, rust and BYMV, with chocolate spot being the most destructive. Creighton *et al.* (1985) reported that yield losses due to *B. fabae* alone may reach 50%.

Gerlach & Rudnick (1972) found that an early infection (early/mid-July) resulted in a 30-40% yield loss in northern Germany, whereas infection at the end of July or beginning of August affected yield only by 5-10%. In Egypt, annual losses vary between 5 and 20% (Hanounik & Hawtin, 1982). According to Griffiths & Amin (1977), yield loss depends largely on the inoculation site. Whereas a maximum disease severity of 40% at the flowering nodes reduced seed yield by 35%, infection below and above the flowering nodes did not cause significant yield losses. Williams (1975) found that a yield reduction of 27% was solely due to a reduced number of pods, whereas the yield of beans per pod was not affected. The severe defoliation, i.e., up to node 9 after flowering and up to node 13 at harvest (= 50% defoliation), did not lead to a yield reduction because the net assimilation rate indicated that leaves of diseased plants were 30-40% more productive than those on healthy plants.

Harrison (1978) found that seed infection reduces seed viability.

Symptoms. Smith *et al.* (1988) described the chocolate spot disease as causing "rust-coloured to dark-brown or grey, more or less circular spots up to several mm in diameter on the leaves, petals and pods, but elongated on the stems" in dry conditions (Fig. 21). Under wet or humid conditions, the fungus spreads rapidly, both inter- and intracellularly, producing both pectolytic enzymes and non-enzymic phytotoxins. Lesions blacken, increase in size and coalesce, leading to a destructive blight. This is referred to as the aggressive stage of the disease when most of the leaves drop off and the stems bend, causing the plants to fall over. The fungus sporulates on the dead tissues. Under alternately wet and dry

Fig. 21. Faba bean plant infected with chocolate spot disease

conditions, concentric rings may be formed as the growth of a lesion starts and stops. These lesions are distinguished from those of *A. fabae* by the absence of pycnidia. According to Dixon (1981a), infected young pods are stunted and the ovules develop irregularly or not at all. Mature pods become blackened, with the discolouration extending to the seeds. Black sclerotia are formed in stem tissues when *B. fabae* has become well established, but are mostly found in culture (Dixon, 1981a).

Pathogen. *Botrytis fabae* belongs to the Ascomycetes; no teleomorph has been described (Smith *et al.*, 1988). It is easily distinguished from *B. cinerea*, which also attacks faba beans, by its larger conidia, measuring 15-24 x 11-18 μ compared with 9-12 x 7-10 μ (Fig. 22a, b; Harrison, 1983). In contrast to *B. cinerea*, *B. faba* produces sclerotia abundantly in culture.

a

b

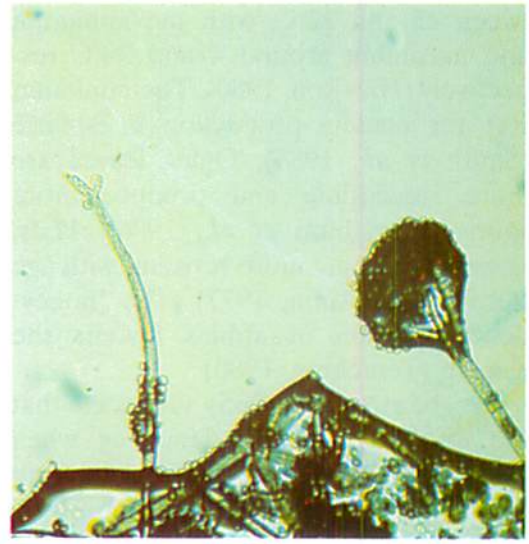


Fig. 22. (a) Conidia and conidiophores of *Botrytis fabae*; (b) conidia and conidiophores of *Botrytis cinerea*

Their size is variable, mostly 1-1.7 mm and rarely up to 3 mm (Ellis & Waller, 1974).

Hanounik & Maliha (1986) suggested that at least four races of *B. fabae* exist.

Epidemiology. The pathogen mainly overwinters as sclerotia in plant debris. In humid weather, conidia are produced which infect the seedlings. Other possible ways of over wintering are as hyphae living saprophytically, or as resting mycelia. Alternative sources of inoculum are volunteer faba bean plants and *V. sativa* weedy plants (Harrison, 1979). The disease is spread by windborne conidia that may travel over large distances. Both wind and rain play a role in the dispersal, with wind being more important (Fitt *et al.*, 1985). Infection requires a relative humidity (RH) of at least 86%; a water film is not necessary (Harrison, 1984). Lesion growth below 70% RH is very slow, and is directly proportional to RH between 70 and 100%. The optimum temperature ranges between 15 and 22°C, with the minimum and maximum around 4 and 30°C respectively (Harrison, 1980). The minimum RH for conidia production is 80-90% (Smith *et al.*, 1988). Older leaves are more susceptible and produce more spores (Creighton *et al.*, 1986). Pods, however, become more resistant with age (Griffiths & Amin, 1977). The "honeydew" excretion of aphids favours the disease (Teuteberg, 1980).

Creighton *et al.* (1985) suggested that the disease is most damaging when leaves at flowering nodes become infected during pod formation. They correlated disease development with the number of spores dispersed and collected on horizontal slides coated with glycerine jelly. The critical number is about 500 spores/cm²/d before or during flowering.

In China, a highly significant correlation between disease severity and the days of continuous rainfall (> 0.1 mm/d) during early to mid-April (at the flowering stage of the crop) was found (Liang Xun-yi, 1989).

Frosts that freeze the leaves may favour the development of an epidemic by encouraging sporulation on infected leaves (Creighton *et al.*, 1986). Irrigation always increased the amount of chocolate spot on leaves and flowers, and increased the yield only in a dry year (Fitt *et al.*, 1986).

Harrison (1978) isolated *B. fabae* from commercial seed lots; however, most infected seeds gave rise to healthy plants. Moreover, the pathogen could not be detected after seed storage for 9 months. The author suggested that seed-borne infection does not play an important role in the transmission of chocolate spot.

Detection in seed. Harrison (1978) plated the seeds on 2% malt extract agar after 10 min surface sterilization in 10% Chloros (ICI; 1% w/v available chlorine) and rinsing in sterile water. Incubation was for 14 days at 20 ± 2°C, under normal laboratory lighting, which encouraged production of sclerotia.

Control. Creighton *et al.* (1985) reported that a single spray of benomyl (0.5 kg a.i./ha) during flowering gave significant yield increases, but no increase was observed with sprays before or after flowering. Bainbridge *et al.* (1985) found foliar sprays of benomyl more effective than iprodione, prochloraz or thiabendazole. Weather conditions played an important role in all

experiments. Fitt *et al.* (1986) concluded from their experiments that benomyl sprays are likely to be beneficial only in wet years with severe damage of chocolate spot. Harrison (1988) cautioned that the continued use of benomyl would encourage the spread of benomyl-resistant strains, and advised that other fungicides be used.

Bainbridge *et al.* (1985) attributed the effect of benomyl seed treatment (0.8 g a.i./kg seed) to the protection against early infection and, to a lesser extent, to the control of seed-borne inoculum. They found no further benefit with the addition of thiram to the seed treatment.

Removal of debris from a previous bean crop, either by burning or soil cultivation, will reduce the initial inoculum (Smith *et al.*, 1988).

2. *Botrytis cinerea* Pers. [teleomorph *Botryotinia fuckeliana* (de Bary)]

Geographical distribution. Worldwide, but most prevalent in humid temperate and subtropical areas.

Economic importance. The pathogen is not of primary importance in faba beans.

Symptoms. The pathogen causes grey mould in many crops and contributes to the chocolate spot syndrome on faba beans, but is apparently less aggressive than *B. fabae* and therefore less important (Harrison, 1988). Grey mould can be easily identified in many host plants (other vegetables, strawberries, grapes) by the abundant off-white to grey mycelia covered with dark conidia. Jellis & Bond (1980) reported severe pod rotting caused by *B. cinerea*, with the fungus infecting through the flower parts.

Pathogen. *Botrytis cinerea* is the conidial (imperfect) state of *Sclerotinia fuckeliana*. Sclerotia are black and their size varies between 1 and 5 mm, depending on the isolate.

The colourless to brown macroconidia are ellipsoidal to obovoid and measure 6-18 x 4-11 μ. They are produced on dark, branched conidiophores of up to 2 mm length and 16-30 μ thickness. Microconidia develop from clusters of phialides (Dixon, 1981a).

Epidemiology. Conidia are disseminated by wind or in rain splashes. Saprophytic mycelia or sclerotia on plant debris can overwinter. Spores and mycelia may be seed-borne on 46 different species (Richardson, 1979).

Detection in seed. For the detection of *B. cinerea* in sunflower seeds, Anselme & Champion (1981a) recommended the blotter test with a 3% malt solution and incubation for 9 days at 20°C in darkness. The typical grey mycelium will develop abundantly on infected seeds. In flax seed, however, Anselme & Champion (1981b) found a test on malt extract agar superior to the blotter test.

Control. Many fungicides were found to be effective in controlling this pathogen (benomyl, carbendazim, captan, dichlofluanid, iprodione, thiram); however, attention should be paid to the development of resistance (Dixon, 1981a). According to Teuteberg (1980), cultural measures such as planting in wind-exposed sites, early and not-too-dense sowing, increasing pH to at least 6.5 and the burying of plant residues of the previous crop are most important.

Fusarium Diseases (*Fusarium* spp.)

1. Wilt (*Fusarium oxysporum* Schlecht. emend. Snyd. & Hans. f.sp. *fabae*)

Geographical distribution. *Fusarium oxysporum* is distributed worldwide (Booth, 1970); reports on f.sp. *fabae* have come from Canada, Czechoslovakia, Japan, Poland, USSR (Mattusch, 1980), Egypt (Mohamed, 1982), Sudan (Hussein, 1982), Iraq (Salt, 1983) and China (Yu & Fang, 1948a).

Economic importance. Early infection reduces quality and quantity of the seed (Salt, 1983).

Symptoms. Smith *et al.* (1988) described the symptoms as light vein-clearing on the older leaves, accompanied by chlorosis of the lamina and/or wilting, which then progress to younger leaves (Fig. 31). Often the symptoms start unilaterally on some leaves. Affected parts of the plant turn brown; longitudinal necrotic streaks appear on the stems and spread toward the stem apex. Browning of the vascular tissue can be seen in sections of roots or stems. Typically the disease starts in a crop as foci that spread gradually. Affected plants may die prematurely. Ibrahim & Owen (1981) found that *F. oxysporum* caused a root rot in Sudan.

Pathogen. *F. oxysporum* is an abundant saprophyte in soil and on organic matter. Some strains have specific pathogenic activity. Some are poorly specialized and cause seedling blight, necrosis or rot. About 80 formae speciales (pathotypes specific to species) have been identified, and several are subdivided into races (specific to cultivars within a species). Except for the Gramineae, most families are attacked (Booth, 1970). Richardson (1979) listed 20 of the formae speciales as seed-borne, and later added 4 (Richardson, 1981) and 1 (Richardson, 1983).

In culture, microconidia are always present. They are oval-ellipsoid, mono-

Fig. 23. Symptoms of *Fusarium* wilt on faba beans

or bicellular, and formed on short unbranched phialides. Their size is 5-12 x 2.2-3.5 μ. Macroconidia are abundant and usually 3-5 septate, fusoid, slightly curved, and often with a foot-shaped basal cell (Fig. 24). They form first on individual phialides, then form sporodochia. According to septation, their size varies (27-66 x 3-5 μ). Chlamydospores are solitary or in short chains. No teleomorph is known. Growth on PDA is rapid, and colony colours may vary from dark blue or dark purple when sclerotia are abundant to cream, tan or orange when sporodochia are abundant (Booth, 1970; Nelson *et al.*, 1983).

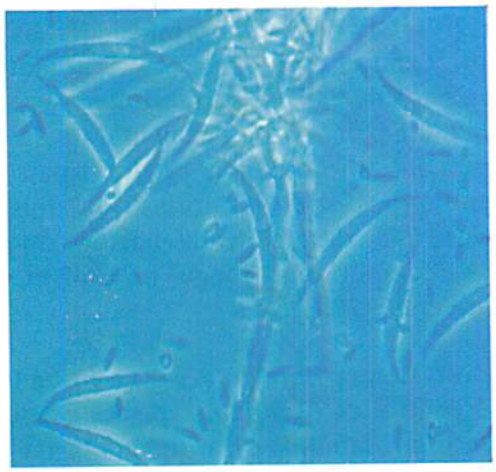


Fig. 24. Micro- and macroconidia of *Fusarium oxysporum*

Epidemiology. *Fusarium* wilts are classic soil-borne diseases, with infected plant debris being the main source of inoculum. Chlamydospores can persist in an inactive form for several years. The pathogens also can be spread in irrigation water with infected plants, but rarely by seed. Disease development is favoured by acid soil, potassium deficiency, ammonium nitrogen fertilizer and high temperatures (Smith *et al.*, 1988).

Detection in seed. Ibrahim & Owen (1981) found that peptone PCNB agar (Nash & Snyder, 1962), with 1.5% Difco peptone, 2% agar, 0.1% KH_2PO_4, 0.05% $MgSO_4$ x 7 H_2O, 300 ppm streptomycin, and 1:1000 PCNB 75% WP) without pretreatment gave better results than the blotter test. On this medium the different *Fusarium* species develop distinct culture characteristics that make identification easier. Pretreatment with 0.5% sodium hypochlorite for 10 min greatly reduced the frequency of isolation, suggesting that surface contaminants play a major role.

For the detection of *F. oxysporum* in chickpea seeds, Haware *et al.* (1986) used Czapek Dox agar with 500 mg PCNB, 25 mg malachite green, 750 mg streptopenicillin and 2 g yeast extract/liter medium. They recommended surface sterilization for 2 min in 2.5% sodium hypochlorite. Alternatively, they suggested a seedling symptom test of surface-sterilized seeds, where the seedlings are observed for at least 40 days for symptoms of wilt.

Colony appearance on PDA is variable, depending on the strain. Generally, the aerial mycelium is at first white, and the medium discolours to various shades from violet to deep purple: colonies may appear cream or orange if sporodochia are abundant (Smith *et al.*, 1988).

Control. Hussein (1982) reported that various fungicides applied as seed dressing had no effect on disease incidence. Later planting, however, had a significant effect. *Fusarium oxysporum* rapidly developed resistance to benzimidazole fungicides (Smith *et al.*, 1988).

Salt (1983) gave several examples of crop rotation of 4-5 years being an efficient control measure.

2. *Fusarium solani* (Mart.) Appel & Wollenw. emend. Snyd. & Hans. (root rot)

Geographical distribution. Salt (1983) summarized reports about *F. solani* as a pathogen on faba beans from Belgium, Britain, Canada, China, Colombia, Cyprus, Czechoslovakia, Egypt, France, Germany, Greece, Japan, Mexico, Peru, Poland, Sudan, Switzerland and USSR.

Economic importance. *Fusarium solani* is one of the pathogens contributing to the dry root rot complex, which is the most widespread and damaging root disease of faba beans (Salt, 1983). Smith *et al.* (1988) attributed substantial yield losses in Europe and North America to *F. solani.*

Symptoms. According to Mattusch (1980), symptoms are similar to those caused by *Rhizoctonia solani*, namely a brown-black discolouration of roots and stem basis, followed by yellowing of tips and borders of older leaves, which then turn brown. Occasionally young leaves die without showing disease symptoms. Salt (1983) pointed out that high temperature and water stress aggravate the disease. He also described dusty white or pinkish spore masses on the stem base and upper part of the root.

Pathogen. The pathogen occurs on hosts distributed among 66 families (Booth & Waterston, 1964). Richardson (1979) listed 16 hosts in which the pathogen is seed-borne, and later added 3 (Richardson, 1981) and 13 (Richardson, 1983). Micro- and macroconidia are produced on 45-80 x 2.5-3 μ long, irregularly branched phialides. The oval to cylindrical microconidia measure 8-12 x 2-4 μ and are sometimes 1-septate. The macroconidia are 1- to 6-septate and measure 35-55 x 4.5-6 μ. Their dorsal and ventral surfaces are parallel for most of their length, and the apical cell is blunt and rounded. The size of the globose chlamydospores is 9-12 x 8-10 μ. Typical colours of a colony on PDA are greyish-white to bluish-brown, but never orange. The perfect state is *Nectria haematococca* Berk & Br. (Nelson *et al.*, 1983; Salt, 1983).

Epidemiology. Mohamed (1982) reported that *F. solani* f.sp. *fabae* infected faba beans. Lamari & Bernier (1985) found that *F. solani* and *F. graminearum* were not pathogenic to faba beans in Canada. These contradictions may be due to apparently host-specific forms in this species, and the relatively narrow optimum temperature range of 26-28°C (Smith *et al.*, 1988).

Control. Eisa & Barakat (1978) achieved good control of *Fusarium* species causing seedling damping-off with benomyl + thiram, carboxin + captan, or PCNB at 4 g/kg seed, with the first two increasing yield significantly. A crop rotation avoiding all legume species for 6-8 years is the main means of control, according to Smith *et al.* (1988).

3. Other *Fusarium* species

Geographical distribution. Ibrahim & Owen (1981) isolated *F. equiseti*, *F. moniliforme*, and *F. solani* from faba beans in Sudan. These species were not found to be pathogenic. *Fusarium acuminatum* caused a root rot of faba

Table 2. Characteristics of *Fusarium* species found on faba bean (after Nelson *et al.*, 1983).

Species	Microconidia	Macroconidia	Undersurface
F. acuminatum	sparse	thin, strongly curved	carmine red or tan-brown
F. avenaceum	sparse	very long and slender	tan to carmine red to dark brown
F. culmorum	absent	stout, thick-walled	
F. equiseti	oval to comma-shaped	strongly septate, thick-walled	tan to brown, brown flecks
F. graminearum	absent	straight to sickle-shaped	carmine red
F. moniliforme	oval to club-shaped	sometimes rare, slightly sickle-shaped	colourless to dark purple

bean (Harrison, 1981) and has been isolated from seed. Mattusch (1980) summarized literature on *F. avenaceum* from Canada, China, Finland, Japan, Poland and USSR, on *F. culmorum* from Finland and on *F. graminearum* f.sp. *fabae* from Japan.

Symptoms. Lamari & Bernier (1985) found that *F. avenaceum* caused a severe root rot of faba bean seedlings in Canada. According to Yu & Fang (1948b), *F. avenaceum* var. *fabae* causes a wilt in faba beans.

Pathogens. Some characteristics of different *Fusarium* species are summarized in Table 2.

Epidemiology. Yu & Fang (1948b) isolated *F. avenaceum* from the seed coat, but not from the cotyledons, and concluded that the seeds are contaminated during threshing.

Downy mildew [*Peronospora viciae* (Berk.) Caspary]

Geographical distribution. Dixon (1981b) listed references from Argentina, Australia, Canada, Chile, Europe, India, Kenya, New Zealand, Tunisia, USA, USSR and Zimbabwe.

Economic importance. Most references in the literature refer to losses induced by the pathogen in pea, reaching up to 20% (Olofsson, 1966). According to Mukerji (1975), the pathogen causes severe losses in cool, wet years at temperatures between 15 and 20°C.

Symptoms. Younger leaves show light grey, greenish spots that enlarge into

Fig. 25. Faba bean leaves with symptoms of downy mildew

lesions covering more than half of the leaf area. Older lesions turn brown (Fig. 25), desiccate, and lead to leaflet distortion. Light grey sporangiophores and sporangia can be observed on the undersurface, occasionally also on the upper surface. No infection on pods and stems of faba beans is reported. A systemic infection leads to dwarfing and distortion of either the entire plant or of only a few nodes (Dixon, 1981b).

Pathogens. Besides faba bean, *P. viciae* attacks vetch, pea and sweet pea (*Lathyrus odoratus*). Sporangiophores measure 160-750 x 3-13 μ and are unbranched for at least two-thirds of their length. Each end bears a single oval to elliptical sporangium of 15-30 x 15-20 μ. Oospores are spherical, light brown to deep yellowish pink with a reticulate surface and measure 25-37 μ in diameter (Mukerji, 1975). Matthews (1981) reported the existence of at least eight races in *P. viciae*.

Epidemiology. According to Smith *et al.* (1988), spread of the pathogen is via rain and wind-transported sporangia for which optimal germination occurs at 4-8°C. Formation of sporangia requires 90% RH for more than 12 hours and temperatures below 15°C. Therefore it is not surprising that the pathogen is mostly found in cool and moist climates. Oospore production is favoured by temperatures in excess of 20°C. Oospores may survive in the soil for 10-15 years (Dixon, 1981b).

According to Dixon (1981b), seed-borne infection has not been conclusively demonstrated as a means of transmission, but infected seeds may fail to germinate or develop. Smith *et al.* (1988), however, assumed that long-range transmission is likely to be by seed infection.

Detection in seed. To locate the pathogen in pea seeds, Mence & Pegg (1971) used a microtome section technique with subsequent staining in safranin and alcoholic aniline blue. For the detection of *Peronospora manshurica* in soybean seeds, Hansen & Mathur (1987) recommended, as well as direct inspection for typical "crusts" of oospores, a seed-washing test with subsequent centrifuging at 2000-2500 rpm for 5 min. Oospores can be detected in the sediment under a microscope.

Control. Margot (1983) reported reliable control of *P. viciae* on peas by treatment with metalaxyl at rates of 35-70 g a.i./100 kg seed. Sprays of metalaxyl, alone or

with mancozeb, considerably reduced disease incidence and severity (Dixon, 1981b). Furthermore, deep tillage and extended crop rotations were recommended.

Rust [*Uromyces fabae* (Grev.) de Bary ex Fuckel] syn. *Uromyces viciae-fabae* (Pers.) Schroet.

Geographical distribution. The CMI Distribution Maps of Plant Diseases (Commonwealth Agricultural Bureaux, 1977) showed that the pathogen is present in 76 countries; Gaunt (1983) found that rust is prevalent in all areas where the crop is grown.

Economic importance. Williams (1978) found that although the disease has little effect on vegetative growth, the yield loss amounted to a maximum of about 10% in a resistant, and about 45% in a susceptible, variety. These losses were almost wholly caused by the decrease in weight of seeds per pod. Lapwood *et al.* (1984) achieved a 31% yield increase by treatment with propiconazole and benomyl (total of five sprays). Bernier & Conner (1982) reviewed the literature and reported yield losses of 5-20% and occasionally up to 50% in Egypt, and of 45% in the case of early infestations in Australia; however, the disease does not seem to be a major problem in Europe and Canada. The fungus has a wide host range, which includes many other legumes (Gaunt, 1983).

Symptoms. The disease can be easily recognized by rust-coloured pustules on leaves and stems of faba bean (Fig. 26a, 6) and other legumes, which are formed by urediospores. Later in the season, lesions of darker teliospores are produced mainly on stems and petioles (Gaunt, 1983).

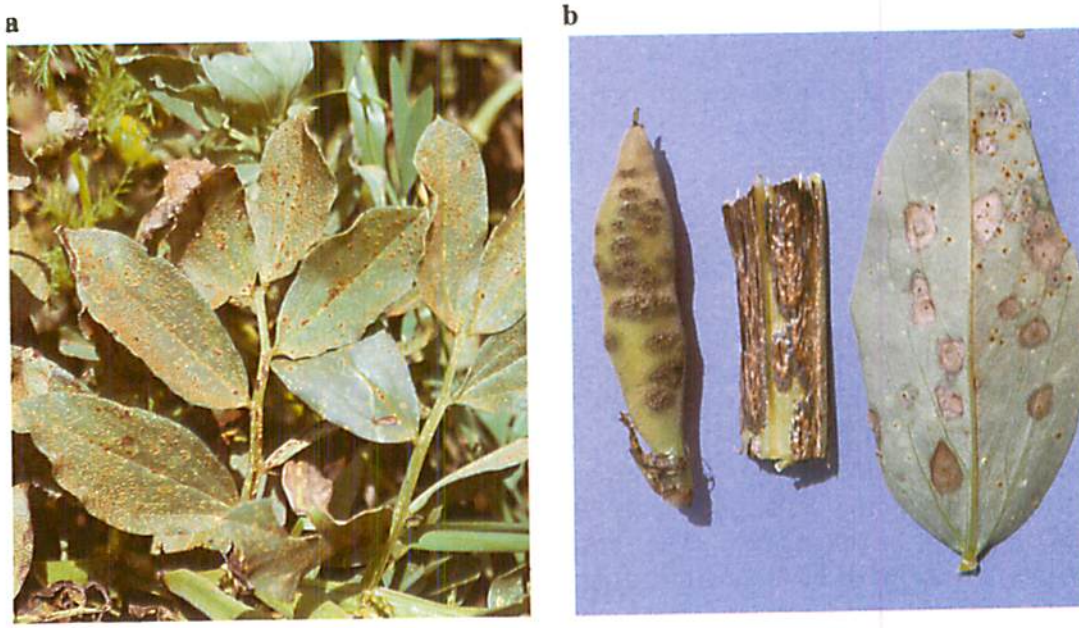


Fig. 26. (a) Faba bean plant affected by rust; (b) rust on pods and stems of faba beans

Pathogen. *Uromyces viciae-fabae* is a macrocyclic autoecious rust with spherical hyaline aeciospores (18-16 μ) and elliptical to obovoid yellowish urediospores (22-28 x 19-22 μ). Urediospores have a finely echinulate wall of yellow to sienna colour. The teliospores are similar in shape (25-40 x 18-26 μ), but with chestnut-coloured walls and yellow 100-μ-long pedicels. A number of races have been recorded (Laundon & Waterston, 1965; Dixon, 1981a). *Uromyces viciae-fabae* also infects pea, lentil and wild and cultivated species of *Vicia* and *Lathyrus* (Nene *et al.*, 1988).

Epidemiology. Aeciospores may overwinter only in Mediterranean climates, but not in northern regions. Urediospores and/or teliospores may remain viable for 1-2 years and can be disseminated with the seeds. High atmospheric humidity favours infection. Late irrigations may promote the severity of the disease (Smith *et al.*, 1988).

Detection in seed. The spores are borne on the seed surface and can be detected in a seed-washing test.

Control. In the experiments of Williams (1978), benomyl at 1 kg a.i./ha at 14-day intervals from emergence to flowering prevented natural infection in all plots. Yeoman *et al.* (1987) found that benodanil, fenpropimorph, maneb, mancozeb, maneb + mancozeb, propiconazole, thiram, triadimefon and zineb poly + tridemorph controlled rust. The best results for control of a combined infection of rust and chocolate spot were achieved with maneb + mancozeb, which also gave the highest yield increase.

Other Fungal Diseases

1. *Colletotrichum lindemuthianum* (Sacc. & Magnus) Br. & Cav. (anthracnose)

Geographical distribution. The pathogen is distributed worldwide (Commonwealth Agricultural Bureaux, 1985).

Economic importance. Most recorded instances indicate *Phaseolus* bean and cowpea as hosts, suggesting that this is not an important pathogen of faba bean. Faba bean is listed as a host plant by Richardson (1979) and Mordue (1971).

Symptoms. The disease symptom is an anthracnose of leaves, pods and stems. Characteristic features are the light salmon pink spore masses on grey or brown stem and pod lesions (Mordue, 1971).

Pathogen. Round or elongated acervuli are produced on infected tissue. They are approximately 300 μ in diameter, with setae of 4-9 μ width and less than 100 μ length. Hyaline, single-celled conidia measure 11-20 x 2.5-5.5 μ. On PDA, acervuli with pale salmon spore masses can be observed (Mordue, 1971).

Epidemiology. Infected seeds appear to be the most important source of inoculum. Humid weather with moderate temperature is favourable for the development of anthracnose (Smith *et al.*, 1988).

Detection in seed. For the detection of *C. lindemuthianum* in *Phaseolus* beans, Anselme & Champion (1981c) recommended a blotter test where the seeds are rolled into blotter paper after a

pretreatment of 10 min in 1% sodium hypochlorite. The blotters are incubated in plastic bags for 7 days at 20°C, and the cotyledons are examined, after removal of the seed coat, for black sunken spots with acervuli containing the typical conidia.

The fungus also can be detected easily in the blotter test, where seeds plated on wet blotters are incubated at 20°C for 7 days under 12/12-hour light/dark cycles. Acervuli of the fungus can be seen on the infected seeds under a stereoscopic microscope (S.B. Mathur, pers. comm.).

Control. Clean seed is the most important means of control. Seed certification schemes are in force in several countries (Mordue, 1971). Fungicide application is rarely economic in the field, whereas systemic fungicides applied as seed treatment can prevent seed transfer (Smith *et al.*, 1988).

2. *Cercospora zonata* Wint.

According to Smith *et al.* (1988), this pathogen is widespread in Europe. Srivastava (1982) reported its occurrence in Uttar Pradesh, India, and described the symptoms as irregular dark grey to black leaf spots.

3. *Rhizoctonia solani* Kühn

This pathogen is mostly known to be soil-borne, but was reported by Neergaard (1977) also to be seed-borne in several hosts, including *Vicia faba*. It belongs to the group *mycelia sterilia*, which means no conidia are produced. Salt (1982) listed *R. solani* as one of the pathogens associated with the wilt and root rot complex, which is widespread in dry areas. In Egypt, *R. solani* caused severe losses in early, but not in late, plantings (Mohamed, 1982). Fungicidal seed treatments with PCNB, thiram or benomyl were effective in controlling infection of germinating seeds and young seedlings (Salt, 1983).

Chapter 5
Stem Nematode [*Ditylenchus dipsaci* (Kühn) Filipjev]

Geographical distribution

Decker (1981) reported wide distribution in Europe, and also in Argentina, Australia, Brazil, Canada, North Africa, Turkey, UAR, USA and USSR. Surprisingly, faba beans in Egypt were free of this nematode (Augustin, 1985).

Economic importance

This nematode may be more important in other crops such as alfalfa, cereals and flowering bulbs. Hanounik & Sikora (1980) reported that the frequency of diseased plants exceeded 80% in some locations in Syria.

Symptoms

Stems of infested plants show a reddish-brown discolouration that turns black with age. The symptoms usually start at the base and may extend to the pod-bearing region (Fig. 27). Further symptoms depend largely on the race: the "giant race" may cause stunting and twisting of infested stems, and even of leaf petioles and pods, whereas the "oat race" seldom causes distortion, but stems may be thinner than normal (Hooper, 1971). Symptoms may be confused with those of chocolate spot. Heavily infested pods are often distorted and contain many infested seeds (Hooper, 1983).

Infested seeds contain dried fourth-stage larvae, particularly in the slit of the hilum. Often necrotic patches can be seen after removal of the testa (Hooper, 1971).

Fig. 27. Damage caused by stem nematodes

Pests

The nematode is very polyphagous and, besides faba bean, also attacks alfalfa, clovers, pea, onion, oats, rye, maize, sugar beet, strawberry and many weeds (Caubel, 1983; Hooper, 1983). Several races are known, which vary in distribution, pathogenicity and host range. The oat race seems to be more prevalent in Europe, whereas the giant race,

attacking only faba beans, is more prevalent in North Africa and the Middle East (Hooper, 1983).

Adult nematodes are usually 1-1.5 mm long, or in the giant race, 1.5-2.3 mm.

Population dynamics

Neergaard (1977) listed 14 different hosts, out of a total of more than 400 species, in which the nematode is seed-borne to various extents. The females lay up to 500 eggs in plant tissue. The second of four juvenile stages emerges from the egg. In onion, the lifecycle is 19-23 days at 25°C (Hooper, 1983). Ait Ighil & Caubel (1986) found up to 25,000 nematodes in one seed. The number of infested seeds harvested was higher if the source of infestation was seed rather than soil.

Larvae can survive in the seeds for at least 4 years (Hooper, 1971); the maximum recorded time is 23 years (Caubel, 1983). Survival in soil can occur for several years (Hooper, 1983).

Green (1979) found that the percentage of plant infection was up to 86% lower than the percentage of infected seeds. In this experiment the number of nematodes per seed was relatively low (1-168), so that the requirement of at least one nematode of each sex was not met in many cases.

Green & Sime (1979) found 38% of commercial faba bean seed stocks in England infested with *D. dipsaci*. Steiner & Lamprecht (1983) reported 19% of the certified seed lots tested in West Germany in 1978-80 to be infested, whereas only 8% were infested in 1982, particularly those originating in areas with more humid climatic conditions (Lamprecht & Steiner, 1984).

Detection in seed

Caubel (1987) recommended two alternatives: the soaking, and the mistifier method. The former is easier, requiring soaking of the seeds overnight, decanting, rinsing with fresh water which is added to the decanted sample, settling for 4 hours and examination under a stereoscopic microscope with transmitted light. With this method, only rather superficially borne nematodes will be extracted. With the mistifier method, more active specimens are recovered. In the latter method, the seeds are placed on a coarse sieve over a funnel and exposed to a fine mist of water for 48 hours. A second funnel with a closed stem is placed underneath the first, allowing a gentle overflow of the excess water. The nematodes will sink to the bottom of the second funnel and can be collected from there for examination.

Control

Green & Sime (1979) suggested that inspection of seed crops would help reduce infection. However, the seed infestation may develop in lightly infested plants that may not show symptoms at the time of field inspection, or a low incidence may be overlooked. Caubel (1983) recommended seed certification schemes, crop rotation, or the use of resistant varieties. With a large-seeded species like faba bean, fumigation with methyl bromide may be phytotoxic at the rate required to eradicate the nematodes (Caubel, 1983). Aldicarb is effective in controlling seed- and soil-borne infestation at 4 kg a.i./ha for row treatment, and at 10 kg a.i./ha as broadcast application (Hooper, 1983).

Chapter 6
Bruchids

Callosobruchus spp., *Bruchidius* spp.

Geographical distribution

Callosobruchus chinensis (L.) and *C. maculatus* (F.) are widespread and were reported from tropical and subtropical areas on all continents (Southgate, 1978). Kranz *et al.* (1977) stated that the pest was spread by international trade in pulses.

Economic importance

Losses in storage may amount to 60% under warm conditions. In addition, there are effects on seed quality (protein denaturation), and contamination by faeces and pieces of insect chitin (van Emden *et al.*, 1988). According to Siddig (1982), the losses in Sudan amount to 30%.

Symptoms

The eggs can be seen easily, as well as the holes through which the adults bore from the seeds (Fig. 28).

Pests

These beetles belong to the family Bruchidae in the order Coleoptera. *Callosobruchus chinensis* (L.), *C. maculatus* (F.), and *Bruchidius incarnatus* (Boh.) are able to oviposit in stored faba beans. Their behaviour and biology are similar. The size of the adult beetle is 2.5-3.5 mm. The body is oval and rust-coloured with brown or black spots. Females of *C. chinensis* have more markedly serrated antennae than *C. maculatus* (Kranz *et al.*, 1977).

Population dynamics

The two *Callosobruchus* species seem to attack faba bean less frequently than cowpea, chickpea, lentil and other crops. Southgate (1978) and Hariri (1981) did not list faba bean among the hosts. The beetles infest the seeds after harvest and are true storage pests. *Callosobruchus maculatus* is reported to infest mature pods in the field in drier areas (Kranz *et al.*, 1977). One or more eggs are laid on the testa of the seed, and the newly

Fig. 28. Eggs and exit holes of *Bruchidius* sp.

hatched larvae bore into the cotyledons where they complete their cycle. Five or more generations per year are common in warmer climates (Kamel, 1982).

Detection in seed

X-ray machines, which are very expensive, allow detection of larvae, pupae and adults in seeds. Visual inspection of seeds for eggs and bore-holes of adults also will reveal an infestation.

Control

Fam & Ahmed (1985) reported genotypes with resistance to *C. maculatus*. Details of fumigation were given by Bond (1984). Aluminum phosphide (phosphine) has less effect on seed viability than methyl bromide, particularly if the seed moisture is relatively high. Generally, repeated fumigation should be avoided (Bond, 1984).

Bruchus spp.

Geographical distribution

While Bardner (1983) assumed that *Bruchus* spp. have achieved a worldwide distribution due to international seed trade, Decelle (1981) maintained that, although *B. rufimanus* has been reported from some African countries, it has not become indigenous in these areas.

Economic importance

Hariri (1981) reported up to 70% infestation of faba beans with *B. rufimanus* in Syria.

Symptoms

The holes through which the larvae bore into the seeds can be seen as small black points on the seed surface (Fig. 29a). The exit holes of the adults are about 2-3 mm large and can be seen first as "windows" with just the seed coat remaining (Fig. 29b). An adult *Bruchus dentipes* is shown in Figure 30.

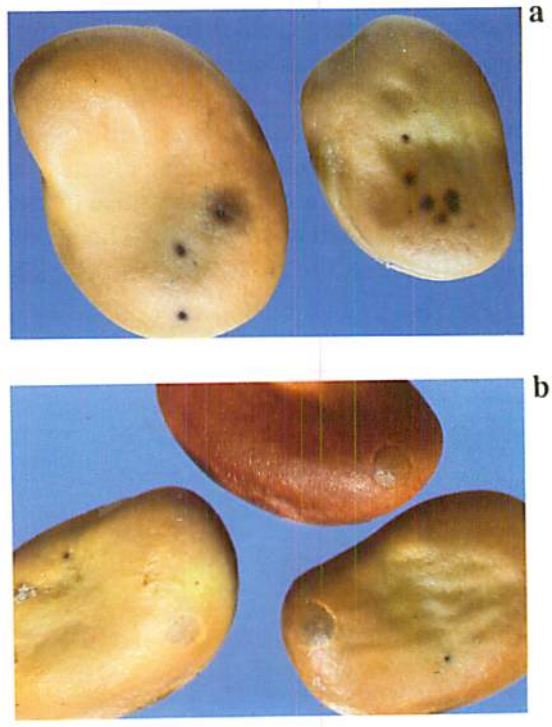


Fig. 29. (a) Faba bean seeds with black bore holes; (b) "windows" in faba bean seeds infested with *Bruchus* sp.

Fig. 30. *Bruchus dentipes*

Pests

Faba beans are attacked by *Bruchus rufimanus* Boh. and *Bruchus dentipes* Baudi.

Population dynamics

Bruchus spp. produce only one generation per year. Unlike *Bruchidius* spp. and *Callosobruchus* spp., the adults need nectar and pollen and are unable to breed in stored seeds (Bardner, 1983). Planting of infested seeds creates a source of infestation for a subsequent crop (van Emden *et al.*, 1988). The seeds are infested in the pods by larvae, which feed until after harvest. Pupation usually takes place in storage and the adults will not emerge until after planting (Kamel, 1982).

Control

Bardner (1983) recommended sprays during flowering with insecticides safe to bees, such as endosulfan. Kamel (1982) reported that an annual routine fumigation of beans stored for seed decreased the infestation in the subsequent crop from more than 12% to less than 1%.

Chapter 7
Parasitic Weeds

Orobanche spp. (Broomrape)

Geographical distribution

According to Musselman (1980), the *Orobanche* spp. originated in Southern Europe and/or the Middle East, where they are still of the greatest importance (Kranz *et al.*, 1977). *Orobanche ramosa* was later introduced to Cuba, Mexico and the USA, and *Orobanche minor* Smith to the USA, New Zealand and East Africa (Musselman, 1986). Jacobsohn (1986) suggested that *O. ramosa* had been introduced into the USA with imported crop seeds. The distribution seems to be restricted to areas with a Mediterranean climate, i.e., semi-arid with low temperatures to induce germination (Musselman, 1986).

In 1985, *O. minor* was reported for the first time in Ethiopia, probably introduced with faba bean seed (Telaye & Saxena, 1986). No other *Orobanche* species is known to occur in Ethiopia.

Economic importance

Parker (1986) estimated that a total of 800,000 ha is infested with *O. crenata*. According to Schlüter & Aber (1980), *Orobanche* caused catastrophic losses in the late seventies in Morocco. Susceptible legumes are no longer planted in *Orobanche*-infested areas. In Egypt, Zahran (1982) reported a 60% yield loss due to *Orobanche* when infestation reached 1000 stems/ha. Sauerborn & Saxena (1987) estimated yield loss due to *Orobanche crenata* in Syria to be between 5 and 100%.

Symptoms

Shoots of *Orobanche* usually appear after flowering. At earlier stages, the host plants may show symptoms of water stress, such as wilting and stunted growth. This is due to the parasite's competition for water (Cubero, 1983). In Morocco, Schmitt (1979) found some regions in which the faba beans were barely visible and the areas resembled *Orobanche* fields.

Pathogens

Although *Orobanche* spp. are often classified as weeds, their mode of directly attacking host plants coupled with their inability to develop without the presence of a host justify the term "pathogen". They form haustoria to tap their hosts for nutrients and water in a manner similar to fungal pathogens.

According to Cubero *et al.* (1988), the three species *O. crenata* Forsk., *O. ramosa* L. and *O. aegyptiaca* Pers. attack faba beans, with the single-stemmed *O. crenata* being the most important (Fig. 31). The plants lack chlorophyll and have fleshy stems with scale-like leaves (Fig. 32; Musselman, 1980). In "The Greek Herbal of Dioscorides," which was compiled during the first century A.D., *Orobanche* is described as "used as a potherb, either raw, or sod, being eaten out of a platter as Asparagus" (Gunther, 1959). Although the translator assigned the botanical name *Cuscuta europea*, the description leaves no doubt that the author refers to an *Orobanche* species. Before flowering, the stalks of *O. crenata* indeed resemble the white asparagus

Fig. 31. Faba bean plants attacked by *Orobanche crenata*

Fig. 32. *Orobanche aegyptiaca/Orobanche ramosa*

that is popular in Europe. The beautiful, orchid-like whitish flowers are characteristic. In contrast, *O. ramosa* and *O. aegyptiaca* have blue flowers. The taxonomy of these species is not clear, and they are sometimes considered as *O. ramosa/O. aegyptiaca* complex (Musselman 1986; Linke *et al.*, 1989), which seems justified in view of their similar biology and host range (Parker 1986).

Epidemiology

The seeds are tiny and in 1 gram there are up to 200,000 seeds. One plant with several stems can release one million seeds (van Emden *et al.*, 1988). While wind and water can disseminate the reticulate brown seeds (Kranz *et al.*, 1977), Mesa-Garcia *et al.* (1986) found that the seeds were mainly spread in the row direction, indicating an effect of tillage and harvesting. Seeds can remain viable in the soil for 15-20 years (Cubero *et al.*, 1988). The optimum for germination is between 18 and 25°C, and the maximum around 27°C. Generally, a germination stimulant is excreted by the host plant (Cubero *et al.*, 1988).

Detection in seed

Orobanche seeds, which contaminate faba bean seeds superficially, can be detected either by direct inspection under a stereomicroscope, or in a washing test. At the International Center for

Fig. 33. Pouring the washing suspension on a sieve for inspection for *Orobanche* seeds

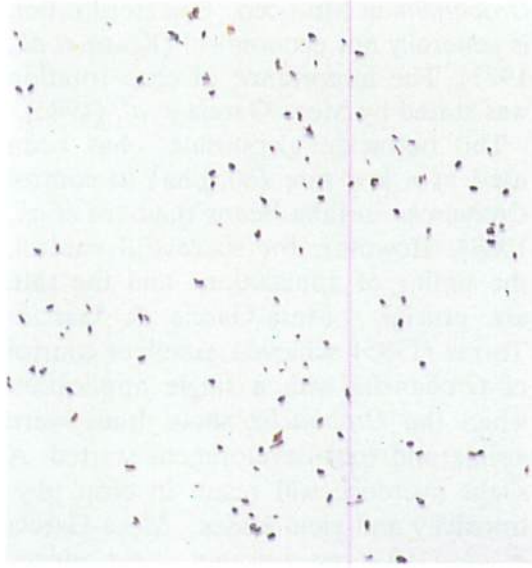


Fig. 34. *Orobanche* seeds after washing

Agricultural Research in the Dry Areas (ICARDA), legume seeds are submerged in water with several drops of detergent, shaken vigourously, and the washing liquid poured through a sieve covered with white filter paper (Fig. 33). *Orobanche* seeds can be detected by the naked eye; occasionally confirmation under a stereomicroscope may be necessary (Fig. 34).

Control

Besides chemical control, Musselman (1980) listed mechanical, cultural and biological means, such as trap crops (stimulating germination, but not supporting parasitism), catch crops (stimulating both germination and parasitism) and insects attacking *Orobanche* directly. Figure 35 shows *Phytomyza orobanchiae* attacking

Fig. 35. Stem of *Orobanche crenata* attacked by *Phytomyza orobanchiae*

Orobanche in Morocco. Soil sterilization is generally not economical (Kranz *et al.*, 1977). The importance of crop rotation was stated by Mesa-Garcia *et al.* (1986).

The herbicide glyphosate has been used at a low rate (80 g/ha) to control *Orobanche* in faba beans (Cubero *et al.*, 1988). However, for successful control, the timing of application and the rate are crucial. Mesa-Garcia & Garcia-Torres (1985) achieved excellent control of *Orobanche* with a single application when the *Orobanche* shoot buds were visible and root development started. A slight overdose will result in crop phytotoxicity and yield losses. Mesa-Garcia *et al.* (1984) even found slight phytotoxicity at a rate of 60 g/ha, particularly when applied at the vegetative stage. Zahran *et al.* (1988) tested various chemicals under field conditions in Egypt. Two late postemergent sprays of glyphosate (0.064 kg a.i./ha) were superior to pre- and postemergence applications of dazomet (25 and 50 kg a.i./ha), carbofuran (2.5 and 5 kg a.i./ha) and fluazifop-butyl (0.58 and 0.89 kg a.i./ha). The herbicide imazaquin also was effective in controlling *Orobanche*, but did not have a significant effect on yield.

Cuscuta spp. (Dodder)

Jha & Dutta (1982) reported that *Cuscuta hyalina* parasitized faba beans in India. Cubero (1983) mentioned several *Cuscuta* species as parasites on faba beans (Fig. 36), but did not consider them serious pests. Sauerborn & Saxena (1987) reported a frequency of 30-55% in faba bean fields in Northern Syria. Compared with the many reports of this parasitic weed on other host plants, such as clover and alfalfa, it seems of negligible economic importance on faba bean.

Fig. 36. Faba bean plants attacked by *Cuscuta* sp.

Chapter 8
Concomitant Contaminations with Other Pests/Pathogens

A number of pests or pathogens not previously listed could be associated with faba bean seeds and be disseminated through seed. They are reported here only briefly. Foremost are weed seeds. Although seed cleaning in a large-seeded crop such as faba bean should not pose a difficulty, various weed seeds may be mixed with the faba beans.

Nematodes could be contaminating faba bean seeds either as cysts (*Heterodera goettingiana*), galls (*Meloidogyne* spp.) or in soil clods mixed with the seeds (migratory nematodes such as *Radopholus similis*, *Rotylenchulus reniformis*, *Pratylenchus* spp. and others). All nematodes mentioned are reported to occur on faba beans (Hooper, 1983) and therefore might contaminate the seeds in the process of harvesting.

Soil mixed with faba bean seeds also may harbour otherwise predominantly or strictly soil-borne fungi such as *Pythium* spp., *Aphanomyces* spp., *Phytophthora* spp. and others.

Sclerotia, e.g., those of *Sclerotinia sclerotiorum*, easily get mixed with seeds and were reported to contaminate faba bean seeds (Neergaard, 1977).

Frequently plant debris such as parts of stems, leaves, pods, etc. is associated with the seeds. Fungi that survive in or on plant debris are *Macrophomina phaseoli*, *Phoma* spp., *Erysiphe* spp. and other powdery mildews. Although chances of transmission of one of the above-mentioned pathogens with seeds is fairly small, it warrants attention in the context of quarantine.

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