

Safe Movement of ICRISAT's Seed Crops Germplasm

Information Bulletin No. 81



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Abstract

This information bulletin is a part of the report of the project- Global Public Goods II, Activity 3.1 entitled "Safe Movement of Seed Crops Germplasm and Protection of CGIAR Germplasm Banks". This contains information on various aspects of global seed germplasm exchange of ICRISAT's mandate crops (sorghum, pearl millet, chickpea, pigeonpea, groundnut and small millets) through the Plant Quarantine Laboratory and National Bureau of Plant Genetic Resources, Indian Council of Agricultural Research, Government of India. The bulletin mainly focuses on the most important client countries importing ICRISAT's mandate crops germplasm and their quarantine requirements; phytosanitary requirements for export of ICRISAT's mandate seed crops to countries across the globe and technical information on the quarantine significant pests and diseases of ICRISAT's mandate crops. This bulletin will be useful to those who are involved in germplasm exchange at national and international levels.

Cover: (Clockwise from top left) **Seed infected by** *Rhizoctonia bataticola* of groundnut, *Moesziomyces penicillariae* of pearl millet, *Ascochyta rabiei* of chickpea. **Seed infested by** *Callosobruchus analis* of pigeonpea and *Sitophilus oryzae* of sorghum (inset).

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Safe Movement of ICRISAT's Seed Crops Germplasm

(A part of GPG II Activity 3.1. Safe Movement of
Seed Crops Germplasm and Protection
of CGIAR Germplasm banks)

Information Bulletin No. 81

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Plant Quarantine Laboratory



**International Crops Research Institute
for the Semi-Arid Tropics**

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Contents

Foreword	v
Introduction.....	1
Germplasm exchange of ICRISAT mandate crops.....	2
Most frequent client countries.....	2
Sorghum	3
Pearl millet.....	3
Chickpea.....	4
Pigeonpea	4
Groundnut.....	5
Small millets	5
Quarantine testing procedures for import.....	6
Routine tests.....	6
Specific tests	6
Quarantine testing procedures for export.....	10
Issuance of Phytosanitary certificate	12
Packaging and dispatch	12
Quarantine significant pests	13
Phytosanitary requirement for import and export	14
Import	15
Export	16
Technical Guidelines of Quarantine Significant Pests of Seed Crops	58
Sorghum [<i>Sorghum bicolor</i> (L.) Moench].....	58
Pearl millet [<i>Pennisetum glaucum</i> (L.) R. Br.].....	107
Chickpea (<i>Cicer arietinum</i> L.)	137
Pigeonpea (<i>Cajanus cajan</i> L.)	164
Groundnut (<i>Arachis hypogaea</i> Linn.).....	184
Finger millet (<i>Eleusine coracana</i> L.).....	223

Foreword

I am extremely delighted to write a foreword for the Global Public Goods II, Activity 3.1, report 'Safe Movement of ICRISAT's Seed Crops Germplasm'. International exchange of germplasm is critical to genetic improvement of crop cultivars to meet the ever-increasing demand of food, feed and fodder. With increasing global vulnerability to agricultural bioterrorism, the role of plant quarantine departments at the national and international levels becomes the first line of defense in bio-security, which is critical to food security. This report documents varied aspects of concerns related to germplasm exchange of ICRISAT's mandate crops, protocols and procedures for germplasm exchange. This also includes the phytosanitary requirement for ICRISAT mandate crops, quarantine significant pests and technical guidelines for quarantine significant pests.

Exchange of germplasm must flow for conservation of genetic diversity across countries for utilization in research, This will help realize the dream of food security in most developing countries where food production is still way below the demand. International exchange of seed crops germplasm increases phytosanitary risks that involves introduction of exotic insect-pests and pathogens. This publication will play a crucial role in safe movement of ICRISAT's mandate crops germplasm across the globe for crop improvements, without having the phytosanitary risks. The Plant Quarantine Laboratory of ICRISAT in collaboration with the National Bureau of Plant Genetic Resources of the Indian Council of Agricultural Research, plays a major role in minimizing phytosanitary risk. This publication will be very useful in the day-to-day activity of plant quarantine laboratories in fulfilling the quarantine requirement for the countries importing ICRISAT's crop germplasm.

I am extremely happy to put on record that ICRISAT's Plant Quarantine Laboratory plays a crucial role under the existing new world order of the WTO regime, with an impeccable record of exchanging healthy germplasm by strictly adhering to the national and international quarantine protocols.

Our Plant Quarantine Laboratory has so far exported 1.2 million germplasm seed samples to 172 countries and imported 0.16 million germplasm samples from 96 countries. All this has taken place in the backdrop of adhering to highest and modern phytosanitary standards and protocols with no introduction of any exotic pests, diseases or weeds.

My best wishes to the staff of our Plant Quarantine Laboratory for significantly contributing towards the goals set at national and international levels towards world food security. This will ultimately contribute to the improvement in the lot of smallholder farmers and the poor in the semi-arid tropics, and help them grow their way out of poverty.

William D Dar
Director General, ICRISAT

Introduction

The information contained in this bulletin was compiled under the project Global Public Goods II (GPG2), Activity 3.1 entitled “Safe Movement of Seed Crops Germplasm and Protection of CGIAR Germplasm Banks”. The project activity on compilation of information related to germplasm exchange of ICRISAT’s mandate crops was a brief one during February to July 2009. The Plant Quarantine Laboratory (PQL) at ICRISAT-Patancheru facilitates the global exchange of germplasm of ICRISAT’s mandate crops (sorghum, pearl millet, chickpea, pigeonpea, groundnut and small millets). As per the Memorandum of Understanding between the Government of India and ICRISAT, restricted movement of seeds of ICRISAT’s mandate crops into and out of India is permitted after observing the National Plant Quarantine regulations. Under this, National Bureau of Plant Genetic Resources (NBPGR), Regional Station, Rajendranagar, Hyderabad, Andhra Pradesh, of the Indian Council of Agricultural Research monitors the phytosanitary standards for ICRISAT’s germplasm exchange. So far, ICRISAT through PQL has imported 0.16 million seed germplasm samples from 96 countries and exported 1.2 million seed germplasm samples to 172 countries of the world. All these have been achieved by strictly adhering to the phytosanitary standards and protocols of plant quarantine procedures with no record of introducing any exotic pests. Different countries have different quarantine requirements and phytosanitary standards. On the basis of the germplasm exchanged through PQL, the different information was gathered to fulfill the objective of the project and compiled in the form of a bulletin. This bulletin includes the germplasm exchanged, most client countries importing ICRISAT’s mandate crops and their quarantine regulations, protocols and procedures for import and export, list of quarantine significant pests and diseases prepared as per the import permit received from importing countries. Phytosanitary requirement for import and export of ICRISAT’s seed germplasm is the focal point of the bulletin and technical guidelines prepared for quarantine significant pests is the most unique feature of this bulletin. This bulletin will become the most important guidelines for safe exchange of seed germplasm of ICRISAT’s mandate crops and will also be very useful to the scientific community involved in exchange of germplasm.

Germplasm exchange of ICRISAT mandate crops

Since 1974, ICRISAT has been exchanging germplasm for its mandate crops across the countries in the world. So far a large number of germplasm samples have been imported (168,200) and exported (1,251,411) to researchers in various countries (Table 1)

Table 1. Crop-wise numbers of seed samples exchanged during 1974-2008.

Import			
Crop	Consignments	Samples	Countries
Sorghum	528	73,676	70
Pearl millet	245	26,441	47
Chickpea	231	29,337	33
Pigeonpea	176	7,697	50
Groundnut	255	20,326	51
Small millets	77	10,723	32
Total	1,493	168,200	96
Export			
Sorghum	4,229	520,089	135
Pearl millet	1,773	188,859	117
Chickpea	2,701	314,629	124
Pigeonpea	2,239	86,561	145
Groundnut	1,837	120,014	133
Small millets	196	21,259	59
Total	12,975	1,251,411	172

Most frequent client countries

Top 10 countries importing ICRISAT's germplasm and breeding lines (1974-2008) are considered as most frequent client countries. The crop wise number of consignments exported to client countries with their quarantine requirements are provided below.

Sorghum

Country	No of consignment (samples)	IP required	Additional declaration
Kenya	206 (44,318)	Yes	Research purposes and treated with suitable fungicide
USA	204 (24,474)	Yes	None
Thailand	188 (18,078)	Yes	Free from GMO
Burkina Faso	177 (36,858)	No	None
Mali	172 (28,459)	No	None
Sudan	164 (23,105)	No	None
Mexico	154 (23,597)	Yes	Seeds are free from <i>Claviceps africana</i> , <i>Burkholderia andropogoni</i> and <i>Periconia circinata</i>
UK	142 (3,382)	No	None
Ethiopia	131 (21,731)	Yes	Seeds are free from virus and other diseases and pests
Niger	131 (17,198)	No	None

Pearl millet

Country	No of consignments (samples)	IP required	Additional declaration
Niger	181 (33,924)	Yes	None
UK	153 (7,855)	Yes	None
USA	123 (3,507)	Yes	None
Sudan	85 (11,814)	Yes	None
Pakistan	72 (10,253)	Yes	Free from mycoplasmas/mollicutes
Zimbabwe	69 (14,306)	Yes	The seed lot was tested in a laboratory and found free from <i>Ascochyta sorghi</i> , <i>Claviceps</i> spp, <i>Sphacelia</i> sp., <i>Cochliobolus lunatus</i> , <i>Penicillium oxalicum</i> , <i>Peronosclerospora</i> sp., <i>Sphacelotheca</i> sp., <i>Tolyposporium ehrenergii</i> , <i>Pseudomonas syringae</i> , <i>Xanthomonas campestris</i> pv. <i>holicicola</i> , <i>X. rubrisorghii</i> . The seed lot was found free from <i>Sytotroga cerealla</i> , <i>Tribolium castanum</i> , <i>Plodia interpunctuella</i> , <i>Prostathanus truncatus</i>
Burkina Faso	62 (32,120)	No	None
Senegal	62 (12,583)	No	None
Kenya	52 (6,820)	Yes	Seed treatment with suitable fungicides
Mali	52 (4,581)	No	None

Chickpea

Country	No of consignments (samples)	IP required	Additional declaration
Bangladesh	203 (28,069)	Yes	Methyl bromide fumigation
Pakistan	187 (41,596)	Yes	None
USA	176 (12,268)	Yes	None
Nepal	141 (17,811)	No	None
Syria	120 (25,685)	No	None
Australia	116 (9,110)	Yes	None
Mexico	103 (10,934)	Yes	Seeds are free from <i>Trogoderma granarium</i>
Ethiopia	102 (20,856)	Yes	Seeds are free from <i>Aspergillus flavus</i> , <i>Phoma medicaginis</i> and other seed-borne diseases and treated with systemic fungicide
Myanmar	99 (15,701)	No	None
UK	94 (777)	Yes	None

Pigeonpea

Country	No of consignments (samples)	IP required	Additional declaration
USA.	173 (3,365)	Yes	None
Kenya	106 (8,426)	Yes	Seed are free from virus diseases and <i>Colletotrichum cajani</i> , pea seed-borne mosaic virus and <i>Pseudomonas pisi</i>
Nepal	92 (6,650)	No	None
Philippines	87 (2,864)	Required	Seeds are free from Alfalfa mosaic virus, Bean leafroll virus, Broad bean wilt virus, Tobacco streak virus and tomato spotted wilt virus, and other allied microorganisms.
Thailand	83 (2,307)	No	None
Sri Lanka	67 (2,893)	Yes	None
Indonesia	65 (3,093)	No	None
Bangladesh	59 (1,603)	Yes	Methyl bromide fumigation
UK	58 (472)	Yes	None
Japan	56 (436)	Yes	None

Groundnut

Country	No of consignments (samples)	IP required	Additional declaration
USA	127 (2,807)	Yes	None
UK	104 (3,078)	Yes	None
PR China	89 (4,289)	Yes	None
Thailand	73 (3,903)	No	None
Indonesia	72 (17,286)	Yes	Free from <i>Trogoderma granarium</i>
Vietnam	70 (6,103)	No	None
Philippines	70 (3,103)	Yes	Seeds are free from <i>Pratylenchus zeae</i> , <i>Aphasmatylenchus straturatus</i> , <i>Aphelenchoides arachidis</i> and <i>Verticillium albo-atrum</i> , Bean common mosaic virus, Cowpea mild mottle virus, Groundnut yellow spot virus, Peanut clump virus, <i>Holotrichia serrata</i> , <i>Macrophomina phaseolina</i> , <i>Pratylenchus thorni</i> , <i>Trogoderma granarium</i> and other allied microorganisms.
Malawi	66 (27,791)	Yes	Seed plants in active growth phase found free from Peanut mottle virus, Peanut marginal chlorosis virus, Peanut stunt virus and seed free from Khapra beetle (<i>Trogoderma granarium</i>), <i>Carydon</i> sp. and other injurious pests. Lines not produced through genetic manipulation.
Niger	60 (9,748)	No	None
Sri Lanka	52 (1,827)	Yes	Free from Peanut mottle virus, Peanut marginal chlorosis virus and Peanut stunt virus

Small millets

Country	No of consignments (samples)	IP required	Additional declaration
Kenya	20 (5,045)	Yes	None
Zimbabwe	11 (1,216)	Yes	<i>Ascochyta sorghi</i> , <i>Claviceps</i> sp., <i>C. purpurea</i> , <i>Sphaecelia</i> sp., <i>Cochliobolus lunatus</i> , <i>Penicillium xalicum</i> , <i>Peronosclerospora sorghi</i> , <i>Sphacelotheca</i> sp., <i>Tolyposporium ehrenbergii</i> , <i>Pseudomonas syringae</i> , <i>Xanthomonas campestris</i> pv. <i>holicicola</i> and <i>X. rubrisorghi</i> , <i>Prostaphanus</i> sp. and other storage stored pests
Germany	11 (840)	No	None
USA	9 (921)	Yes	None
Zambia	8 (1,907)	No	None
UK	8 (212)	Yes	None
Ethiopia	7 (760)	Yes	None
PR China	7 (746)	No	None
Sudan	7 (249)	No	None
Italy	6 (478)	No	None

Quarantine testing procedures for import

All import consignments are subjected to seed health testing procedures at National Bureau of Plant Genetic Resources, Regional Station, Rajendranagar, Hyderabad and released to plant quarantine lab to carry out the grow out test either in plant quarantine greenhouse or at Post-entry quarantine Isolation Area (PEQIA) at ICRISAT to screen for exotic pests. Brief accounts of various tests performed in the germplasm import flow chart are given below.

Routine tests

Visual examination. Each consignment is examined under illuminated magnifying lens (2X) and cleaned to eliminate the storage pests and pathogens in the form of sclerotia, nematode galls, weed seeds and soil clods. In specific cases, samples are also examined under low power stereo-binocular microscope to detect the presence of seed borne rust, anthracnose and downy mildew spores.

Blotter test. After visual examination each seed sample is plated for pathological examination as recommended by International Seed Testing Association (ISTA) for observation of seed associated pathogens (fungi/bacteria/nematodes). Petri-dishes containing seeds are incubated for seven days at $20 \pm 2^\circ \text{C}$ under alternate light and darkness.

Microscopic examination. After seven days of incubation, samples are examined under a stereo-binocular microscope for the presence of pathogens. Seeds showing poor germination or infection by pathogenic fungi, bacteria or nematodes are rejected. A detailed record of the seed samples and pathogens detected is maintained in a register.

Specific tests

Radiography. Chickpea, pigeonpea, groundnut and other legume seeds are X-rayed for detection of latent infestation by insect pests, particularly *bruchids* and *chalcids* and their developing instars. The procedure involves exposure of seed samples to soft X-rays emitted by Softex X-ray equipment specially designed for the purpose. The seed sample is placed on a Polaroid film and exposed to X-rays. Images of adult insects, instars and eggs can be seen in the print as dark patches on the seed. Apparently healthy seeds showing internal infestation are rejected for release.

Agar plate method. The principle of recording in the agar plate test is macroscopic examination of fungal and bacterial colonies. The method is reliable and quick, but one has to be well acquainted with colony characters of different fungi and bacteria on agar media. Seeds are generally pre-treated with mild disinfectant such as sodium hypochlorite (1% aqueous solution) before plating on agar to prevent the growth of saprophytic pathogens. Potato dextrose agar, Potato carrot agar, Malt extract agar and Oat meal agar for fungi and Nutrient agar and Tetrazolium chloride agar for bacteria are the commonly used media.

Sedimentation. Seed samples of sorghum and pearl millet are picked up at random and washed with distilled and sterilized water, then centrifuged. The suspension is examined microscopically for oospores of downy mildew, smut spores, nematodes and *Striga* seeds.

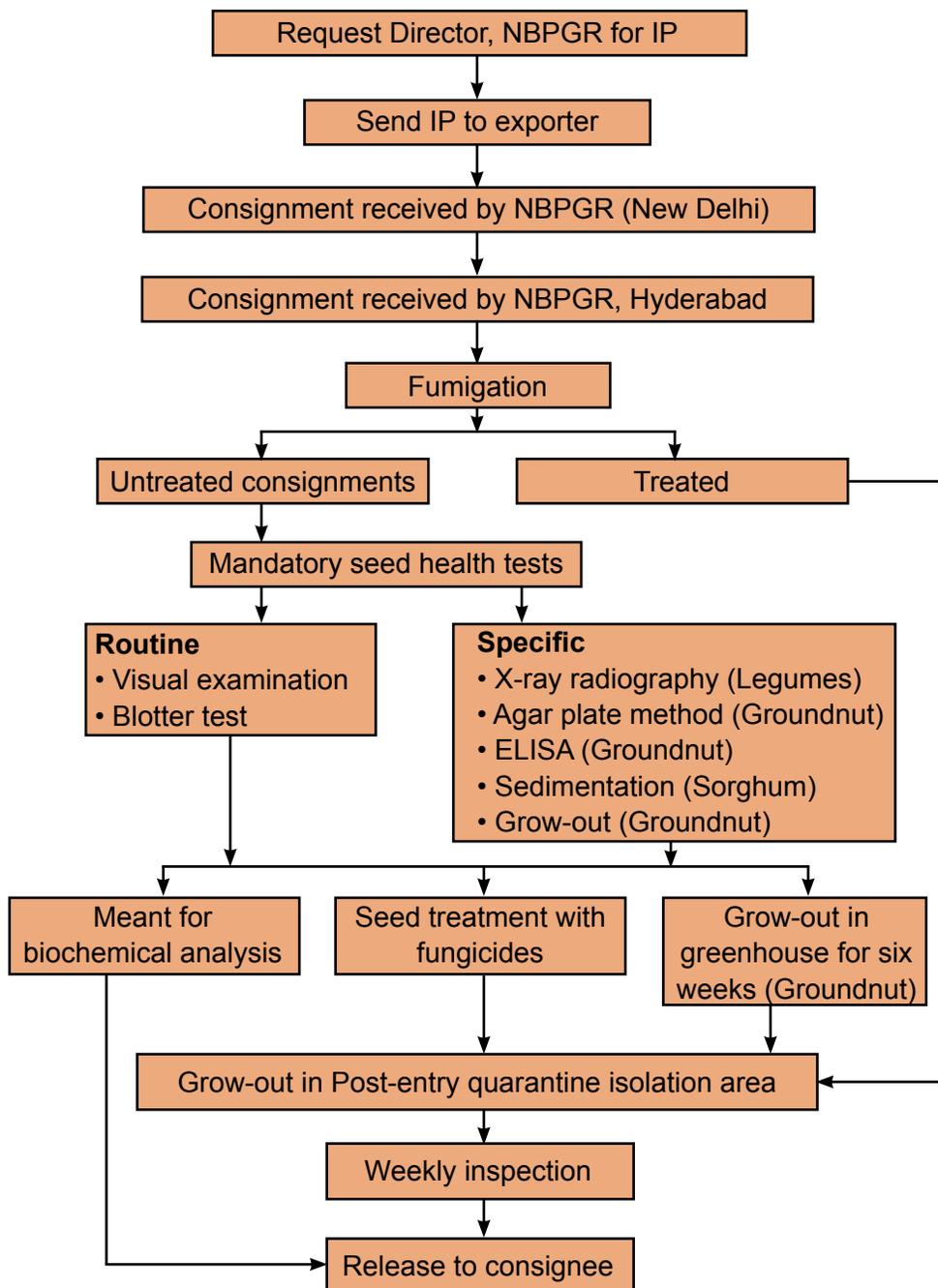
Enzyme-linked immunosorbent assay (ELISA). The test is used to detect seedborne viruses in groundnut seed as well as in plants that are subjected to grow-out test. Generally, 10 seeds per accession are used in the test for economic reasons. A piece of tissue (of about 50 mg) from cotyledon opposite the embryo is removed using a sterilized razor blade. Ten such seed samples of each germplasm line are pooled and processed by ELISA. The cut seeds are placed in a wooden seed storage tray having the same configuration as the ELISA plate and held until the test is completed. The pooled tissues are ground in a mortar at 1:50 w/v dilution of 0.01 M carbonate buffer, pH 9.6 containing 0.01 M sodium diethyl dithio-carbonate. Appropriate positive and negative controls are used. Antisera are cross-adsorbed with healthy groundnut seed extracts at 1 g tissue/20 ml of antibody buffer for 1 h at 37°C. The antisera to Peanut mottle virus (PeMoV) and Peanut stripe virus (PStV) are used at 1:5000 dilutions. Goat antirabbit Fc specific Ig G conjugated with alkaline phosphatase enzyme is used at 1:5000 dilutions. The substrate used is P-nitro phenyl phosphate @ 0.25 mg/ml. The plates are incubated for 30 min at room temperature. The color developed is recorded visually. Absorbance values are recorded at 405 nm in an ELISA reader. Samples showing absorbance values, 3-times more than that of healthy seeds are regarded as positive.

PeMoV and PStV are taken out from the seed storage tray and cotyledon tissue obtained from each seed is tested again individually by ELISA to identify the particular seed(s) infected with the viruses. Seeds of groundnut germplasm found negative in ELISA tests are grown after appropriate fungicidal treatment in plastic pots containing sterilized soil mixed with

fertilizer in a greenhouse. The plants are observed for virus symptoms up to 4 weeks and those that show virus or virus-like symptoms are kept separately. All healthy looking plants are ELISA tested by pooling the leaf tissues of 10 or <10 plants of each accession. Four-week-old seedlings that are found free from viruses are transplanted in the post-entry quarantine isolation field for further observations until harvest.

Post-entry quarantine inspection. Plant quarantine, which acts with the principle that prevention is better than cure, has the responsibility of preventing entry, spread and multiplication of hazardous pests. Pathogens, which may not be routinely detected in seed health testing procedures, are likely to cause disease on field-grown crops. Therefore, all imported ICRISAT mandate crop germplasm accessions are grown for one season in Post-entry quarantine Isolation Area (PEQIA) at ICRISAT. There is an exemption on imports for destructive chemical analysis. Weekly inspections are undertaken to detect exotic pests associated with growing plants by the scientists of NBPGR and ICRISAT's plant quarantine lab.

Seed health testing protocol at ICRISAT-PQL for import



Quarantine testing procedures for export

Normally, 3 to 4 weeks and a maximum of 12 weeks (in case of other tests, such as ELISA, growing out, agar test, and radiographic tests) are needed to process each export germplasm request. A brief account of various tests performed in the germplasm export flow chart is given below.

Pre-export field inspection. Plant quarantine scientists inspect the source crop from which seed samples are intended for export from seedling stage to flowering/pre-harvest stage to record the additional declaration in phytosanitary certificate. Untreated, healthy seeds are submitted for quarantine processing.

Fumigation. All seed samples received at PQL are fumigated either by vacuum fumigation or atmospheric fumigation to kill the stored grain pests. Vacuum fumigation is used for sorghum, chickpea and pigeonpea, whereas atmospheric fumigation is used for groundnut and pearl millet. In vacuum fumigation methyl bromide is used at 32 g/m³ for four hours. In atmospheric fumigation, aluminium phosphide is used at 3g/m³ for 72–120 h.

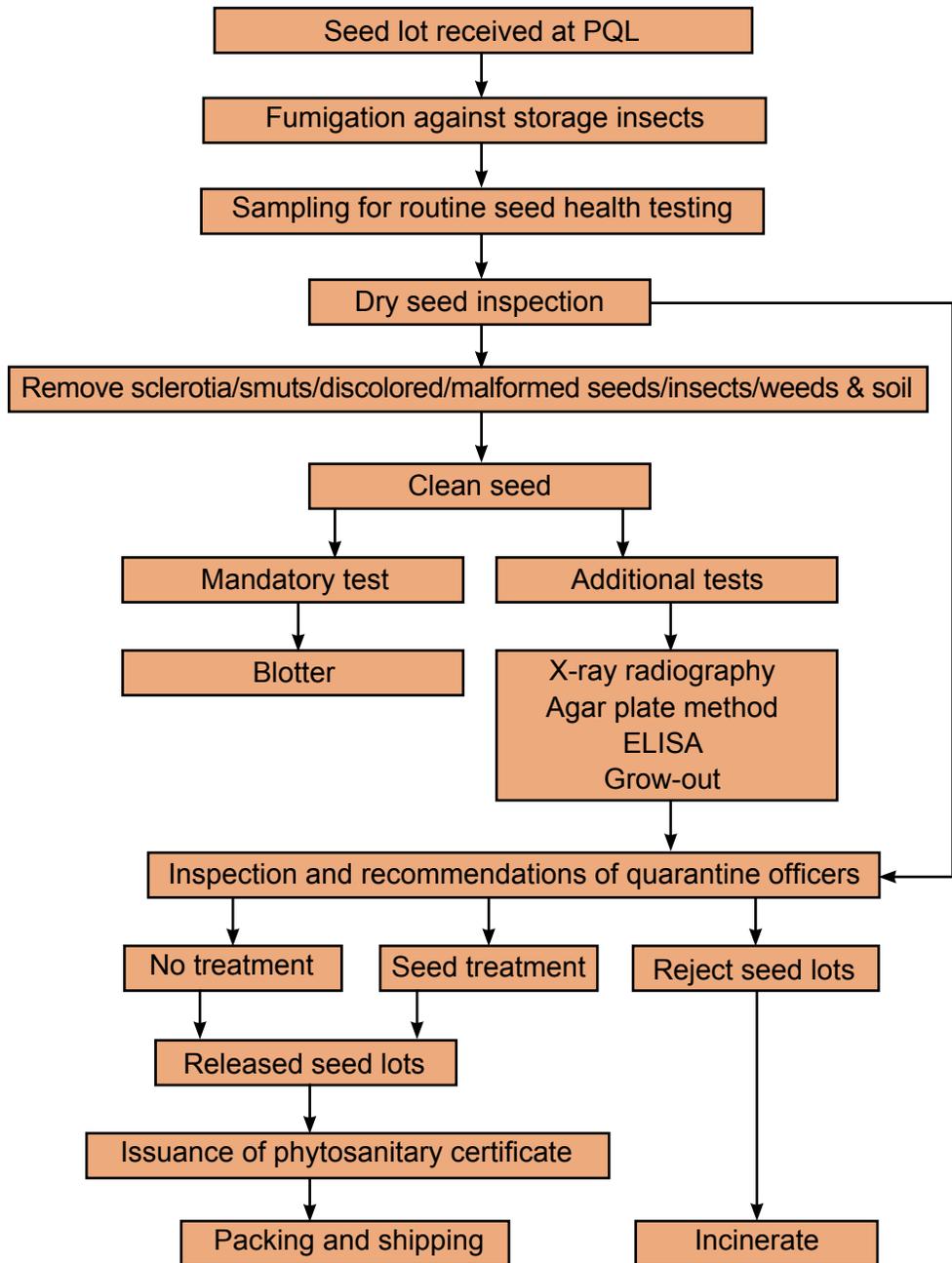
Visual examination. Each seed sample is examined under illuminated magnifying lens (2X magnification) and visually cleaned. Inert pathogen propagules (smut sori, ergot sclerotia and nematode galls), weed seed, crop debris, soil clods, stones and other foreign material are removed. Small shrunken, discolored seeds or damaged seeds are removed.

Blotter test. After visual examination each seed sample is plated for pathological examination as recommended by ISTA for observation of seed associated pathogens (fungi/bacteria/nematodes). Petri-dishes containing seeds are incubated for seven days at 20±2°C under alternate light and darkness.

Microscopic examination. After seven days of incubation, samples are examined under the stereo-binocular microscope for the presence of pathogens. Seeds showing poor germination or infection by pathogenic fungi or bacteria or nematodes, are rejected. A detailed record of the seed samples and pathogens detected is maintained and kept for scrutiny by the NBPGR scientists, who then confirm the identity of quarantine significant pathogens and recommend specific salvaging treatment, if necessary.

Inspection by NBPGR scientists. Quarantine scientists inspect the results of the visual examination and the incubation tests. The seed samples with pathogens having quarantine significance in the importing country are rejected.

Seed health testing protocol at ICRISAT-PQL for export



Voucher samples. A small quantity of seed (depending upon sample size) is collected from each sample as voucher specimen for storage as a reference in the medium term module of NBPGR, Hyderabad.

Obligation of importing country quarantine regulations. Each consignment is checked for the import permit with additional declaration and any other requirements, such as no commercial value certificate or certificate of origin.

Seed treatment. All seed samples are treated with suitable pesticides (fungicides and an insecticide) to keep the consignment free from pathogens and stored grain pests. Routine seed treatment followed at PQL (Table 2).

Table 2. Chemical treatment schedule for seed exports used at plant quarantine lab of ICRISAT.

Crop	Chemical names and dosages		
	Chlorpyrifos/Lindane dust (2-6g kg ⁻¹)*	Benomyl or Carbendazim (2.5 g kg ⁻¹)	Thiram (2g kg ⁻¹)
Chickpea	√	√	√
Groundnut	√	--	√
Pigeonpea	√	√	√
Sorghum	√	√	√
Millets	√	--	√

* Dose varies as per the seed size.

Issuance of Phytosanitary certificate

Samples that are found infected with plant quarantine significant pathogens are rejected. In case of rejected samples, the consignors/exporters may resubmit the samples from a different source. The re-submitted samples undergo similar processing procedure for clearance. Phytosanitary certificates (PCs) are issued by NBPGR for healthy samples.

Packaging and dispatch

Each consignment is packed in a cardboard carton along with a letter addressed to the consignee by the Head, PQL, and ICRISAT honoring intellectual property right (IPR) regulation. Labels such as “seeds are treated with chemical,” “seed has no commercial value,” are affixed to the box along with original PC and IP in separate yellow-colored envelope. The consignment must bear the seal of NBPGR on the face of the package before dispatch to the designated destination.

Quarantine significant pests

A large number of samples are exchanged through the PQL as mentioned above to numerous countries around the world. Most of the countries have import regulations and have submitted import permits to import ICRISAT's seed germplasm. The pests mentioned in the import permits received from various countries are considered as quarantine significant pests. These are listed below (Tables 3 & 4).

Table 3. List of important quarantine significant pests of ICRISAT mandate cereals.

Sorghum	Pearl millet	Small millets
Fungi		
<i>Periconia circinata</i> (L. Mangin) Sacc.	<i>Sclerospora graminicola</i> (Sacc.) Schroet	
<i>Peronosclerospora sorghi</i> Weston and Uppal. (Shaw)	<i>Claviceps fusiformis</i> Loveless.	
<i>Colletitrichum graminicola</i> Ces.	<i>Moesziomyces penicillariae</i> (Bref.) Vanky.	<i>Cochliobolus lunatus</i> PR Nelson & Hassis
<i>Claviceps sorghi</i> Kulkarni Seshadri & Hegde.	<i>Bipolaris setariae</i> (Saw.) Shoem.	
<i>Sporisorium sorghi</i> Link in Willd.	<i>Pyricularia grisea</i> (Cke.) Sacc.	
<i>Cercospora sorghi</i> Ellis & Everh.		
<i>Exserhilum turcicum</i> Pass.		
<i>Ascochyta sorghi</i> sacc.		
Bacteria		
<i>Burkholderia andropogonis</i> Smith.	<i>Pseudomonas syringae</i> pv. <i>syringae</i> Van Hall.	<i>Pseudomonas syringae</i> pv. <i>syringae</i>
<i>Xanthomonas vasicola</i> pv. <i>holcicola</i> Elliott.	<i>Xanthomonas vasicola</i> pv. <i>holcicola</i> Elliott.	<i>Xanthomonas vasicola</i> pv. <i>holcicola</i> Elliott.
	<i>Xanthomonas campestris</i> (Pammel.) Dowson pv. <i>Pennamericanum</i> .	<i>Xanthomonas campestris</i> (Pammel.) Dowson pv. <i>Pennamericanum</i> .
Insects		
<i>Corcyra cephalonica</i> Stainton.		
<i>Ephesthia cautella</i> Walker.	<i>Plodia interpunctella</i> Hubner.	<i>Plodia interpunctella</i> Hubner.
<i>Oryzaephilus surinamensis</i> Linnaeus.	<i>Prostephanus truncatus</i> Horn.	<i>Prostephanus truncatus</i> Horn.
<i>Plodia interpunctella</i> Hubner.	<i>Sitotroga cerealella</i> Olivier.	<i>Tribolium Castaneum</i> Herbst.
<i>Rhizopertha dominica</i> Fabricius.	<i>Tribolium Castaneum</i> Herbst.	
<i>Sitophilus oryzae</i> Linnaeus.		
<i>Sitotroga cerealella</i> Olivier.		
<i>Prostephanus truncatus</i> Horn.		
<i>Tribolium Castaneum</i> Herbst.		
<i>Trogoderma granarium</i> Everts		

Table 4. List of Important Quarantine significant pests of ICRISAT mandate legumes.

Chickpea	Pigeonpea	Groundnut
Fungi		
<i>Ascochyta rabiei</i> (Pass.) Labr.	<i>Colletotrichum cajani</i> Rangel.	<i>Verticillium dahliae</i> Kleb.
	<i>Alternaria alternata</i> (Fries) Keissler.	<i>Colletotrichum dematium</i> (Pers.) Grove
<i>Fusarium Oxysporum f. sp. ciceri</i> (Padwick) Snyder & Hans.	<i>Lasiodiplodia theobromae</i> Pat.	<i>Rhizoctonia bataticola</i> (Tassi) E.J. Butler [(<i>Macrophomina phaseolina</i> (Tassi) Goid.)
<i>Colletotrichum dematium</i> (Pers.) Grove.		
<i>Phomopsis longicolla</i> Hobbs.		
<i>Phom medicaginis</i> Malbr. & Roum.		
<i>Botrytis cinerea</i> Pers. Ex Fr.		
<i>Colletotrichum dematium</i> (Pers ex Fr) Grove.		
Bacteria		
<i>Pseudomonas syringae</i> Van Hall pv. <i>pisi</i> (Sackett) Young et al.	<i>Pseudomonas syringae</i> Van Hall pv. <i>pisi</i> (Sackett) Young et al.	<i>Ralstonia solanacearum</i> (Smith) Yabuuchi et al.
Viruses		
		Peanut mottle virus (PMoV)
		Peanut stripe virus (PSTV)
		Peanut stunt virus (PSV)
		Peanut clump virus (PCV)
Nematode		
	<i>Heterodera cajani</i> Koshy.	<i>Ditylenchus destructor</i> Thorne.
		<i>Aphelenchoides arachidis</i> Bos.
Insects		
<i>Callosobruchus analis</i> Fabricius.	<i>Callosobruchus analis</i> Fabricius.	<i>Caryedon serratus</i> Olivier.
<i>Trogoderma granarium</i> Everts.	<i>Trogoderma granarium</i> Everts.	<i>Tribolium Castaneum</i> Herbst
		<i>Trogoderma granarium</i> Everts.

Phytosanitary requirement for import and export

ICRISAT's seed germplasm reached 172 countries and ICRISAT received germplasm from 96 countries. A large number of countries have their own phytosanitary standards for safe exchange. The crop-wise phytosanitary standards for import (Table 5) and export are mentioned below.

Import

Table 5. ICRISAT mandate crops into India as per Plant Quarantine Order 2003.

Plant species	Import permit	ADs required for pests/diseases
Sorghum/ <i>Sorghum</i> spp.	Required	Bacterial blight (<i>Burkholderia andropogoni</i>) Bacterial leaf streak (<i>Xanthomonas vesicola</i> pv. <i>holcicola</i>) Milo disease (<i>Periconia circinata</i>)
Pearl millet (<i>Pennisetum glaucum</i>)	Required	Groundnut testa nematode (<i>Aphelenchoides arachidis</i>) from Nigeria
Chickpea (<i>Cicer arietinum</i>)	Required	Pod & stem blight (<i>Phomopsis longicolla</i>)
Pigeonpea (<i>Cajanus cajan</i>)	Required	<i>Richardia brasiliensis</i> from Australia, Mozambique, Myanmar, Nepal <i>Heterodera glycines</i> (Cyst nematode) from China <i>Apomyelois ceratoniae</i> (carob moth) from Iran <i>Melanagromyza chalcosoma</i> (pod fly) from Kenya
Groundnut (<i>Arachis</i> spp.)	Required	(a) Scab (<i>Sphaceloma arachidis</i>) (b) Bacterial wilt (<i>Ralstonia solanacearum</i>) (African strains) (c) Peanut stripe virus (d) Peanut stunt virus (e) Tobacco streak virus (f) Seed Bruchid (<i>Stator pruininus</i>) (g) Testa Nematode (<i>Aphelenchoides arachidis</i>)
Minor millets		
Finger millet (<i>Eleusine coracana</i>)	Required	Nil
Foxtail millet (<i>Setaria italica</i>)	Required	Foxtail mosaic virus and wheat streak mosaic virus from USA
Little millet (<i>Panicum sumatrense</i>)	Required	Nil
Barnyard millet (<i>Echinochloa crusgalli</i>)	Required	Nil
Proso millet (<i>Panicum miliaceum</i>)	Required	Nil
Kodo millet (<i>Paspalum scrobiculatum</i>)	Required	Nil

Phytosanitary requirement for seed crop – Sorghum

Country	Import permit	Pathogens				Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi										
Afghanistan	-	-	-	-	-	-	-	No	-	-	-	-	-	
Argentina	+	-	-	-	-	<i>Trogoderma</i> spp.	<i>Cirsium arvense</i> , <i>Striga</i> spp.	No	-	-	Seeds are free from <i>Trogoderma</i> spp., <i>Cirsium arvense</i> and <i>Striga</i> spp	-	-	
Australia	+	-	-	-	-	-	-	No	+	-	-	-	Seeds should be free from live insects, other plant material, other seed and soil.	
Azerbaijan	-	-	-	-	-	-	-	No	-	-	-	-	-	
Barbados	-	-	-	-	+	-	-	No	-	-	-	-	-	
Belgium	-	-	-	-	-	-	-	No	-	-	-	-	-	
Botswana	-	-	-	-	-	-	-	No	-	-	-	-	-	
Brazil	-	-	-	-	+	-	-	No	-	-	-	-	-	
Cameroon	-	-	-	-	-	-	-	No	-	-	-	-	-	
Canada	+	-	-	<i>Tilletia controversa</i> , <i>Urocystis agropyri</i> , and <i>Tilletia indica</i>	-	-	-	No	-	-	The seeds have been harvested from their mother plants free from dwarf bunt (<i>Tilletia controversa</i>), flag smut (<i>Urocystis agropyri</i>), and Karnal bunt (<i>Tilletia indica</i>).	-	-	
China	-	-	-	-	-	-	-	No	-	-	-	-	-	

Continued

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Colombia	+	-	-	<i>Ustilago kenjiana</i> , <i>Ustilago cruenta</i> , <i>Peronospora sorghi</i> , <i>Periconia circinata</i> , <i>Sphacelotheca cruenta</i> , <i>Sphacelia sorghi</i> , <i>Tolyposporium ehrenbergii</i> and <i>Sphacelotheca sorghi</i>	-	Trogoderma granarium	-	No	-	-	The material must be free from <i>Ustilago kenjiana</i> and <i>Ustilago cruenta</i> . The material should be inspected during its vegetation period and found free from <i>Peronospora sorghi</i> , <i>Periconia circinata</i> , <i>Sphacelotheca cruenta</i> , <i>Sphacelia sorghi</i> , <i>Tolyposporium ehrenbergii</i> and <i>Sphacelotheca sorghi</i> . The seeds should be free from <i>Trogoderma</i> (Dermestidae) infestation.	-	-
Denmark	-	-	-	-	-	-	No	-	-	-	-	-	-
East Timor	+	-	-	-	-	-	No	-	-	-	-	-	Seeds should be free from live insects, other plant material, other seed and animal material
Egypt	Import permission	-	-	-	-	-	No	-	-	-	-	-	-

Continued

Phytosanitary requirements for seed crop – Sorghum *continued*.

Country	Import permit	Pathogens				Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi										
El-Salvador	+	-	-	-	-	-	-	No	-	-	-	-	-	
Eritrea	-	-	-	-	-	-	-	No	-	-	-	-	-	
Ethiopia	+	-	-	-	-	-	-	No	-	-	Seeds are free from quarantine insect pests, disease and pathogens and natural soil	-	-	
Fiji Is.	+	-	-	-	-	-	-	No	-	Treated with suitable fungicide	Seeds are free from smut and downy mildew and from weed seeds	-	-	
France	-	-	-	-	-	-	-	No	-	-	-	-	-	
Germany	+	-	-	-	-	-	-	No	-	-	-	-	-	
Ghana	+	-	-	-	-	-	-	No	-	-	-	-	-	
Georgia	+	-	-	-	-	-	-	No	-	-	Should be free from <i>Trogoderma granarium</i> and <i>Callisobruchus analis</i> , <i>Corcyra cephalonica</i> , <i>Sitophilus oryzae</i> , <i>Rhizopertha dominica</i> , <i>E. Cautella</i> , <i>O.surinamensis</i>	-	-	
Haiti	+	-	-	-	-	-	-	No	-	-	-	-	-	
Honduras	-	-	-	-	-	-	-	No	-	-	-	-	-	
Indonesia	+	-	-	-	-	-	-	No	-	-	-	-	-	
Iran	-	-	-	-	-	-	-	No	-	-	-	-	-	
Italy	+	-	-	-	-	-	-	No	-	-	-	-	-	

Continued

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Japan	-	-	-	-	-	-	No	-	-	-	-	Consignment should be sent through only Air Mail	-
Kenya	+	-	-	-	-	-	No	-	Treat with appropriate fungicide	-	-	-	Material is for research purpose only, and free from soil, chaff and/or leaf mold
Korea DPR	-	-	-	-	-	-	No	-	-	-	-	-	-
Kuwait	-	-	-	-	-	-	No	-	-	-	-	-	-
Malawi	+	Maize dwarf mosaic virus, Sugarcane mosaic virus	Burkholderia andropogonis	Periconia circinata, Sclerotinia sorghi, Claviceps spp.	-	-	No	+	-	-	The parent plants were inspected during active growth period and found free from Pseudomonas andropogonis, Maize dwarf mosaic virus, Sugarcane mosaic virus, Periconia circinata, Sclerotinia sorghi, Claviceps spp. The consignment is also free from stored pests	-	-

Continued

Phytosanitary requirements for seed crop – Sorghum continued.

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Malaysia	+	Maize dwarf mosaic virus, Sugar-cane mosaic virus	-	-	-	-	-	No	-	-	The parent plants were inspected during active growth period and found free from Maize dwarf mosaic virus, Sugarcane mosaic virus	-	-
Mali	-	-	-	-	-	-	-	No	-	-	-	-	-
Mexico	+	-	Burkholderia andropogonis	Claviceps africana, periconia circinata	-	-	-	No	-	-	Seeds are free from <i>Claviceps africana</i> , <i>Burkholderia andropogonis</i> and <i>Periconia cirinata</i> . Material is for research purpose, no commercial value, donation certificate	-	-
Morocco	+	-	-	-	-	-	-	No	-	-	Material is for research purpose. no commercial value, donation certificate	-	-
Mozambique	+	Maize dwarf mosaic virus	-	-	-	-	-	No	-	-	The parent plants were inspected during active growth period and found free from Maize dwarf mosaic virus and seeds are laboratory tested and found free from quarantine objectionable and harmful organism	-	-

Continued

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Myanmar	-	-	-	-	-	-	No	-	-	-	-	-	
Netherlands	-	-	-	-	-	-	No	-	-	-	-	-	
Niger	-	-	-	-	-	-	No	-	-	-	-	-	
Nigeria	+	Maize dwarf virus	Xanthomonas panici, Erwinia speewartii	Sclerospora macrospora, S. philippinensi, S. sacchari, Specelochea cruenta, S. reliana, S. ehrenbergii, Ustilago spp, Pyricularia setariae, Periconia circinata, Diatreae saccharalis, Chiloauricilius tanymechus dilaticollis, Atherigona oryzae	-	-	No	+	-	The parent plants were inspected during active growth period and found free from pathogenes Sclerospora macrospora, S. philippinensi, S. sacchari, Specelochea cruenta, S. reliana, S. ehrenbergii, Ustilago spp, Pyricularia setariae, Xanthomonas panici, Erwinia speewartii, Periconia circinata, Diatreae saccharalis, Chiloauricilius tanymechus dilaticollis, Atherigona oryzae, Maize dwarf virus and virulant strains of rust.	-	-	
Norway	-	-	-	-	-	-	No	-	-	-	-	-	
Oman	-	-	-	-	-	-	No	-	-	-	-	-	

Continued

Phytosanitary requirements for seed crop – Sorghum continued.

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Pakistan	+	-	-	-	-	-	-	No	-	Treat with appropriate fungicide	-	-	Consignment should be free from soil and include a seed testing report from the country of origin
Peru	+	-	-	-	-	-	-	No	-	-	-	-	-
Philippines	+	Barley yellow dwarf viruses, Maize streak virus, Maize stripe	<i>Pseudomonas syringae</i> pv. <i>syringae</i>	-	-	<i>Oedaleus senegalensis</i> , <i>Petrobia interpunctuella</i> , <i>Schistocerca gregaria</i>	-	No	-	-	Seeds were harvested from healthy plants which were free from Barley yellow dwarf viruses. Maize streak virus, Maize stripe, <i>Pseudomonas syringae</i> pv. <i>syringae</i> , <i>Oedaleus senegalensis</i> , <i>Petrobia interpunctuella</i> , <i>Schistocerca gregaria</i>	-	-
Russia	-	-	-	-	-	-	-	No	-	-	-	-	-
Sierra Leone	-	-	-	-	-	-	-	No	-	-	-	-	-
Solomon Is.	+	-	-	-	-	-	-	No	-	-	-	-	The seed lot is free from borer, other injurious pests, soil and other plant debris
Somalia	-	-	-	-	-	-	-	No	-	-	-	-	-
South Africa	+	-	-	-	-	-	-	No	-	-	-	-	-
Sri Lanka	+	-	-	-	-	-	-	No	-	-	-	-	-

Continued

Country	Import permit	Pathogens				Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi										
Sudan	-	-	-	-	-	-	-	No	-	-	-	-	-	
Syria	-	-	-	-	-	-	-	No	-	-	-	-	-	
Tanzania	+	-	-	-	-	-	-	No	-	-	-	-	-	
Thailand	+	-	-	-	-	-	-	No	+	-	-	-	-	
Taiwan	-	-	-	-	-	-	-	No	-	-	-	-	-	
Turkey	-	-	-	-	-	-	-	No	-	-	-	-	-	
UAE	-	-	-	-	-	-	-	No	-	-	-	-	-	
UK	-	-	-	-	-	-	-	No	-	-	-	-	-	
Uruguay	-	-	-	-	-	-	-	No	-	-	-	-	-	
USA	+	-	-	-	-	-	-	Yes	-	-	-	-	Seeds should be free from diseases and pests, soil, weed seeds and bear the address of designated plant inspection station.	
Uzbekistan (USSR)	-	-	-	-	-	-	-	No	-	-	-	-	-	
Venezuela	-	-	-	-	-	-	-	No	-	-	-	-	-	
Vietnam	+	-	-	-	-	-	-	No	+	-	-	-	-	
Yemen Rep.	-	-	-	-	-	-	-	No	-	-	-	-	-	

Continued

Phytosanitary requirements for seed crop – Sorghum continued.

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Zimbabwe	+	-	Pseudomonas syringae, Xanthomonas campestris pv. holcicola, X. rubrisorghii	Ascochyta sorghi, Claviceps spp, Sphaecelia sp., Cochliobolus lunatus, Penicillium oxalicum, Perinosclerospora sp., Sphaecelotheca sp., Tolyposporium ehrenbergii, Cercospora sorghi, Exserohilum turcicum	-	Sytotroga cerealia, Tribolium castanum, Plodia interpunctella, Prostanthes sp.	-	No	-	The seed lot was tested in a laboratory and found free from Ascochyta sorghi, Claviceps spp, Sphaecelia sp., Cochliobolus lunatus, Penicillium oxalicum, Perinosclerospora sp., Sphaecelotheca sp., Tolyposporium ehrenbergii, Cercospora sorghi, Exserohilum turcicum, Pseudomonas syringae, Xanthomonas campestris pv. holcicola, X. rubrisorghii. The seed lot was found free from Sytotroga cerealia, Tribolium castanum, Plodia interpunctella, Prostanthes castanum	The consignment has to be released to the head, Plant Protection Research Institute	-	

Phytosanitary requirement for seed crop – Pearl millet

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Afghanistan	-	-	-	-	-	-	-	No	-	-	-	-	-
Australia	+	-	-	-	-	-	-	Yes	+	-	-	Only small qty, max. 1.0 kg can be imported, each shipment should be packed in new container	Seeds should be free from live insects, other plant material, other seed and soil
Austria	-	-	-	-	-	-	-	No	-	-	-	-	-
Azerbaijan	-	-	-	-	-	-	-	No	-	-	-	-	-
Belgium	-	-	-	-	-	-	-	No	-	-	-	-	-
Botswana	+	-	-	-	-	<i>Prostethanus truncatus, Trogoderma granarium</i>	-	No	-	-	Seeds are free from <i>Prostethanus truncatus, Trogoderma granarium</i>	-	-
Bulgaria	-	-	-	-	-	-	-	No	-	-	-	-	-
Burkina Faso	-	-	-	-	-	-	-	No	-	-	-	-	-
Canada	+	-	-	-	-	-	-	No	-	-	-	-	-
China	-	-	-	-	-	-	-	No	-	-	-	-	-

Continued

Phytosanitary requirement for seed crop – Pearl millet *continued*.

Country	Import permit	Pathogens				Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi										
Colombia	+	-	-	-	-	-	-	No	-	-	The samples have been inspected during active growth and found free from <i>Peronospora sorghi</i> , <i>Periconia circinata</i> , <i>Spacelotheca cruenta</i> , <i>Space-otheca sorghi</i> , <i>Tolyposporium ehrenbergii</i> and <i>Sphaecelia sorghii</i>	-	-	
Denmark	-	-	-	-	-	-	-	No	-	-	-	-	-	
Egypt	+	-	-	-	-	-	-	No	-	Fumigation required	Experimental purpose and no commercial value	-	-	
El-Salvador	-	-	-	-	-	-	-	No	-	-	-	-	-	
Eritrea	-	-	-	-	-	-	-	No	-	-	-	-	-	
Ethiopia	+	-	-	-	-	-	-	No	-	-	Inspected during active growth period and found free from viruses and other diseases and pests	-	-	
France	-	-	-	-	-	-	-	No	-	-	-	-	-	
Gambia	-	-	-	-	-	-	-	No	-	-	-	-	-	
Germany	-	-	-	-	-	-	-	No	-	-	-	-	-	
Ghana	+	-	-	-	-	-	-	No	-	-	-	-	-	

Continued

Country	Import permit	Pathogens				Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi										
Greece	-	-	-	-	-	-	-	No	-	-	-	-	-	
Honduras	Import permission	-	-	-	-	-	-	No	-	-	-	-	-	
Indonesia	-	-	-	-	-	-	-	No	-	-	-	-	-	
Hawaii (USA)	-	-	-	-	-	-	-	No	-	-	-	-	-	
Iran	-	-	-	-	-	-	-	No	-	-	-	-	-	
Japan	-	-	-	-	-	-	-	No	-	-	-	Consignment should be sent only through Air Mail	-	
Jordan	Import permission	-	<i>Pseudomonas pisi</i>	-	-	-	-	No	-	-	Crop was inspected and harvested free from <i>Pseudomonas pisi</i>	-	-	
Kenya	+	-	-	-	-	-	-	No	-	Treat with appropriate fungicide	-	-	-	
Kuwait	-	-	-	-	-	-	-	No	-	-	-	-	-	
Mali	-	-	-	-	-	-	-	No	-	-	-	-	-	
Mexico	+	-	-	<i>Alternaria padwickii</i> , <i>Balansia oryzae</i> , <i>Claviceps fusiforme</i> and <i>Bipolaris setariae</i>	-	<i>Cadra cautella</i>	-	No	-	-	Seed samples were laboratory tested and found free from <i>Cadra cautella</i> , <i>Alternaria padwickii</i> , <i>Balansia oryzae</i> , <i>Claviceps fusiforme</i> and <i>Bipolaris setariae</i> , donation certificate material for re-search purpose and no commercial value	-	-	

Continued

Phytosanitary requirement for seed crop – Pearl millet *continued*.

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Mozambique	-	-	-	-	-	-	No	-	-	-	-	-	-
Myanmar	-	-	-	-	-	-	No	-	-	-	-	-	-
Niger	-	-	-	-	-	-	No	-	-	-	-	-	-
Nigeria	+	-	<i>Xanthomonas panici</i>	<i>Pyricularia penniseti</i> , <i>Sclerospora graminicola</i> , <i>Tolyposporium penicillariae</i>	-	-	No	+	-	The parent plants were inspected during active growth period and found free from pathogens	-	-	-
Pakistan	+	-	-	-	-	-	No	-	-	The parent plants were inspected during active growth period and found free from micoplasmal/ mollicutes	-	-	-
Peru	+	-	-	-	-	-	No	-	-	-	-	-	-
Philippines	+	Maize dwarf mosaic virus	<i>Pseudomonas syringae</i> pv. <i>Syringae</i> , <i>Parboea stewartii</i>	-	-	-	No	-	-	Seeds were harvested from healthy plants that were free from <i>Pseudomonas syringae</i> pv. <i>syringae</i> , <i>Parboea stewartii</i> and Maize dwarf mosaic virus	-	-	-

Continued

Country	Import permit	Pathogens				Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi										
Senegal	-	-	-	-	-	-	-	No	-	-	-	-	-	
South Africa	+	-	-	-	-	-	-	No	-	-	-	-	-	
Sudan	-	-	-	-	-	-	-	No	-	-	-	-	-	
UAE	-	-	-	-	-	-	-	No	-	-	-	-	-	
UK	-	-	-	-	-	-	-	No	-	-	-	-	-	
USA	+	-	-	-	-	-	-	Yes	-	-	-	-	Seeds should be free from diseases and pests, soil, weed seeds and bear the address of designated plant inspection station.	
Uganda	+	-	-	-	-	-	-	No	-	Treat with appropriate fungicide and insecticide	Plants must be inspected at regular intervals by plant quarantine officials during active growth period	-	-	
Uzbekistan(USSR)	-	-	-	-	-	-	-	No	-	-	-	-	-	
Venezuela	-	-	-	-	-	-	-	No	-	-	-	-	-	
Vietnam	+	-	-	-	-	-	-	No	+	-	-	-	-	
Yemen Rep.	-	-	-	-	-	-	-	No	-	-	-	-	-	
Zambia	+	-	-	-	-	-	-	No	+	-	-	-	The consignment is additionally accompanied by original fumigation certificate and copy of plant import permit.	

Continued

Phytosanitary requirement for seed crop – Pearl millet *continued*.

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Zimbabwe	+	-	Pseudomonas syringae, Xanthomonas campestris pv. holcicola, X. rubrisorghii	Ascochyta sorghi, Claviceps spp., Sphacelia sp., Cochliobolus lunatus, Pyricularia setariae, Penicillium oxalicum, Perinosclerospora sp., Sphacelotheca sp., Tolyposporium ehrenbergii, Tillitia barclayana, Ustilago crameri	-	Sytrogace-realla, Tribolium castanum, Plodia interpunctuella, Prosiathanes castanum	-	No	-	-	The seed lot was tested in a laboratory and found free from Ascochyta sorghi, Claviceps spp. Sphacelia sp., Cochliobolus lunatus, Penicillium oxalicum, Perinosclerospora sp., Sphacelotheca sp., Tolyposporium ehrenbergii, Tillitia barclayana, Ustilago crameri, Pseudomonas syringae, Xanthomonas campestris pv. holcicola, X. rubrisorghii. The seed lot was found free from Sytrogace cerealla, Triboilium castanum, Plodia interpunctella, Prosiathanes castanum	-	-

Phytosanitary requirement for seed crop – Chickpea

Country	Import permit	Pathogens				Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi										
Afghanistan	-	-	-	-	-	-	-	-	No	-	-	-	-	-
Azerbaijan	-	-	-	-	-	-	-	-	No	-	-	-	-	-
Australia	+	-	-	-	-	-	-	-	Yes	+	-	-	-	Seeds should be free from live insects, other plant material, other seed and soil
Austria	-	-	-	-	-	-	-	-	No	-	-	-	-	-
Bangladesh	+	-	-	-	-	-	-	-	No	-	Methyl bromide fumigation required	-	-	-
Brazil	+	-	-	-	-	-	-	-	No	-	-	The material is donation for research purpose in Brazil. So it has no commercial value.	-	-
Cambodia	-	-	-	-	-	-	-	-	No	-	-	-	-	-
Canada	-	-	-	-	-	-	-	-	No	-	-	-	-	-
China	+	-	-	-	-	<i>Ditylenchus dipsaci</i>	<i>Callosobruchus analis</i> and <i>C. phaseoli</i>	<i>Cuscuta chinensis</i> , <i>C. europaea</i> , <i>C. indecora</i>	No	-	-	-	-	Seeds should be free from all stored grain pests mentioned in the Import permit and Import permit number should be mentioned in Phytosanitary Certificate
Cote d'Ivoire	-	-	-	-	-	-	-	-	No	-	-	-	-	-

Continued

Phytosanitary requirement for seed crop – Chickpea continued.

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Denmark	-	-	-	-	-	-	No	-	-	-	-	-	-
Eritrea	-	-	-	-	-	-	No	-	-	-	-	-	-
Ethiopia	+	-	-	Aspergillus flavus, Phoma medicaginis	-	-	No	-	Treat with systemic fungicide	Seeds are free from Aspergillus flavus and Phoma medicaginis and other seed-borne diseases	-	-	-
Fiji Is.	-	-	-	-	-	-	No	-	-	-	-	-	Seeds are believed to be free from all forms of diseases or insects
France	-	-	-	-	-	-	No	-	-	-	-	-	-
Germany	-	-	-	-	-	-	No	-	-	-	-	-	-
Indonesia	-	-	-	-	-	-	No	-	-	-	-	-	-
Iran	+	Pea early browning tobnavirus	Pseudomonas syringae pv. pisi.	-	-	-	No	-	-	Parent plants were inspected during active growth period and found free from Pea early browning tobnavirus and Pseudomonas syringae pv. pisi.	-	-	-
Iraq	-	-	-	-	-	-	No	-	-	-	-	-	-

Continued

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Israel	+	Alfalfa mosaic alfamovirus, Bean yellow mosaic virus, potyvirus, Pea seed borne mosaic potyvirus, Broad bean mottle bromovirus	-	<i>Didymella rabiei</i>	-	-	-	No	-	-	Crop inspected during active growth period and found free from <i>Didymella rabiei</i> ; Alfalfa mosaic alfamovirus, Bean yellow mosaic virus, potyvirus, Pea seed borne mosaic potyvirus, Broad bean mottle bromovirus	-	-
Italy	-	-	-	-	-	-	No	-	-	-	-	-	-
Japan	-	-	-	-	-	-	No	-	-	-	Consignment should be sent only through Air Mail	-	-
Jordan	Import permission	-	-	-	-	-	No	-	-	-	-	-	-

Continued

Phytosanitary requirement for seed crop – Chickpea continued.

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Kenya	+	-	<i>Pseudomonas pisi</i>	-	-	-	No	-	-	Seeds were harvested from plants inspected in active growth and found free from virus diseases <i>Pseudomonas pisi</i>	-	-	
Korea DPR	-	-	-	-	-	-	No	-	-	-	-	-	
Lebanon	-	-	-	-	-	-	No	-	-	-	-	-	
Malawi	+	Marginal chlorosis and Pea-nut stunt viruses, Alfalfa mosaic virus, Pea mosaic virus, Tomato spotted wilt virus	-	-	<i>Aphelenchoides arachidis</i>	-	No	+	-	The parent plants were inspected during active growth period and found free from Marginal chlorosis, Peanut stunt viruses, Alfalfa mosaic virus, Pea mosaic virus, Tomato spotted wilt virus, Bacterial blight (<i>Pseudomonas pisi</i>).	-	-	
Malaysia	+	-	-	-	-	-	No	-	-	-	-	Seed must be free from soil and pests	
Mali	-	-	-	-	-	-	No	-	-	-	-	-	

Continued

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Mexico	+	-	-	-	<i>Trogoderma granarium</i>	-	No	-	-	-	Seeds are free from <i>Trogoderma granarium</i> . Material is for research purpose, no commercial value, donation certificate	-	-
Morocco	+	-	-	-	-	-	No	-	-	-	Material is for research purpose, no commercial value, donation certificate	-	-
Mozambique	-	-	-	-	-	-	No	-	-	-	-	-	-
Myanmar	-	-	-	-	-	-	No	-	-	-	-	-	-
Nepal	-	-	-	-	-	-	No	-	-	-	-	-	-
Niger	-	-	-	-	-	-	No	-	-	-	-	-	-
Nigeria	+	-	-	-	-	-	No	+	-	-	The parent plants were inspected during active growth period and found free from all known pests and weeds of chickpea	-	-
Norway	-	-	-	-	-	-	No	-	-	-	-	-	-
Pakistan	+	-	-	-	-	-	No	-	-	-	-	-	-

Continued

Phytosanitary requirement for seed crop – Chickpea continued.

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Papua New Guinea	+	-	-	-	<i>Trogoderma granarium</i> , <i>Coxiella burnetii</i>	-	No	-	-	Seeds are free from peanut witches broom phytoplasma and related phytoplasma, and free from foreign matter, foreign insect especially Khapra beetle (<i>Trogoderma granarium</i>), Cattle tick (<i>Coxiella burnetii</i>)	-	-	
Peru	+	-	-	-	-	-	No	-	-	-	-	-	-
Philippines	+	-	-	<i>Gibberella</i> sp.	-	<i>Callosobruchus analis</i> , <i>C. chassoli</i> , <i>Trogoderma granarium</i>	No	-	-	The seeds are free from <i>Callosobruchus analis</i> , <i>C. chassoli</i> , <i>Trogoderma granarium</i> , <i>Gibberella avaracea</i> and other seed borne organisms	-	-	-
Portugal	-	-	-	-	-	-	No	-	-	-	-	-	-
Senegal	-	-	-	-	-	-	No	-	-	-	-	-	-
Slovakia	-	-	-	-	-	-	No	-	-	-	-	-	-
South Africa	+	<i>Peanut stunt virus</i>	-	-	<i>Trogoderma granarium</i>	-	No	-	-	The parent plants were inspected during active growth and found free from Peanut stunt virus and <i>Trogoderma granarium</i>	-	-	-

Continued

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Spain	-	-	-	-	-	-	No	-	-	-	-	-	
Sudan	-	-	-	-	-	-	No	-	-	-	-	-	
Sweden	-	-	-	-	-	-	No	-	-	-	-	-	
Switzerland	-	-	-	-	-	-	No	-	-	-	-	-	
Syria	-	-	-	-	-	-	No	-	-	-	-	-	
Tanzania	+	-	-	-	-	-	No	-	-	-	-	-	
Tunisia	-	-	-	-	-	-	No	-	-	-	-	-	
Turkey	-	-	-	-	-	-	No	-	-	-	-	-	
UAE	-	-	-	-	-	-	No	-	-	-	-	-	
UK	-	-	-	-	-	-	No	-	-	-	-	-	
Ukraine	-	-	-	-	-	-	No	-	-	-	-	-	
USA	+	-	-	-	-	-	Yes	-	-	-	-	Seeds should be free from diseases and pests, soil, weed seeds and bear the address of designated plant inspection station.	
Uzbekistan (USSR)	-	-	-	-	-	-	No	-	-	-	-	-	
Vietnam	+	-	-	-	-	-	No	+	-	-	-	-	

Continued

Phytosanitary requirement for seed crop – Chickpea continued.

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Yemen Rep.	-	-	-	-	-	-	No	-	-	-	-	-	-
Zambia	+	Alfalfa mosaic virus, Lettuce mosaic virus	-	<i>Didymella rabiei</i> , <i>Thaciolytis padwickii</i> , <i>Oromyces cesciceris arietini</i>	-	-	No	-	-	The parent plants were inspected during active growth period and found free from Alfalfa mosaic virus, Lettuce mosaic virus, <i>Micosporella rabiei</i> , <i>Thaciolytis padwickii</i> , <i>Oromyces cesciceris arietini</i>	-	-	-
Zimbabwe	+	Pea mosaic virus	<i>Pseudomonas pisi</i>	-	-	-	No	-	-	Parent plants were inspected during active growth and found to be free from bacterial blight of peas (<i>Pseudomonas pisi</i>) and Pea mosaic virus	-	-	-

Phytosanitary requirement for seed crop – Pigeonpea

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Afghanistan	-	-	-	-	-	-	No	-	-	-	-	-	-
Armenia	-	-	-	-	-	-	No	-	-	-	-	-	-
Australia	+	-	-	-	-	-	No	-	-	-	Shipment should be sent to Australian Quarantine Inspection Service	-	Seeds are free from live insects, other plant material, other seed and soil
Austria	-	-	-	-	-	-	No	-	-	-	-	-	-
Bahamas	-	-	-	-	-	-	No	-	-	-	-	-	-
Bangladesh	+	-	-	-	-	-	No	-	-	Methyl bromide fumigation required	-	-	-
Barbados	+	-	-	-	-	-	No	-	-	-	-	-	-
Belgium	-	-	-	-	-	-	No	-	-	-	-	-	-
Bhutan	-	-	-	-	-	-	No	-	-	-	-	-	-
Bolivia	-	-	-	-	-	-	No	-	-	-	-	-	-
Cambodia	-	-	-	-	-	-	No	-	-	-	-	-	-
Cameroon	-	-	-	-	-	-	No	-	-	-	-	-	-
Canada	+	-	-	-	-	-	No	-	-	-	-	-	-
China	+	-	-	-	-	-	No	-	-	-	-	-	-
Congo	+	-	-	-	-	-	No	-	-	-	-	-	-
Costa Rica	+	-	-	-	-	-	No	-	-	-	-	-	-
Cote d'Ivoire	-	-	-	-	-	-	No	-	-	-	-	-	-
Denmark	-	-	-	-	-	-	No	-	-	-	-	-	-

Continued

Phytosanitary requirement for seed crop – Pigeonpea *continued*.

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
East Timor	+	-	-	-	-	-	No	-	-	-	-	-	Import permit should be sent with consignment and consignment should be free from soil
Egypt	-	-	-	-	-	-	No	-	-	-	-	-	-
Ethiopia	+	-	-	-	-	-	No	-	-	Treat with fungicide	Seeds are free from diseases and pests	-	-
Fiji Is.	+	-	-	-	-	-	No	-	-	-	Seeds are free from all forms of diseases and weed seeds	-	-
Germany	-	-	-	-	-	-	No	-	-	-	-	-	-
Ghana	+	-	-	-	-	-	No	-	-	-	-	-	-
Guatemala	+	-	-	-	-	-	No	-	-	Fumigation required	Material is for experimental purpose and has no commercial value	-	-
Haiti	-	-	-	-	-	-	No	-	-	-	-	-	-
Honduras	-	-	-	-	-	-	No	-	-	-	-	-	-
Indonesia	-	-	-	-	-	-	No	-	-	-	-	-	-
Iran	-	-	-	-	-	-	No	-	-	-	-	-	-

Continued

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Jamaica	+	-	-	-	<i>Globodera rostochinensis</i>	-	No	-	-	-	Crop was inspected and harvested free from injurious pests and diseases and seeds are grown in area free from golden nematode	-	-
Japan	-	-	-	-	-	-	No	-	-	-	-	Consignment should be sent through Air Mail only	-
Jordan	Import permission	-	-	-	-	-	No	-	-	-	-	-	-
Kenya	+	-	<i>Pseudomonas pisi</i>	<i>Colletotrichum cajani</i>	-	-	No	-	-	-	Seeds for research purpose, no commercial value, seeds are free from seed-borne viruses, <i>Pseudomonas pisi</i> and <i>Colletotrichum cajani</i>	-	-
Korea DPR	-	-	-	-	-	-	No	-	-	-	-	-	-
Kyrgyzstan	-	-	-	-	-	-	No	-	-	-	-	-	-
Laos PDR	+	-	-	-	-	-	No	-	-	-	-	-	-

Continued

Phytosanitary requirement for seed crop – Pigeonpea *continued*.

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Malaysia	+	Marginal chlorosis and pea-nut stunt viruses	-	-	Aphelenchoides arachidis	-	-	No	-	-	The seeds are free from groundnut testa nematode (<i>Aphelenchoides arachidis</i>), Marginal chlorosis and Pea-nut stunt viruses	-	-
Mali	+	-	-	-	-	-	No	-	-	-	-	-	-
Mauritius	+	-	-	-	<i>Trogoderma granarium</i>	-	No	-	-	-	Seeds were harvested from plants free from pea blight and <i>Trogoderma granarium</i>	-	-
Mexico	+	-	-	-	-	-	No	-	-	-	-	-	-
Mozambique	-	-	-	-	-	-	No	-	-	-	-	-	-
Myanmar	-	-	-	-	-	-	No	-	-	-	-	-	-
Nepal	-	-	-	-	-	-	No	-	-	-	-	-	-
Niger	-	-	-	-	-	-	No	-	-	-	-	-	-
Nigeria	+	-	-	-	-	-	No	+	-	-	The parent plants were inspected during active growth period and found free from all known pests and weeds of pigeonpea	-	-
Niue Islands	+	-	-	-	-	-	No	+	-	-	-	-	Seed samples confirmed 100% pure with no weed contaminants

Continued

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Panama	+	-	-	-	<i>Trogoderma granarium</i> , <i>Coxiella burnetii</i>	-	No	-	-	Seeds are free from Khapra beetle, Cattle tick	-	-	
Pakistan	-	-	-	-	-	-	No	-	-	-	-	-	
Papua New Guinea	+	-	-	-	<i>Trogoderma granarium</i> , Cattle tick	-	No	-	-	Seeds are free from peanut witches broom phytoplasma and related phytoplasma, and free from foreign matter, foreign insect especially Khapra beetle (<i>Trogoderma granarium</i>), Cattle tick (<i>Coxiella burnetii</i>)	-	-	
Philippines	+	Alfalfa mosaic virus, Bean leaf role virus, Broad bean wilt virus, Tomato streak virus and Tomato spotted wilt virus	-	-	-	<i>Hoplolaimus indicus</i> , <i>Amaranthus hybridus</i> , <i>A. retroflexus</i> , <i>Ambrosia artemisiifolia</i> , <i>Paratrichoderus porosus</i>	No	-	-	Seeds were harvested from healthy plants that were free from Alfalfa mosaic virus, Bean leaf role virus, Broad bean wilt virus, Tomato streak virus and Tomato spotted wilt virus	-	-	
Puerto Rico	-	-	-	-	-	-	No	-	-	-	-	-	
Senegal	-	-	-	-	-	-	No	-	-	-	-	-	
Solomon Is.	+	-	-	-	-	-	No	-	-	-	-	-	

Continued

Phytosanitary requirement for seed crop – Pigeonpea *continued*.

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
South Africa	+	-	-	-	-	-	No	-	-	-	Parent plant inspected during active growth and found to be free from <i>Colletotrichum cajani</i>	-	-
Switzerland	-	-	-	-	-	-	No	-	-	-	-	-	-
Syria	+	-	-	-	-	-	No	-	-	-	Seeds are free from viral diseases	-	-
Taiwan	-	-	-	-	-	-	No	-	-	-	-	-	-
Thailand	-	-	-	-	-	-	No	-	-	-	-	-	-
UAE	-	-	-	-	-	-	No	-	-	-	-	-	-
UK	-	-	-	-	-	-	No	-	-	-	-	-	-
USA	+	-	-	-	-	-	Yes	-	-	-	-	-	Seeds should be free from diseases and pests, soil, weed seeds and bear the address of designated plant inspection station.
Uzbekistan (USSR)	-	-	-	-	-	-	No	-	-	-	-	-	Seeds should be free from quarantine and other hazardous organism/pests, diseases, weeds

Continued

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Vietnam	+	-	-	-	-	-	No	+	-	-	-	-	-
Zambia	-	-	-	-	-	-	No	-	-	-	-	-	-
Zimbabwe	+	-	-	<i>Alternaria tenuis-sima</i> , <i>Colletotrichum cajani</i> , <i>Phoma</i> spp., <i>Lasidiplodia pheodromae</i>	-	-	No	-	-	-	The parent plants were inspected during active growth period and found free from <i>Alternaria</i> sp., <i>Colletotrichum cajani</i> , <i>Phoma</i> spp., <i>Lasidiplodia pheodromae</i> . The consignment is free from live insects and insect eggs.	-	-

Phytosanitary requirement for seed crop – Groundnut

Country	Import permit	Pathogens				Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi										
Afghanistan	-	-	-	-	-	-	-	No	-	-	-	-	-	
Argentina	+	-	-	-	<i>Ditylenchus destructor</i>	<i>Trogoderma</i> spp.	<i>Striga</i> spp.	No	-	-	Seeds are free from <i>Trogoderma</i> spp, <i>Cirsium arvense</i> , <i>Striga</i> spp and <i>Ditylenchus destructor</i>	-	-	
Armenia	-	-	-	-	-	-	-	No	-	-	-	-	-	
Australia	+	-	-	-	-	-	-	Yes	+	-	-	-	Seeds should be free from live insects, other plant material, other seed and soil	
Azerbaijan	-	-	-	-	-	-	-	No	-	-	-	-	-	
Bangladesh	-	-	-	-	-	-	-	No	-	-	-	-	-	
Barbados	+	-	-	-	-	-	-	No	-	-	-	-	-	
Belgium	-	-	-	-	-	-	-	No	-	-	-	-	-	
Cambodia	-	-	-	-	-	-	-	No	-	-	-	-	-	
Cameroon	-	-	-	-	-	-	-	No	-	-	-	-	-	
China	-	-	-	-	-	-	-	No	-	-	-	-	-	
Denmark	-	-	-	-	-	-	-	No	-	-	-	-	-	
East Timor	+	-	-	-	-	-	-	No	-	-	-	-	Import permit should be sent with consignment and comment should be free from soil	
Egypt	-	-	-	-	-	-	-	No	-	-	-	-	-	

Continued

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Eritrea	-	-	-	-	-	-	No	-	-	-	-	-	-
Ethiopia	+	-	-	-	-	-	No	-	-	-	-	-	After treatment, seeds are found free from diseases and pests
Fiji Is.	+	-	-	-	-	-	No	-	-	Seeds are free from weed seeds	-	-	-
Georgia	-	-	-	-	-	-	No	-	-	-	-	-	-
Germany	-	-	-	-	-	-	No	-	-	-	-	-	-
Ghana	+	-	-	-	-	-	No	-	-	-	-	-	-
Haiti	-	-	-	-	-	-	No	-	-	-	-	-	-
Indonesia	-	-	-	-	-	-	No	-	-	-	-	-	-
Iran	-	-	-	-	-	-	No	-	-	-	-	-	-
Iraq	+	Alfalfa mosaic alfamovirus, Bean yellow mosaic virus, Pea seed borne mosaic polyvirus, Broad bean mottle broomovirus	-	<i>Didymella rabiei</i>	-	-	No	-	-	-	-	-	-
Italy	-	-	-	-	-	-	No	-	-	-	-	-	-

Continued

Phytosanitary requirement for seed crop – Groundnut *continued*.

Country	Import permit	Pathogens			Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi								
Japan	-	-	-	-	-	No	-	-	-	Consignment should be sent only through Air Mail	-	
Korea	-	-	-	-	-	No	-	-	-	-	-	
Kyrgyzstan	-	-	-	-	-	No	-	-	-	-	-	
Malawi	+	Peanut mottle virus, Peanut mottle virus, Peanut clump virus, Peanut stunt virus	-	-	<i>Carydon gonagra</i> and <i>Trogoderma granarium</i>	No	+	-	The parent plants were inspected during active growth period and found free from Peanut mottle virus, Peanut mottle clump virus, Peanut stunt virus. The consignment is also free from <i>Carydon gonagra</i> and <i>Trogoderma granarium</i>	-	-	
Malaysia	+	Marginal chlorosis and peanut stunt viruses	-	-	-	No	-	-	The seeds are free from groundnut testa nematode (<i>Aphelenchoides arachidis</i>), Marginal chlorosis and Peanut stunt viruses	-	-	
Mali	+	-	-	-	-	No	-	-	-	-	-	
Morocco	+	-	-	-	-	No	-	-	Material is for research purpose, no commercial value, donation certificate	-	-	

Continued

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Mozambique	-	-	-	-	-	-	No	-	-	-	-	-	
Myanmar	-	-	-	-	-	-	No	-	-	-	-	-	
Nepal	-	-	-	-	-	-	No	-	-	-	-	-	
Niger	-	-	-	-	-	-	No	-	-	-	-	-	
Nigeria	+	-	<i>Burkholderia solaniserum</i>	<i>Diplodia gossypina</i>	<i>Meloidogyne arenaria</i>	-	No	+	-	The parent plants were inspected during active growth period and found free from Collar rot (<i>Diplodia gossypina</i>), Slim disease (<i>Pseudomonas solaniserum</i> , Root knot nematode (<i>Meloidogyne arenaria</i>))	-	-	
Pakistan	+	-	-	-	-	-	No	-	-	-	-	-	
Papua New Guinea	+	-	<i>Pantoea stewartii</i>	<i>Peronosclerospora</i> spp.	-	<i>Trogoderma granarium</i> , <i>Coxiella burnetii</i>	No	-	-	Seeds are free from peanut witches broom phytoplasma and related phytoplasma, and free from foreign matter, foreign insects especially Khapra beetle (<i>Trogoderma granarium</i>), Cattle tick (<i>Coxiella burnetii</i>)	-	-	

Continued

Phytosanitary requirement for seed crop – Groundnut continued.

Country	Import permit	Pathogens				Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi										
Philippines	+	Bean common mosaic virus, Cowpea mild mottle virus, Groundnut yellow spot virus, Peanut clump virus	-	Macrophomina phaseolina, Verticillium albo-atrum	Pratylenchus thomei, Aphelenchoides arachidis, Pratylenchus zeae, Aphasmatylenchus straturatus	Trogoderma granarium, Holotrichia serrata	Holotrichia serrata	No	-	-	Seeds are free from Aphelenchoides arachidis, Pratylenchus zeae+L38e, Bean common mosaic virus, Cowpea mild mottle virus, Groundnut yellow spot virus, Peanut clump virus, Macrophomina phaseolina, Verticillium albo-atrum, Pratylenchus thomei, Trogoderma granarium, Holotrichia serrata and other elite microorganism	-	-	
Senegal	-	-	-	-	-	-	-	No	-	-	-	-	-	
Sierra Leone	-	-	-	-	-	-	-	No	-	-	-	-	-	
South Africa	+	-	-	Didymella rabiei	-	-	-	No	-	-	The parent plants are inspected during active growth and found free from Ascochyta rabiei	-	-	

Continued

Country	Import permit	Pathogens				Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi										
Sri Lanka	+	<i>Peanut mottle virus, Peanut marginal chlorosis, Peanut stunt virus</i>	-	-	-	-	-	No	-	The parent plants were inspected during active growth period and found free from <i>Peanut mottle virus, Peanut marginal chlorosis, Peanut stunt virus</i>	-	-	-	
Sudan	-	-	-	-	-	-	-	No	-	-	-	-	-	
Tadjikistan	-	-	-	-	-	-	-	No	-	-	-	-	-	
Tanzania	+	-	-	-	-	-	-	No	-	The field was inspected during active growth period and found to be free from <i>Erysiphe pisi</i> DC var. <i>pisi</i> and peanut stripe virus	-	-	-	
Thailand	-	-	-	-	-	-	-	No	-	-	-	-	-	
Togo	-	-	-	-	-	-	-	No	-	-	-	-	-	
Turkey	-	-	-	-	-	-	-	No	-	-	-	-	-	
UAE	-	-	-	-	-	-	-	No	-	-	-	-	-	
UK	-	-	-	-	-	-	-	No	-	-	-	-	-	
USA	+	-	-	-	-	-	-	Yes	-	-	-	-	Seeds should be free from diseases and pests, soil, weed seeds and bear the address of designated plant inspection station.	

Continued

Phytosanitary requirement for seed crop – Groundnut *continued.*

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Uzbekistan (USSR)	-	-	-	-	-	-	-	No	-	-	-	-	-
Vietnam	+	-	-	-	-	-	-	No	-	-	-	-	-
Yemen Rep.	-	-	-	-	-	-	-	No	-	-	-	-	-
Zambia	+	-	-	Glomer- alla sp and Didymospha- eria arachidi- cola	-	-	-	No	-	-	The parent plants were inspected during active growth period and found free from <i>Glomer- alla cingulata</i> and <i>Didymosphaeria arachidicola</i> . The consignment is additionally accompanied by original fumigation certificate and copy of plant import permit.	-	-
Zimbabwe	+	Peanut mottle virus, Peanut mottle clump virus, Peanut stunt virus	-	<i>Physalospora berkeleyi</i> , <i>Puccinia arachidis</i>	-	-	-	No	-	-	The parent plants were inspected during active growth period and found free from Peanut mottle virus, <i>Physalospora berkeleyi</i> , <i>Puccinia arachidis</i> , <i>Achelenchoides arachidis</i> , Peanut mottle clump virus, Peanut stunt virus	-	-

Phytosanitary requirement for seed crop – Small millets

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Finger millet													
Australia	+	-	-	-	-	-	-	Yes	-	-	-	Shipment should be sent to Australian Quarantine Inspection Service	Seeds should be free from live insects, other plant material, other seed and soil
Botswana	+	-	-	-	-	<i>Prostethanus truncatus</i> , <i>Trogoderma granarium</i>	-	No	-	-	Seeds are free from <i>Prostethanus truncatus</i> , <i>Trogoderma granarium</i>	-	-
Denmark	-	-	-	-	-	-	-	No	-	-	-	-	-
France	-	-	-	-	-	-	-	No	-	-	-	-	-
Germany	-	-	-	-	-	-	-	No	-	-	-	-	-
Ghana	+	-	-	-	-	-	-	No	-	-	-	-	-
Kenya	+	-	-	-	-	-	-	No	-	Treat with appropriate fungicide	-	-	-
Norway	-	-	-	-	-	-	-	No	-	-	-	-	-
South Africa	+	-	-	-	-	-	-	No	-	-	-	-	-
Sudan	-	-	-	-	-	-	-	No	-	-	-	-	-
Uganda	+	-	<i>Pantoea stewartii</i>	<i>Peronosclerospora sorghi</i> .	-	-	-	No	+	-	-	-	Seeds should be free from diseases <i>Peronosclerospora sorghi</i> , <i>Pantoea stewartii</i>

Continued

Phytosanitary requirement for seed crop – Small millets continued.

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
USA	+	-	-	-	-	-	-	Yes	-	-	-	-	Seeds should be free from diseases and pests, soil, weed seeds and bear the address of designated plant inspection station.
Zambia	-	-	-	-	-	-	-	No	-	-	-	-	-
Zimbabwe	+	-	<i>Pseudomonas syringae</i> , <i>Xanthomonas campestris</i> pv. <i>holcicola</i> , <i>X. rubrisorghii</i>	<i>Ascochyta sorghi</i> , <i>Claviceps</i> spp., <i>Sphacelia</i> sp., <i>Cochliobolus lunatus</i> , <i>Penicillium oxalicum</i> , <i>Peronosclerospora</i> sp., <i>Sphaerolotheca sp.</i> , <i>Tolyposporium ehrenbergii</i>	-	<i>Sytotroga cerealia</i> , <i>Tribolium castanum</i> , <i>Plodia interpunctella</i> , <i>Prostathanes castanum</i>	-	No	-	-	The seed lot was tested in a laboratory and found free from <i>Ascochyta sorghi</i> , <i>Claviceps</i> spp., <i>Cochliobolus lunatus</i> , <i>Penicillium oxalicum</i> , <i>Peronosclerospora</i> sp., <i>Sphaerolotheca sp.</i> , <i>Tolyposporium ehrenbergii</i> , <i>Pseudomonas syringae</i> , <i>Xanthomonas campestris</i> pv. <i>holcicola</i> , <i>X. rubrisorghii</i> . The seed lot was found free from <i>Sytotroga cerealia</i> , <i>Tribolium castanum</i> , <i>Plodia interpunctella</i> , <i>Prostathanes castanum</i> .	-	-

Continued

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Foxtail millet													
Belgium	-	-	-	-	-	-	No	-	-	-	-	-	-
Botswana	+	-	-	-	<i>Prostethanus truncatus</i> , <i>Trogoderma granarium</i>	-	No	-	-	Seeds are free from <i>Prostethanus truncatus</i> , <i>Trogoderma granarium</i>	-	-	-
Germany	-	-	-	-	-	-	No	-	-	-	-	-	-
Uruguay	+	-	-	-	-	<i>Striga</i> spp.	No	-	-	The seeds were produced from an area free from <i>Striga</i> spp. The seeds were free from <i>Cochilobolus lunatus</i> .	-	-	-
Sudan	-	-	-	-	-	-	No	-	-	-	-	-	-
USA	+	-	-	-	-	-	Yes	-	-	-	-	-	Should be free from diseases and pests, soil, weed seeds and bear the address of the designated plant inspection station.
Vietnam	+	-	-	-	-	-	No	+	-	-	-	-	-

Continued

Phytosanitary requirement for seed crop – Small millets *continued*.

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Zimbabwe	+	-	<i>Pseudomonas syringae</i> , <i>Xanthomonas campestris</i> pv. <i>hollicola</i> , <i>X. rubrisorghii</i> , <i>Penicillium osalicum</i> , <i>Perinosclerospora</i> sp., <i>Sphacelotheca lotheca</i> sp., <i>Tolyposporium ehrenergii</i>	-	<i>Sytotroga cerealia</i> , <i>Tribolium castaneum</i> , <i>Plodia interpunctella</i> , <i>Prostathanes castanum</i> and other stored pests	-	No	-	-	The seed lot was tested in a laboratory and found free from <i>Ascochyta sorghi</i> , <i>Claviceps</i> spp., <i>Sphacella</i> sp., <i>Cochliobolus lunatus</i> , <i>Penicillium osalicum</i> , <i>Perinosclerospora</i> sp., <i>Sphacelotheca</i> sp., <i>Tolyposporium ehrenergii</i> , <i>Pseudomonas syringae</i> , <i>Xanthomonas campestris</i> pv. <i>hollicola</i> , <i>X. rubrisorghii</i> . The seed lot was found free from <i>Sytotroga cerealia</i> , <i>Tribolium castanum</i> , <i>Plodia interpunctella</i> , <i>Prostathanes castanum</i>	-	-	

Continued

Country	Import permit	Pathogens			Nematodes	Insects	Weeds	Untreated sample	Non GMO declaration	Chemical treatment requirements	Additional declarations	Shipping requirements	Remark
		Virus	Bacteria	Fungi									
Germany	-	-	-	-	-	-	-	No	-	-	-	-	-
Germany	-	-	-	-	-	-	-	No	-	-	-	-	-
Myanmar	-	-	-	-	-	-	-	No	-	-	-	-	-
Myanmar	-	-	-	-	-	-	-	No	-	-	-	-	-
UK	-	-	-	-	-	-	-	No	-	-	-	-	-

Technical Guidelines of Quarantine Significant Pests of Seed Crops

Sorghum [*Sorghum bicolor* (L.) Moench]

Bacteria

Burkholderia andropogonis Smith.

Synonyms

Pseudomonas andropogonis, *Pseudomonas woodsii*

Disease name

Bacterial leaf stripe or bacterial blight

Importance to CGIAR Centers

High

Significance

In general, the disease is of minor importance on sorghum. Bacterial leaf stripe is considered to be a low to intermediate priority disease of sorghum in eastern Africa.

Symptoms

Initial symptoms are small (1 cm long), linear, interveinal lesions. Lesions on leaves and sheaths are purple, red, yellow or tan, depending on the host reaction. Under favorable conditions, lesions may exceed 20 cm in length and they usually coalesce along the width of the leaf. Water soaking of tissue adjacent to a lesion is usually not observed under field conditions. Bacterial exudates are usually observed from infected portions of the leaf under microscopic observation. Lesions may also occur on the kernel, peduncle and rachis, and also in the pith of the stalk.



S Fig. 1. Bacterial leaf stripe (*Burkholderia andropogonis*) of sorghum. (Source: ICRISAT IB No. 2).

Hosts

Sorghum halepense (aleppo grass), *Sorghum bicolor* (sorghum), *Sorghum sudanense* (Sudan grass), *Trifolium repens* (white clover), *Vicia sativa* (common vetch), *Bougainvillea* sp, *Ceratonia siliqua* (locust bean), *Cicer arietinum* (chickpea), *Dianthus caryophyllus* (carnation), *Gypsophila paniculata* (baby's breath), *Limonium sinuatum* (sea pink), *Trifolium pratense* (purple clover), *Trifolium subterraneum* (subterranean clover), *Tulipa* (tulip), *Vaccinium* (blueberries) and *Zea mays* (maize, also called corn).

Geographic distribution

Worldwide

Not reported from India on sorghum

Biology and transmission

The bacterial cells are gram-negative rods, slightly curved with rounded ends, usually motile due to single flagellum per cell. The flagellum is sheathed. The colonies of these bacteria are mostly smooth on the medium. Plant debris is considered to be the primary over wintering source of *B. andropogonis* for bacterial stripe infection of sorghum (Tarr 1962).

Detection/indexing methods used in CGIAR

Pre export field inspection

Treatment

No suitable treatment is available for eradication of this bacteria

Procedures in CGIAR in case of positive test

At ICRISAT: So far not detected

EPPO protocols

Not available

General references

Tarr SAJ. 1962. Diseases of Sorghum, Sudan Grass and Broom Corn. Kew, Surrey: The Commonwealth Mycological Institute. 298 pp.

CGIAR-published references on seed health

Not available

Xanthomonas vasicola pv. *holcicola* Elliott.

Synonyms

Bacterium holcicola,
Phytomonas holcicola,
Pseudomonas holcicola,
Xanthomonas campestris
pv. *holcicola*, *Xanthomonas*
holcicola

Disease name

Bacterial leaf streak or
bacterial streak

Importance to CGIAR
Centers

Medium

Significance

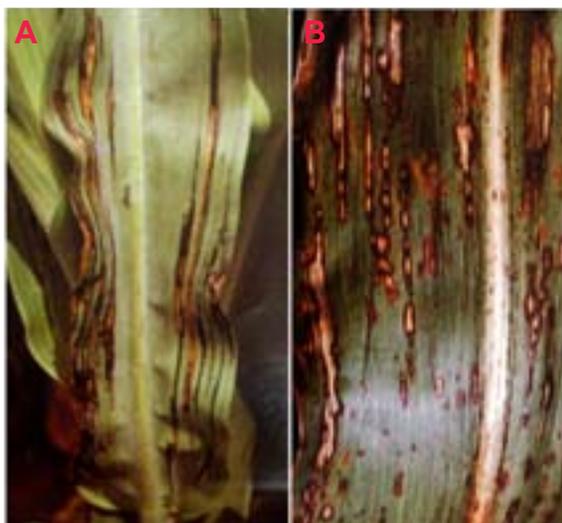
Bacterial leaf streak is of minor importance.

Symptoms

First symptoms are narrow, water-soaked, transparent leaf streaks, 2-3 mm wide by 2-15 mm long, appearing as early as the second leaf stage of the seedling. Lesions soon turn red, become opaque, and at intervals may broaden into somewhat irregularly shaped oval spots with tan centers and narrow red margins. In severe attacks, these coalesce to form long irregular streaks and blotches extending across all or much of the leaf blade, with dead tissue bordered by narrow, dark margins between the reddish-brown streaks. Abundant bacterial exudates are produced as light-yellow droplets, which dry to thin white or cream scales (Williams et al. 1978).

Hosts

Panicum miliaceum (millet), *Setaria italica* (foxtail millet), *Sorghum halepense* (aleppo grass), *Sorghum sudanense* (sudan grass) and *Sorghum bicolor* (common sorghum)



S Fig. 2. Bacterial leaf streak (*Xanthomonas vasicola* pv. *holcicola*) of sorghum: A. leaf streak and B. oval spots (Source: ICRISAT IB No. 2).

Geographic distribution

Worldwide but not reported on sorghum from India

Biology and transmission

Soil borne and infected plant debris transmit the bacteria. No evidence of seed borne bacteria for transmission.

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection

Treatment

No seed treatment

Procedures in CGIAR in case of positive test

At ICRISAT: So far not detected

EPPO protocols

Not available

General references

Williams RJ, Frederiksen RA and Girard JC. 1978. Sorghum and Pearl Millet Disease Identification Handbook. Information Bulletin No. 2. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 88 pp.

CGIAR-published references on seed health

Not available

Fungi

Claviceps sorghi Kulkarni, Seshadri & Hegde.



S Fig. 3. Ergot (*Claviceps sorghi*) of sorghum: A. honeydew stage; B. sclerotial stage and C. sclerotia (Source: ICRISAT IB No. 76).

Synonym

Claviceps africana

Disease name

Ergot

Importance to CGIAR Centers

High

Significance

Yield losses of 10-80% have occurred in hybrid seed production in India and regular annual losses of 12-25% recorded in Zimbabwe. It has been estimated that ergot costs the Australian seed industry A\$4 million annually and the annual production cost in USA increased by \$5 million due to ergot (Bandyopadhyay et al. 1998).

Symptoms

Individual ovaries of florets are replaced by a soft, white, subglobose-shaped growth of mycelium (sphaecelium) from which sticky, liquid droplets of spore-

bearing honeydew (thin to viscous, orange-brown or superficially white) will exude. Under favorable conditions, long (1-2 cm) straight or curved, cream to light brown, hard sclerotia develop (Williams et al. 1978).

Hosts

Sorghum bicolor (common sorghum) and *Sorghum halepense* (aleppo grass).

Geographic distribution

Ergot has been reported from many sorghum growing countries in Asia, Africa, USA and Latin America (Frederickson et al. 1989).

Biology and transmission

The pathogen has sclerotial and sphaelial stages in its life cycle. The sclerotia produces ascospores, which cause primary infection in the florets. The infected florets start oozing honeydew, which mostly contains microconidia. The microconidia are round to oval and reproduces either by budding or by producing germ tubes bearing secondary conidia. The secondary and tertiary conidia are the virulent propagules for causing the infection. Under conditions of high relative humidity, macroconidia at the honeydew surface germinate iteratively to produce aerially-supported secondary conidia, rendering the honeydew white in appearance (Frederickson et al. 1989). Sclerotia mixed with the seed cause the primary infection. Secondary conidia are wind-borne spores for causing epiphytotics. Sometimes insects carry the conidia from plant to plant. Rain splashes also play an important role in spreading the disease.

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection and dry seed examination

Treatment

Sclerotia from the seed lots are removed manually, and the seed samples are treated with captan (3g kg^{-1} seed) to inactivate any conidia attached to the seed surface (Odvody et al. 2000).

Procedures in CGIAR in case of positive test

At ICRISAT, all infected samples are incinerated if they are infected in the field. Sclerotia are separated manually if they come as seed-mix, and the seeds are treated with captan (3g kg^{-1} seed) to inactivate any conidia attached to the seed surface.

EPPO protocols

Not available

General references

Williams RJ, Frederiksen RA and Girard JC. 1978. Sorghum and pearl millet disease identification handbook. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 88 pp.

Bandyopadhyay R, Frederickson DE, McLaren NW, Odvody GN and Ryley MJ. 1998. Ergot: a new disease threat to sorghum in the Americas and Australia. *Plant Disease* 82:356-367.

Frederickson DE, Mantle PG and de Milliano WAJ. 1989. Secondary conidiation of *Sphacelia sorghi* on sorghum, a novel factor in the epidemiology of ergot disease. *Mycological Research* 93:497-502.

Odvody GN, Frederickson DE, Isakeit T, Montes N, Dahlberg JA and Peterson GL. 2000. Quarantine issues arising from contamination of seed with ergot: an update. *In* Global 2000, sorghum and pearl millet diseases III, 23-30 September 2000, Guanajuato, Mexico.

CGIAR-published references on seed health

Ahmed KM and Ravinder Reddy Ch. 1993. A Pictorial guide to the identification of seed borne fungi of sorghum, pearl millet, finger millet, chickpea, pigeon pea and groundnut. Information Bulletin No. 34. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 200 pp.

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Periconia circinata (L.) Mangin Sacc.



S Fig. 4. Milo disease (*Periconia circinata*) of sorghum: A. symptoms on stem and root and B. conidiophores with conidia (Source: www.extension.missouri.edu.com)

Synonyms

Aspergillus circinatus

Disease name

Milo disease

Importance to CGIAR Centers

High

Significance

Losses of up to 50-60% from Milo disease on susceptible varieties grown on infested soil.

Symptoms

Lesions occur on fine lateral roots, secondary roots and prop roots of sorghum. In an advanced stage, periconia rot is characterized by red discoloration of the stele accompanied by flecking with brown host cells from which conidiophores of *P. circinata* arises. Conidia and conidiophores can be seen on the stele and root epidermis. Sometimes, the seedlings

are stunted in susceptible genotypes and the leaves tend to be curly. The crowns of diseased plants, when split, show a dark red discoloration. The infected plants may develop subnormal grains (Mayers 1976).

Hosts

Sorghum bicolor (common sorghum), *Sorghum alnum* (Argentine grass) and *Sorghum halepense* (aleppo grass).

Geographic distribution

Widespread in South Africa. Reported in Australia, France and USA (Mayers 1976).

Biology and transmission

Colonies are small and compact, gray, brown, olivaceous brown or black, hairy. Mycelium mostly immersed but sometimes partly superficial. Stroma frequently present, mid to dark brown, pseudoparenchymatous. Conidiophores are mostly macronematous with stipe and spherical head, looking like rounded pins, pale to dark brown, often appearing black and shining by reflected light. Conidia are catenate and in chains, arising at one or more points of the curved surface of the conidiogenous cell which are monoblastic and poly blastic. Conidia are simple, usually spherical or sub-spherical, occasionally ellipsoidal, oblong or broadly cylindrical, pale to dark brown, verruculose with no septa. *P. circinata* is both seed borne (Mayers 1976) and soil borne (Odvody et al. 1977).

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection.

Treatment

No seed treatment is suggested since it is not available.

Procedures in CGIAR in case of positive test

So far not detected

EPPO protocols

Not available

General references

Mayers PE. 1976. The first recordings of Milo Disease and *Periconia circinata* on sorghum in Australia. Australian Plant Pathology Society Newsletter 5:59-60.

Odvodny GN, Dunkle LD and Edmunds LK. 1977. Characterization of the *Periconia circinata* population in a milo disease nursery. Phytopathology 67:1485–1489.

CGIAR-published references on seed health

Nil

Peronosclerospora sorghi Weston and Uppal (Shaw).



S Fig. 5. Downy mildew (*Peronosclerospora sorghi*) of sorghum: A. chlorosis on leaves; B. mycelial growth on lower surface of leaf; C. the systemic infection and oospore production stage (brown color) and D. oospores produced in parallel bands (Source: ICRISAT IB No. 51).

Synonyms

Sclerospora andropogonis-sorghii, *Sclerospora graminicola* var. *andropogonis-sorghii*, *Sclerospora sorghi*, *Sorosporium andropogonis-sorghii*

Disease name

Downy mildew

Importance to CGIAR Centers

Medium

Significance

Sorghum downy mildew is economically important and widespread in many tropical and subtropical regions of the world. The disease is highly destructive due to the systemic nature of the infection resulting in death of the plants or lack of grain formation in the panicles.

Symptoms

Both systemic and local infections occur. Symptoms appear as chlorotic foliage. The first infected leaf shows chlorosis on the lower part of the lamina, which further grows to cover large part of the leaves. The other leaves on a plant that get infected subsequently show more chlorosis. Under cool and humid weather conditions, the abaxial surface of the chlorotic leaves produce abundant conidia that appear as white downy growth. As the plant grows, the infected leaves start shedding. The local lesions on foliage are the result of the infection by conidia. These appear as stippled, necrotic lesions on leaf blades.

Hosts

Sorghum bicolor (common sorghum), *S. caffrorum* (African millet), *S. sudanense* (Sudan grass), *S. arundinaceum* (common wild sorghum), *S. halepense* (Johnson grass), *Zea diploperennis* (Diploperennial teosinte), *Zea mays* (maize), *Zea mexicana* (teosinte), *Andropogon sorghi* (jowar) and *Panicum trypheron* (aleppo grass).

Geographic distribution

Worldwide

Biology and transmission

The pathogen has sexual spores, oospores that are smooth, globose, spherical and dark brown. The asexual spores, conidia are hyaline, round to oval with papillae. The conidiophores are dichotomously branched with pointed sterigmata bearing conidia (Pande et al. 1997). Initial infections can occur from oospores in the soil and also from conidial showers from infected leaves. In certain regions, the perennial wild grasses, Johnson grass (*Sorghum halepense* and *S. arundinaceum*), are reservoirs of infection and provide primary sources of inoculum. Secondary spread of the disease occurs through wind borne conidia.

Detection/indexing methods used in CGIAR

Pre export field inspection and seed washing test. Quarantine procedures for sorghum downy mildew have been developed (Chakrabarty et al. 1998)

At ICRISAT

Treatment

Seed treatment with metalaxyle (2 g a.i. kg⁻¹ seed)

Procedures in CGIAR in case of positive test

Incineration of infected samples in the field, and rejection of seed samples that test positive under seed washing test.

EPPO protocols

Not available

General references

Chakrabarty SK, Prasada Rao RDJ, Varaprasad K, Singh SD and Girish GA. 1998. The Quarantine procedures for sorghum downy mildew - A Note on the past experience. Indian Journal of Plant Protection 26:167-169.

Pande S, Bock CH, Bandyopadhyay R, Narayana YD, Reddy BVS, Lenné JM and Jeger MJ. 1997. Downy mildew of sorghum. Information Bulletin No. 51. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 32 pp.

CGIAR-published references on seed health

Ahmed KM and Ravinder Reddy Ch. 1993. A Pictorial guide to the identification of seedborne fungi of sorghum, pearl millet, finger millet, chickpea, pigeonpea and groundnut. Information Bulletin No. 34. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 200 pp.

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Colletotrichum graminicola Ces.

Synonyms

Colletotrichum sublineolum, *C. cereale*, *Dicladium graminicola*, *Steirochaete graminicola*, *Vermicularia melicae*

Disease name

Anthracnose

Importance to CGIAR Centers

Low



S Fig. 6. Anthracnose (*Colletotrichum graminicola*) of sorghum. A. lesions on leaf (Source: ICRISAT IB No. 2); B. infected seeds (Source: ICRISAT IB No. 76); C. acervuli on seed and D. conidia (Source: ICRISAT IB No. 34).

Significance

Anthrachnose causes severe foliage damage, resulting in 46% yield loss in West Africa, 50% in USA and up to 16% in India (Thomas et al. 1996).

Symptoms

Anthrachnose on sorghum affects the leaves, stems, peduncles, panicles and seeds. Typical anthracnose symptoms are circular-elliptical dark spots, sometimes with a red pigmentation, which vary in size from 2 mm to more than 2 cm. The centre of mature lesions is straw-colored and contains numerous acervuli containing black seta. Under humid conditions, grey/cream/salmon-colored spore masses are produced. In many instances, leaves can be entirely blighted, and when it attacks the stem, it is known as 'stalk rot' (Thakur et al. 2007).

Hosts

Sorghum bicolor (common sorghum), *Poaceae* (cereals) and *Zizania aquatica* (annual wild rice).

Geographic distribution

Anthrachnose has been observed in most regions of the world where sorghum is grown successfully. It is most prevalent in warm humid regions, notably in many countries of Africa, the southern states of the USA, the northeastern countries of South America, India and Indonesia (Frederiksen 1982).

Biology and transmission

Acervuli are irregular in shape and consist of setae. Setae are brown with dark swollen base and pale rounded tip. The acervuli consist of a gelatinous salmon orange colored conidial mass. Individual conidia are hyaline, single-cell, falcate, with acute apices. It is soil borne, seed borne and wind borne.

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection and blotter test (Girish et al. 2001)

Treatment

Seed treatment with Benomyl + Thiram at the rate 2g kg⁻¹ seed (Ahmed and Ravinder Reddy 1993)

Procedures in CGIAR in case of positive test

At ICRISAT: Incineration of infected samples on the field, and rejection of seed samples that test positive under blotter method.

EPPO protocols

Not available

General references

Frederiksen RA. 1982. Disease problems in Sorghum. Pages 263-271 *in* Sorghum in the Eighties. Vol 1 (House LR, Mughogho LK and Peacock JM, eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Girish AG, Singh SD, Chakrabarty SK, Prasada Rao RDVJ, Surender A, Varaprasad KS and Bramel PJ. 2001. Seed microflora of five ICRISAT mandate crops. *Seed Science and Technology Journal* 29:429-443.

Thakur RP, Reddy BVS and Mathur K. 2007. Screening techniques for Sorghum Diseases. Information Bulletin No. 76. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 92 pp.

Thomas MD, Sissoko I and Sacko M. 1996. Development of leaf anthracnose and its effect on yield and grain weight of sorghum in West Africa. *Plant Disease* 80:151-153.

CGIAR-published references on seed health

Ahmed KM and Ravinder Reddy Ch. 1993. A Pictorial guide to the identification of seed borne fungi of sorghum, pearl millet, finger millet, chickpea, pigeon pea and groundnut. Information Bulletin No. 34. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 200 pp.

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Sporisorium sorghi Link in Willd.

Synonyms

Cintractia sorghi-vulgaris, *Sphacelotheca sorghi*, *Tilletia sorghi-vulgaris*,
Ustilago condensate, *Ustilago sorghi*, *Ustilago tulasnei*

Disease name

Sorghum covered kernel smut or sorghum covered smut

Importance to CGIAR Centers

Medium



S Fig. 7. Covered smut (*Sporisorium sorghi*) of sorghum: A. smuted grain on panicle and B. smut sori (Source: ICRISAT IB Nos. 2 and 34).

Significance

It is considered to be of major economic importance when the seeds are not treated.

Symptoms

Normally, in an infected panicle, individual ovules are replaced by conical to oval smut sori (teliospores or chlamydospores) that are covered by persistent peridia that are larger than normal grain. Initially, each sorus is covered with a light pink or silver-white membrane, which later on ruptures to reveal the brownish-black smut spores. The infected kernels break open, and the microscopic spores adhere to the surface of healthy seeds where they overwinter (Thakur et al. 2007).

Hosts

Sorghum caffrorum, *Sorghum dochna*, *Sorghum sudanense* (Sudan grass), *Sorghum bicolor* (common sorghum).

Geographic distribution

Sorghum growing areas mainly in Africa and Asia

Biology and transmission

Smut sori are generally smooth; oval, conical or cylindrical; and vary in size from those small enough to be concealed by the glumes to those over one cm long. They may be white, gray, or brown. Only seed borne spores cause infection. When a smut-infested kernel is planted, the teliospores (mostly 4 to 7 microns in diameter) germinate along with the seed, forming a 4-celled promycelium (epibasidium) bearing lateral sporidia. The sporidia germinate and infect the developing sorghum seedling. (Sometimes, the teliospores germinate directly by producing germ tubes). Once inside the seedling, the fungus grows systemically, apparently without damaging the plant until heading. At that time, the teliospores replace kernels and are surrounded by a membrane. At maturity, the membrane ruptures releasing the teliospores to contaminate seed or soil. Soil borne teliospores are not considered important in infecting seedlings. The only sources of inoculum for covered smut of sorghum are seeds infested with teliospores of *S. sorghi*. (Frederiksen 2000).

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection, dry seed examination and seed washing test

Treatment

Rejection of the seed samples

Procedures in CGIAR in case of positive test

Incineration of infected samples in the field, and rejection of seed samples that test positive under seed washing test.

EPPO protocols

Not available.

General references

Frederiksen RA. 2000. Covered kernel smut. Page 21 *in* Compendium of Sorghum Diseases, second edition (Frederiksen RA and Odvody GN, eds.). American Phytopathological Society, St. Paul, Minnesota 55121-2097, USA: APS press.

Thakur RP, Reddy BVS and Mathur K. 2007. Screening techniques for Sorghum Diseases. Information Bulletin No. 76. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 92 pp.

CGIAR-published references on seed health

Ahmed KM and Ravinder Reddy Ch. 1993. A Pictorial guide to the identification of seed borne fungi of sorghum, pearl millet, finger millet, chickpea, pigeon pea and groundnut. Information Bulletin No. 34. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 200 pp.

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Cercospora sorghi Ellis & Everh.

Synonyms

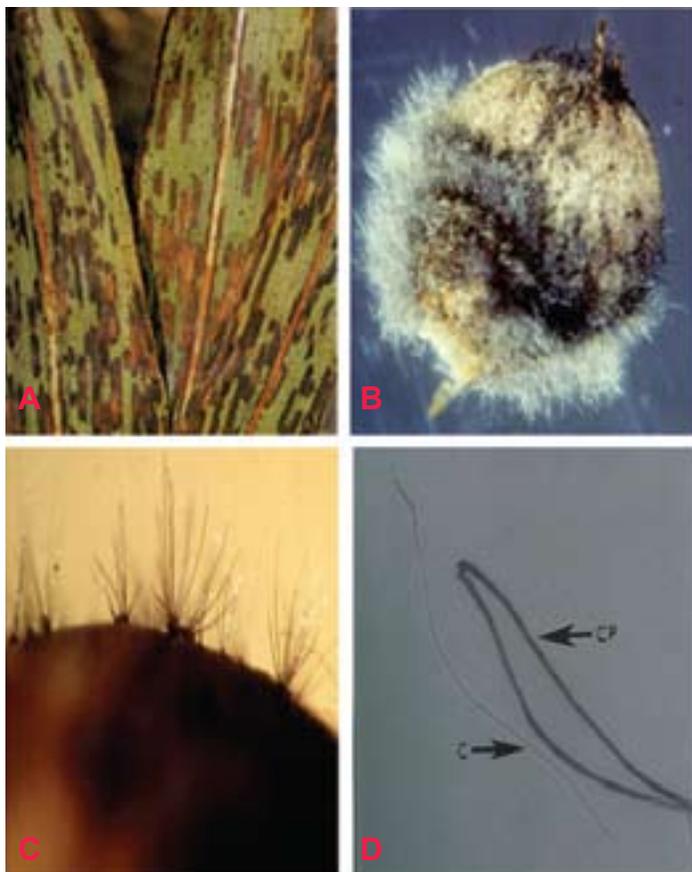
Nil

Disease name

Gray leaf spot or Cercospora leaf spot

Importance to CGIAR Centers

Medium



S Fig. 8. Gray leaf spot (*Cercospora sorghi*) of sorghum: A. leaf spot; B. fungal growth on seed; C. conidiophores on seed and D. conidiophores (CP) and conidium (C) (Source: ICRISAT IB No. 2 and 34).

Significance

Economic impact is difficult to assess because the disease appears late in the crop, as it nears maturity and other foliar diseases are commonly present as well (Odvody 1986). Yield losses due to gray leaf spot are upto 67% in Africa (Marley et al. 2001), and epidemics have occurred sporadically and, in some cases, have been widespread.

Symptoms

The lesions occur mostly on leaf blades and sheaths, and are mostly isolated, but can form continuously to give long stripes. The lesions are dark purple to red with a tan or brown centre. Leaf spots enlarge to become rectangular lesions, which can be 5-15 mm long by 2-5 mm wide (Odvody 1986).

Hosts

Sorghum almum (Argentine grass), *Sorghum dochna*, *Sorghum halepense* (aleppo grass), *Sorghum sudanense* (Sudan grass), *Sorghum bicolor* (common sorghum) and *Zea mays* (maize).

Geographic distribution

Cercospora sorghi occur in most areas where sorghum is grown around the world

Biology and transmission

Conidiophores are dark brown, narrower towards tip, irregular in width, and each conidiophore bears 1-6 conidia. Conidia are multi-septate, hyaline, vesicular, straight or slightly curved with truncate base. The disease is spread seed borne and wind borne.

Detection/indexing methods used in CGIAR

At ICRISAT

Pre export field inspection and blotter test (Girish et al. 2001)

Treatment

Seed treatment with Thiram @ 2.5 g kg⁻¹ seed (Neergaard 1979)

Procedures in CGIAR in case of positive test

At ICRISAT: Incineration of infected samples in the field, and rejection of seed samples that test positive under blotter method.

EPPO protocols

Not available.

General references

Girish AG, Singh SD, Chakrabarty SK, Prasada Rao RDVJ, Surender A, Varaprasad KS and Bramel PJ. 2001. Seed microflora of five ICRISAT mandate crops. *Seed Science and Technology Journal* 29:429-443.

Marley PS, Elemo KA, Aba DA, Onu I and Akintayo I. 2001. Reactions of sorghum genotypes to anthracnose and gray leaf spot under Sudan and Sahel savannah field conditions of Nigeria. *J. Sustain. Agric.* 18:105-116.

Neergaard P. 1979. *Seed Pathology*. Vol 1. Rev. edn. London, UK: Macmillan Press. 839 pp.

Odvodny GN. 1986. Gray leaf spot. Pages 11-12 *in* *Compendium of Sorghum Diseases*. (Frederiksen RA, ed.). American Phytopathological Society, St. Paul, Minnesota 55121-2097, USA: APS press.

CGIAR-published references on seed health

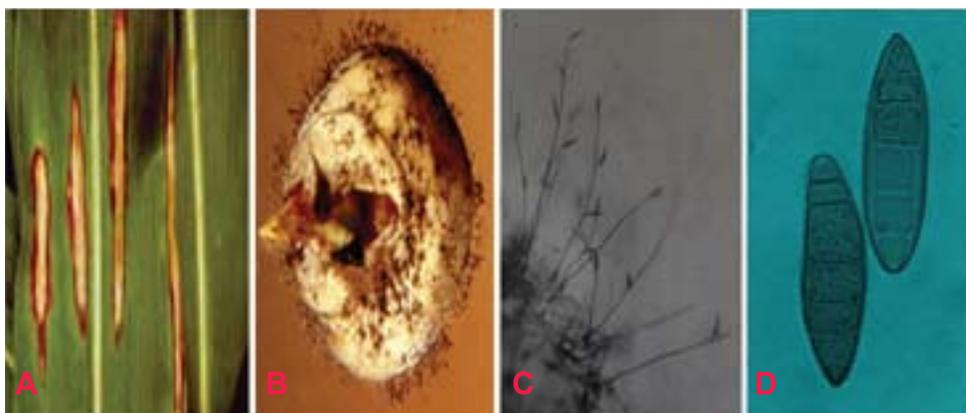
Ahmed KM and Ravinder Reddy Ch. 1993. A Pictorial guide to the identification of seed borne fungi of sorghum, pearl millet, finger millet, chickpea, pigeon pea and groundnut. Information Bulletin No. 34. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 200 pp.

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Exserohilum turcicum Pass.

Synonyms

Bipolaris turcica, *Drechslera turcica*, *Helminthosporium inconspicuum*, *Helminthosporium turcicum*, *Keissleriella turcica*, *Luttrellia turcica*, *Setomelanomma turcica*, *Trichometasphaeria turcica*



S Fig. 9. Leaf blight (*Exserohilum turcicum*) of sorghum. A. typical lesions on leaf; B. fungal growth on seed; C. conidiophores with conidia and D. conidia (Source: ICRISAT IB Nos. 34 and 76).

Disease name

Leaf blight

Importance to CGIAR Centers

Medium

Significance

Grain yield losses of up to 50% occur (Bergquist 2000).

Symptoms

Symptoms are visible from seedling stage to crop maturity stage. Small, reddish or tan spots develop on seedlings, spots later enlarge and coalesce resulting in the wilting of the young leaves. On adult plants, long, elliptical, reddish purple or yellowish lesions develop, first on lower leaves and later progress to upper leaves and stem as well. In humid weather, numerous grayish black spores are produced in the lesions in concentric zones (Thakur et al. 2007).

Hosts

Sorghum bicolor (common sorghum) and *Zea mays* (maize)

Geographic distribution

Widespread in Asia, Africa and Americas

Biology and transmission

The mycelium is hairy and dark gray to brown. Conidiophores are 135-335 µm long and 8-10 µm wide. They are flexuous, simple, erect, with a swollen base and geniculated apex, and bears typically straight or spindle shaped conidia. Conidia are olivaceous brown, straightly curved and taper towards both ends. Conidia are 3-11 distoseptate. Conidia have truncate and protuberant hilum in their basal cell. It is soil borne, wind borne and seed borne.

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection and blotter test (Girish et al. 2001)

Treatment

Seed treatment with Benomyl + Thiram (1:1) at 2g kg⁻¹ seed

Procedures in CGIAR in case of positive test

At ICRISAT: Incineration of infected samples in the field, and rejection of seed samples under positive test under blotter method.

EPPO protocols

Not available

General references

Bergquist RR. 2000. Leaf Blight. Pages 9-10 in Compendium of Sorghum Diseases, second edition (Frederiksen RA and Odvody GN, eds.). American Phytopathological Society, St. Paul, Minnesota 55121-2097, USA: APS press.

Girish AG, Singh SD, Chakrabarty SK, Prasada Rao RDVJ, Surender A, Varaprasad KS and Bramel PJ. 2001. Seed microflora of five ICRISAT mandate crops. Seed Science and Technology Journal 29:429-443.

Thakur RP, Reddy BVS and Mathur K. 2007. Screening techniques for Sorghum Diseases. Information Bulletin No. 76. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 92 pp.

CGIAR-published references on seed health

Ahmed KM and Ravinder Reddy Ch. 1993. A Pictorial guide to the identification of seed borne fungi of sorghum, pearl millet, finger millet, chickpea, pigeon pea and groundnut. Information Bulletin No. 34. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 200 pp.

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

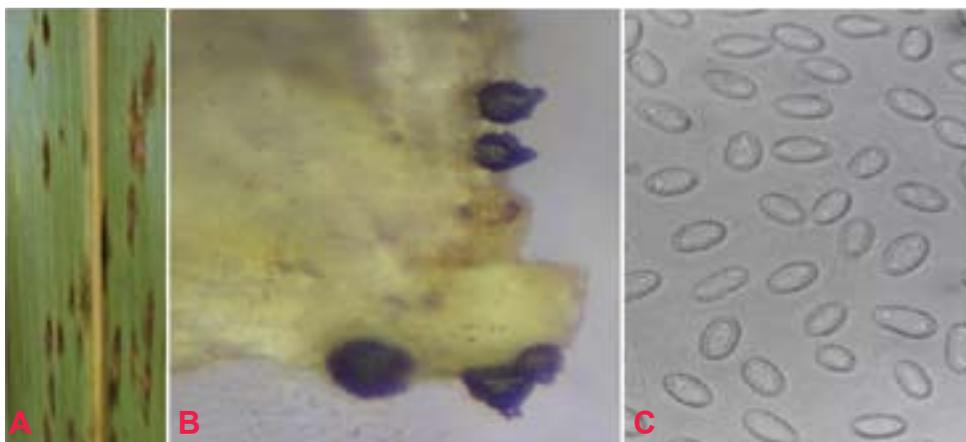
Ascochyta sorghina Sacc.

Synonyms

Ascochyta sorghi, *Didymella exitialis*, *Mycosphaerella ceres*, *Mycosphaerella exitialis*, *Sphaerella ceres*, *Sphaerella exitialis*

Disease name

Ascochyta leaf spot or Rough leaf spot



S Fig. 10. Rough leaf spot (*Ascochyta sorghi*) of sorghum: A. leaf spot symptoms (Source: ICRISAT IB No. 2); B. pycnidia on seed and C. pycnidiospores.

Importance to CGIAR Centers

Medium

Significance

Rough leaf spot is widespread in most sorghum growing countries, particularly in humid areas.

Symptoms

The disease appears as small, circular to oblong, light colored to reddish lesions with well-defined margins near the ends of the leaves. Pycnidia develop as small, hard, black specks in the infected areas. The lesions coalesce as they mature, and may resemble those of leaf blight, but the well-defined margins, or halos around the lesions can distinguish rough leaf spot.

Hosts

Sorghum halepense (aleppo grass), *Sorghum sudanense* (Sudan grass) and *Sorghum bicolor* (common sorghum).

Geographic distribution

Ascochyta sorghi is worldwide in distribution, especially in Europe, Asia and Africa.

Biology and transmission

Pycnidia are densely gregarious, globose-depressed, papillate and large. Pycnidia contains numerous conidia. Conidia are hyaline, oblong-ellipsoid, 2-celled, slightly constricted, minutely pluriguttulate and 20×8 μm (Tarr 1962). These conidia are wind borne to spread the disease. It is also reported to be seed borne.

Detection/indexing methods used in CGIAR

At ICRISAT: Pre-export field inspection and blotter test are used

Treatment

Not known

Procedures in CGIAR in case of positive test

At ICRISAT: Incineration of the infected plants/seed samples

EPPO protocols

Not available

General references

Tarr SAJ. 1962. Diseases of sorghum, sudan grass and broom corn. Kew, England: Commonwealth Mycological Institute.

CGIAR-published references on seed health

Nil

Insects

Corcyra cephalonica Stainton.

Synonyms

Not known

Common name

Rice Meal Moth



S Fig. 11. Rice Meal Moth (*Corcyra cephalonica*) of sorghum: A. adult; B. larvae in infested grain and C. pupa in infested grain (Source: ICRISAT IB No. 12).

Importance to CGIAR Centers

Low

Significance

In one instance, it was found that the weight loss of some infested rice was 7%, whilst the cost of cleaning the grain to make it saleable amounted to 9.4% of the value of the original stock

Symptoms

Infested produce is densely webbed.

Hosts

Oryza sativa (rice), *Manihot esculenta* (cassava), *Myristica fragrans* (nutmeg), *Panicum miliaceum* (wild millet), *Pennisetum glaucum* (pearl millet), *Triticum aestivum* (wheat), *Zea mays* (maize), *Arachis hypogaea* (groundnut), *Cajanus cajan* (pigeonpea), *Cicer arietinum* (chickpea), *Capsicum annuum* (bell pepper), *Ficus carica* (common fig), *Gossypium* (cotton), *Vigna radiata* (bean, mung), *Prunus armeniaca* (apricot), *Sesamum indicum* (sesame), *Theobroma cacao* (cocoa) and *Vigna unguiculata* (cowpea).

Geographic distribution

It is a major storage pest in India, Thailand, Brazil, Ghana, Myanmar, Sri Lanka and Indonesia and several countries in Africa, where major cereal crops are rice, maize, sorghum and other cereals.

Biology and transmission

The adult moth is pale grayish brown, with a wing expanse of 14-24 mm, and the head bears a projecting tuft of scales. The eggs are spherical and white and up to 200 are laid loose in food material. The incubation period is 3-5 days. Larvae are creamy white and web together particles of food and frass with silken threads into galleries in which they live and feed. The larval period is 20-30 days and pupal period 9-10 days. The adult moths are short lived (Teetes et al. 1983).

Detection/indexing methods used in CGIAR

At ICRISAT: Agar plate method

Treatment

Fumigation with methyl bromide @ 32 g m⁻³ for 4 h followed by seed treatment with chlorpyrifos 3 g kg⁻¹ seed (Ghanekar et al. 1996).

Procedures in CGIAR in case of positive test

At ICRISAT: Highly infested samples are rejected

EPPO protocols

Not available

General references

Ghanekar AM, Ranga Rao GV, Murthy KS, Surender A and Shaik Babu Saheb. 1996. Seed protectants for healthy exports. Indian Journal of Plant Protection 24(1-2):37-43.

Teetes GL, Seshu Reddy KV, Leuschner K and House LR. 1983. Sorghum insect identification handbook. Information bulletin No.12. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 125 pp.

CGIAR-published references on seed health

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Ephestia cautella Walker.

Synonyms

Cadra cautella

Common name

Almond Moth

Importance to CGIAR Centers

Low

Significance

Extensive resources are used to control this pest species in industrial flour mills (Nielsen 2000).



S Fig. 12. Almond Moth (*Ephestia cautella*) of sorghum. A. adult and B. larva and pupa with frass (Source: www.UKmoths.org.UK).

Symptoms

Damage always begins on the outside surface of grains or packaging, if these are sufficiently friable to be pierced, and then cut by the mandibles of the first-instar larvae. Dried or partly dried fruits have fissures, which are either natural (such as the hilum) or caused by other means (entry or exit holes made by other primary insect pests or damage caused by rodents). These fissures serve as feeding and anchoring points for the construction of the pupation cocoon, if there is enough space for good air circulation. Thus, damage may be located on the edges of the stores, whether they have already been infested (the surviving caterpillars search for light and air) or during new infestations.

Host

It is a storage pest that affects many cereals including *Sorghum bicolor* (sorghum), *Triticum aestivum* (wheat), *Zea mays* (maize), *Oryza sativa* (rice), *Avena sativa* (oats) and *Hordeum vulgare* (barley). It also attacks *Arachis hypogaea* (groundnut), *Ceratonia siliqua* (locust bean), *Cannabis sativa* (hemp), *Capsicum* (peppers), *Glycine max* (soybean), *Juglans* (walnuts), *Phoenix dactylifera* (date-palm), *Pisum sativum* (pea), *Prunus* (stone fruit), *Prunus dulcis* (almond), *Sesamum* (Sesame), *Solanum tuberosum* (potato) and *Theobroma cacao* (cocoa).

Geographic distribution

Cosmopolitan

Biology

The adult is grayish in color with transverse strips on its outer wings, while at rest fore part is elevated giving a distinct slope to the wings that are wrapped around the body. Wing-expanse is less than 25 mm. The females indiscriminately lay small whitish eggs in cracks of seed in storage. It lays about 250 eggs at a time. The eggs hatch in about 3 days and the young larva spill silk profusely and spin small silken tubes among the food particles. The full-grown larva is 2-12 mm long, white in color with a pinkish tinge. Larval period lasts from 40-50 days depending upon the temperature. The full-grown larvae spin cocoons and pupate therein. The pupal period lasts for about 12 days. The complete life cycle takes about 2 months and thus there are 5 or 6 generations in a year.

Detection/indexing methods used in CGIAR

At ICRISAT: Dry seed examination

Treatment

Fumigation with methyl bromide @ 32 g m⁻³ for 4 h followed by seed treatment with chlorpyrifos 3 g kg⁻¹ seed (Ghanekar et al. 1996).

Procedures in CGIAR in case of positive test

At ICRISAT: Dry seed examination

EPPO protocols

Not available

General references

Ghanekar AM, Ranga Rao GV, Murthy KS, Surender A and Shaik Babu Saheb. 1996. Seed protectants for healthy exports. *Indian Journal of Plant Protection* 24:37-43.

Nielsen PS. 2000. Alternatives to methyl bromide. IPM in flourmills; comparison of a Norwegian and Danish mill. *TemaNord2000*: 510. Nordic Council of Ministers, Copenhagen, Denmark.

CGIAR-published references on seed health

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Oryzaephilus surinamensis Linnaeus.

Synonyms

Anobium frumentarium,
Dermestes sexdentatu, *Dermestes surinamensis*

Common name

Sawtoothed Grain Beetle

Importance to CGIAR Centers

Low

Significance

The sawtoothed grain beetle is a secondary pest that attacks damaged grain. It infests a wide range of grain-like products, from rice to corn flakes to birdseed to pancake flour to tapioca. However, infestations by these pests can lead to substantial contamination with frass and dead bodies. Thus, quality deterioration is an important issue.



S Fig. 13. Sawtoothed Grain Beetle (*Oryzaephilus surinamensis*) of sorghum (Source: www.commons.wikimedia.org).

Symptoms

It is a typical secondary pest, attacking previously damaged or broken kernels to feed, especially on the germ. The larvae also attack the germ in whole cereal grains, thereby altering the nutritional content and reducing the percentage germination.

Hosts

Avena sativa (oats), *Hordeum vulgare* (barley), *Myristica fragrans* (nutmeg), *Oryza sativa* (rice), *Panicum miliaceum* (millet), *Triticum* (wheat), *Zea mays* (maize), *Arachis hypogaea* (groundnut), *Azadirachta indica* (bastard tree), *Ceratonia siliqua* (locust bean), *Helianthus annuus* (sunflower), *Panicum* (millets), *Secale cereale* (rye) and *Vicia faba* (broad bean).

Geographic distribution

Cosmopolitan

Biology and transmission

The sawtoothed grain beetle is a slender, dark brown beetle 2.4–3 mm in size, with characteristic teeth running down the side of the prothorax. The antennae are relatively short and weakly clubbed, and the prothorax has six distinctive tooth-like projections along each side. Eggs are laid singly or in small batches in some crevice in the food packs. The larvae are white, elongate, somewhat flattened and about 4-5 mm long when fully grown; with a pair of abdominal prolegs in addition to the 6 true legs on the thorax. The larval cycle is 27-35 days, with 2-4 molts depending on temperature (Mallis 1990).

Detection/indexing methods used in CGIAR

At ICRISAT

Treatment

Fumigation with methyl bromide @ 32 g m⁻³ for 4 h followed by seed treatment with chlorpyrifos 3 g kg⁻¹ seed (Ghanekar et al. 1996).

Procedures in CGIAR in case of positive test

At ICRISAT: Infested samples are rejected

EPPO protocols

Not available

General references

Ghanekar AM, Ranga Rao GV, Murthy KS, Surender A and Shaik Babu Saheb. 1996. Seed protectants for healthy exports. *Indian Journal of Plant Protection*. 24:37-43.

Mallis A. 1990. Pages 524-526 in *Handbook of Pest Control*. 7th edition. Cleveland: Franzak & Foster Co.

Teetes GL, Seshu Reddy KV, Leuschner K and House LR. 1983. Sorghum insect identification handbook. Information Bulletin No. 12. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 125 pp.

CGIAR-published references on seed health

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Plodia interpunctella Hubner.

Synonyms

Not known

Common name

Indian Meal Moth

Importance to CGIAR Centers

Medium

Significance

Indian Meal Moth is a common grain-feeding pest found around the world, feeding on cereals and dry grain products.



S Fig. 14. Indian Meal Moth (*Plodia interpunctella*) of sorghum (Source: ICRISAT IB No. 12).

Symptoms

Grains on the surface are often held together by a mat of silken webbing containing frass and larval skins. The larvae move through the commodity leaving a trail of webbing and excreta. White, silken cocoons containing the pupae can be seen on the sides of infested bags.

Biology and transmission

Female moths lay between 60 and 400 eggs (Lyon 1991) on a food surface. The eggs are ordinarily smaller than 0.5 mm and not sticky. They hatch in 2 to 14 days. The moth larvae are off-white with brown heads. When these larvae mature, they are usually about 12 mm long. The larval stage lasts from 2 to 41 weeks, depending on the temperature. Adult moths are 8-10 mm in length with 16-20 mm wingspans. The outer half of their forewings is bronze, copper, or dark gray in color, while the upper half is yellowish-gray, with a dark band at the intersection between the two. The entire life cycle may range from 30 to 300 days.

Hosts

Arachis hypogaea (groundnut), *Oryza sativa* (rice), *Prunus* (stone fruit), stored products (dried stored products), *Triticum aestivum* (wheat), *Zea mays* (maize), *Avena sativa* (oats), *Helianthus annuus* (sunflower), *Hordeum vulgare* (barley), *Juglans regia* (Carpathian walnut), *Pistacia vera* (pistachio), *Prunus dulcis* (almond) and *Theobroma cacao* (cocoa).

Geographic distribution

Plodia interpunctella is cosmopolitan in distribution especially in warm climates. In cool temperate countries, it can survive in heated buildings.

Detection/indexing methods used in CGIAR

Treatment at ICRISAT: Fumigation with methyl bromide @ 32 g m⁻³ for 4 h followed by seed treatment with chlorpyrifos 3 g kg⁻¹ seed (Ghanekar et al. 1996).

Procedures in CGIAR in case of positive test

At ICRISAT: Infested samples are rejected

EPPO protocols

Not available

General references

Ghanekar AM, Ranga Rao GV, Murthy KS, Surender A and Shaik Babu Saheb. 1996. Seed protectants for healthy exports. Indian Journal of Plant Protection 24:37-43.

Lyon WF. 1991. "Fact Sheet: Indianmeal Moth". Ohio State University. <http://ohioline.osu.edu/hyg-fact/2000/2089.html>. Retrieved on 2006-09-07.

CGIAR-published references on seed health

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Rhyzopertha dominica Fabricius.

Synonyms

Not known

Common name

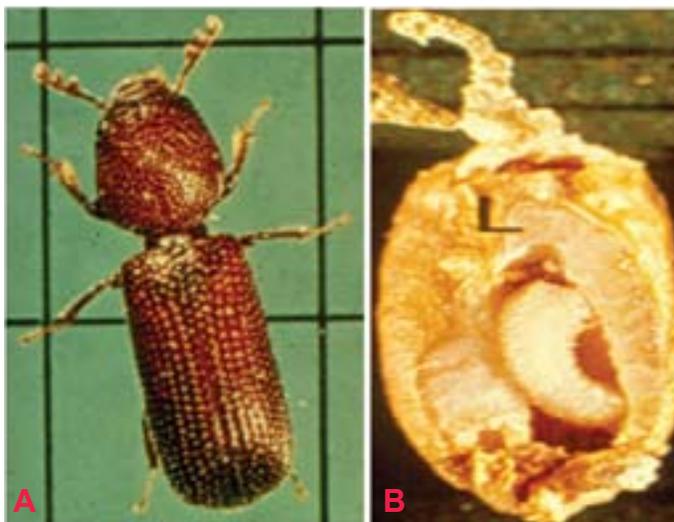
Lesser Grain Borer

Importance to CGIAR Centers

Low

Significance

Rhyzopertha dominica is a pest of several stored products. It is a major pest in wheat and rice. The larvae and adults consume the seed.



S Fig. 15. Lesser Grain Borer (*Rhyzopertha dominica*) of sorghum: A. adult and B. larva in the grain (Source: ICRISAT IB No. 2).

Infestations of *R. dominica* adversely affect quantity and quality of stored seed.

Symptoms

Damaged grains with small holes can be seen under a stereo binocular or with a magnifying lens.

Hosts

Avena sativa (oats), *Hordeum vulgare* (barley), *Oryza sativa* (rice), *Panicum* (millets), *Pennisetum* (feather grass), *Triticum aestivum* (wheat), *Zea mays* (maize), *Coriandrum sativum* (coriander), *Capsicum frutescens* (chilli), *Curcuma longa* (turmeric), *Manihot esculenta* (cassava), *Phaseolus* (beans) and *Zingiber officinale* (ginger).

Geographic distribution

Rhyzopertha dominica is cosmopolitan in its distribution and infestation can be severe.

Biology and transmission

The beetle is small (4 mm long), slender, cylindrical, polished dark-brown or black with a roughened wing surface. The head is turned down and covered by a hood-shaped thorax that bears small patches around the edge. The female lays 300-500 eggs singly or in clusters on grains or in powdery material over a period of 3-6 weeks. In 5-11 days, eggs hatch into fleshy grubs that appear swollen at the extremities. Grubs bore into grains and feed inside. The larval period lasts from 25 to 50 days depending on the season. Pupation takes place within the grain. The pupal period lasts 7-8 days. The total life cycle may take place in 2 months and 3-4 generations in a year (Teetes et al. 1983).

Detection/indexing methods used in CGIAR

At ICRISAT

The simplest method is to sieve a 200-1000 g sample of the grain and look for adults as dry seed examination.

Treatment

Fumigation with methyl bromide @ 32 g m⁻³ for 4 h followed by seed treatment with chlorpyrifos 3 g kg⁻¹ seed (Ghanekar et al. 1996).

Procedures in CGIAR in case of positive test

At ICRISAT: Infested samples are rejected

EPPO protocols

Not available

General references

Ghanekar AM, Ranga Rao GV, Murthy KS, Surender A and Shaik Babu Saheb. 1996. Seed protectants for healthy exports. Indian Journal of Plant Protection 24:37-43.

Teetes GL, Seshu Reddy KV, Leuschner K and House LR. 1983. Sorghum insect identification handbook. Information Bulletin No.12. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 125 pp.

CGIAR-published references on seed health

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Sitophilus oryzae Linnaeus.

Synonym

Sitophilus zeamais

Common name

Rice weevil

Importance to CGIAR Centers

Low

Significance

Moderate loss in sorghum grains in large and small grains. Threshed grain is more susceptible than unthreshed grain; more progeny is produced on threshed than on unthreshed sorghum.



S Fig. 16. Rice Weevil (*Sitophilus oryzae*) of sorghum: A. adult and B. infested grain (Source: ICRISAT IB No. 12).

Geographical distribution

Rice weevil is the most destructive pest of stored grain worldwide, and is cosmopolitan in distribution, but much more damaging in warm and humid countries (Teetes et al. 1983)

Symptoms

Both the adults and larvae feed on grain, which may often be damaged beyond use.

Host

Oryza sativa (rice), *Manihot esculenta* (cassava), *Triticum aestivum* (wheat), *Triticum spelta* (spelt), *Zea mays* (maize), *Cicer arietinum* (chickpea), *Hordeum vulgare* (barley), *Lens culinaris* (small seeded lentil), *Panicum* (millets), *Pennisetum glaucum* (pearl millet), *Vigna angularis* (adzuki bean), *Vigna radiata* (mung bean), *Pisum sativum* (pea), *Secale cereale* (rye) and *Vigna unguiculata* (cowpea).

Biology

Adult weevils are reddish brown; about 4mm long, and have four light reddish or yellowish spots on the wings. The adult female bores a hole in a kernel, deposits a single egg and covers it with a gelatinous fluid. The female may lay 300-550 eggs in 4-5 months. The incubation period is 3 days. The grub is legless, short, stout and whitish with a brown head. The larva matures in 3-6 days. The longevity of the adult is 4-5 months (Teetes et al. 1983).

Detection/indexing methods used in CGIAR

At ICRISAT: Dry seed examination

Treatments

Fumigation with methyl bromide @ 32 g m⁻³ for 4 h followed by seed treatment with chlorpyrifos at 3 g kg⁻¹ seed (Ghanekar et al. 1996).

Procedures in CGIAR in case of positive test

At ICRISAT: Removal of the infested seed if it is less than 5%.

EPPO protocols

Not available

General references

Ghanekar AM, Ranga Rao GV, Murthy KS, Surender A and Shaik Babu Saheb. 1996. Seed protectants for healthy exports. Indian Journal of Plant Protection 24:37-43.

Teetes GL, Seshu Reddy KV, Leuschner K and House LR. 1983. Sorghum insect identification handbook. Information Bulletin No. 12. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 125 pp.

CGIAR published references on seed health

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Sitotroga cerealella Olivier.

Synonyms

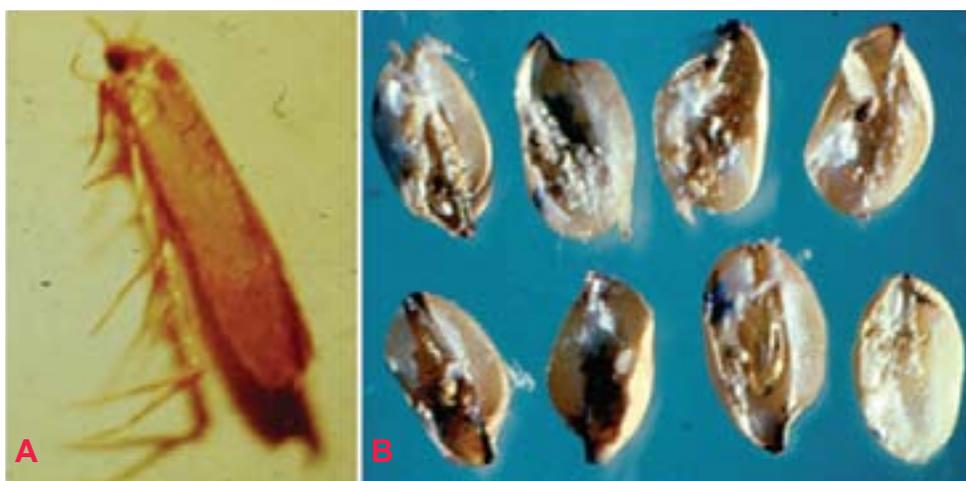
Tinea hordei

Common name

Angoumois Grain Moth

Importance to CGIAR Centers

Medium



S Fig. 17. Angoumois Grain Moth (*Sitotroga cerealella*) of sorghum: A. adult and B. infested grains (Source: ICRISAT IB No. 12).

Significance

An important pest of stored sorghum that can cause losses of up to 50% during storage. High temperature and poor storage hygiene are major factors resulting in insect infestation (Seifelnasr 1992).

Symptoms

Infestation can begin in the fields. In storage, the infestation is confined to the upper layer of the grains. The larva bores into the grain and remains there until it emerges as an adult from round emergence holes. The infested grain is completely hollowed out and filled with larval excreta.

Hosts

Avena sativa (oats), *Hordeum vulgare* (barley), *Oryza sativa* (rice), *Pennisetum glaucum* (pearl millet), *Secale cereale* (rye), *Triticum aestivum* (wheat), *Triticum spelta* (spelt) and *Zea mays* (maize).

Geographic distribution

It is cosmopolitan in distribution. It is one of the primary pests of stored sorghum and rice grain, but is also known to attack maize, wheat and barley.

Biology

The female can lay up to 400 eggs that are deposited indiscriminately on or between the grains, on the panicles in the field, or in the storage. The egg is white and oval, but soon turns bright red and hatches within a week. The tiny larva crawls about searching for a comparatively weak spot through which it enters the grain, and feeds on the internal contents. The larval period is 2-3 weeks. The moth emerges within a week (Teetes et al. 1983).

Detection/indexing methods used in CGIAR

At ICRISAT: Dry seed examination

Treatment

Fumigation with methyl bromide @ 32 g m⁻³ for 4 h followed by seed treatment with chlorpyrifos at 3 g kg⁻¹ seed (Ghanekar et al. 1996).

Procedures in CGIAR in case of positive test

At ICRISAT: Highly infested samples are rejected

EPPO protocols

Not available

General references

Ghanekar AM, Ranga Rao GV, Murthy KS, Surender A and Shaik Babu Saheb. 1996. Seed protectants for healthy exports. Indian Journal of Plant Protection 24:37-43.

Seifelnasr YE. 1992. Farmers' perceptions on management practices of insect pests on stored sorghum in southwestern Ethiopia. *Crop Protection* 26:1817-1825.

Teetes GL, Seshu Reddy KV, Leuschner K and House LR. 1983. Sorghum insect identification handbook. Information Bulletin No. 12. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 125 pp.

CGIAR-published references on seed health

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Prostephanus truncatus Horn.

Synonyms

Dinoderus truncatus

Common name

Larger grain borer

Importance to CGIAR Centers

Low

Significance

A highly damaging pest of sorghum causing upto 20% grain loss (Mailafiya et al. 2008).

Symptoms

Adults frequently initiate their attack on stored seed with intact sheaths by boring into the base of seed. Adults bore into the grains, making neat round holes, and as they tunnel from grain to grain they generate large quantities of grain dust. Adult females lay eggs in chambers bored at right angles to the main tunnels.



S Fig. 18. Larger Grain Borer (*Prostephanus truncatus*) of sorghum (Source: www.agrsci.dk/plb/bembi/africa.com).

Hosts

Manihot esculenta (cassava), stored products (dried stored products), *Zea mays* (maize), *Dioscorea* (yam) and *Triticum aestivum* (wheat).

Geographic distribution

Prostephanus truncatus is indigenous in Central America, tropical South America, and the extreme south of the USA as a major pest. It is also distributed in Africa and Europe, but has restricted distribution in India.

Biology

The adult has the typical cylindrical bostrichid shape with body length of 3-4.5 mm. The declivity is flattened and steep and has many small tubercles over its surface. The limits of the declivity, apically and laterally, are marked by a carina. The antennae are 10-segmented and have a loose three-segmented club; the 'stem' of the antenna is slender and clothed with long hairs and the apical club segment is as wide as, or wider than, the preceding segments. The larvae are white, fleshy and sparsely covered with hairs. They are parallel-sided, ie, they do not taper. The legs are short and the head capsule is small relative to the size of the body.

Detection/indexing methods used in CGIAR

At ICRISAT: Not detected

Treatment

Not suggested due to non-detection of the pest

Procedures in CGIAR in case of positive test

At ICRISAT: Highly infested samples are rejected

EPPO protocols

Not available

General references

Mailafiya DM, Ayertey JN and Cudjoe AR. 2008. Damage and weight loss potential of *Prostephanus truncatus* Horn Coleoptera: Bostrichidae on sorghum grain: implication to cereal grain storage in sub-Saharan Africa. International Journal of pure and applied sciences 2:28-35.

CGIAR-published references on seed health

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Tribolium castaneum Herbst.

Synonyms

Not known

Common name

Red Flour Beetle

Importance to CGIAR Centers

Medium

Significance

Important in stored sorghum grain in several countries.

Symptoms

Infestation by adult beetles can be readily observed by the tunnels they leave when they move through the flour and other granular food products.



S Fig. 19. Red Flour Beetle (*Tribolium castaneum*) of sorghum: A. adult (Source: ICRISAT IB No. 12) and B. infested grains.

Damage is particularly serious in grains such as rice and wheat, which have either been dehusked or processed into other products. When infestation is severe, these products turn grayish-yellow and become moldy, with a pungent odor. Infestation may also be apparent by the appearance of adults on the surface of the grains (Teetes et al. 1983).

Hosts

Arachis hypogaea (groundnut), *Avena sativa* (oats), *Bertholletia excelsa* (Brazil nut), *Hordeum vulgare* (barley), *Juglans* (walnuts), *Lens culinaris* spp. *Culinaris* (lentil), *Oryza sativa* (rice), *Phaseolus* (beans), *Phaseolus lunatus* (lima bean), *Pisum sativum* (pea), *Prunus dulcis* (almond), *Secale cereale* (rye), *Triticum* (wheat), *Triticum spelta* (spelt) and *Zea mays* (maize).

Geographic distribution

Tribolium castaneum is cosmopolitan; found infesting stored grain, seeds, flour, dried fruits, nuts (Teetes et al. 1983).

Biology and transmission

The adult is 2.3-4.4 mm long, rather flat, oblong and chestnut-brown (reddish-brown). It lays about 450 eggs in stored produce. The eggs are minute, cylindrical and white. The incubation period lasts for 5-12 days. The yellowish-white cylindrical grub is covered with fine hairs. The pupa is naked (without a cocoon), yellowish-white, becoming brown later, and adults emerge in 3-7 days (Teetes et al. 1983).

Detection/indexing methods used in CGIAR

At ICRISAT

X-ray radiography is used for suspected samples because it offers a non-destructive method. Dry seed is examined using a magnifying lens to separate the infested seed.

Treatment

Infested seed samples are rejected.

Procedures in CGIAR in case of positive test

At ICRISAT

Fumigation of the samples with methyl bromide @ 32 g m⁻³ for 4 h followed by seed treatment with chlorpyrifos at 3g kg⁻¹ seed (Ghanekar et al. 1996)
Infested samples are rejected.

EPPO protocols

Not available

General references

Ghanekar AM, Ranga Rao GV, Murthy KS, Surender A and Shaik Babu Saheb. 1996. Seed protectants for healthy exports. *Indian Journal of Plant Protection* 24:37-43.

Teetes GL, Seshu Reddy KV, Leuschner K and House LR. 1983. Sorghum insect identification handbook. Information Bulletin No.12. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 125 pp.

CGIAR-published references on seed health

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Trogoderma granarium Everts.

Synonym

Trogoderma afrum, *Trogoderma khapra*, *Trogoderma quinquefasciata*

Common name

Khapra beetle

Importance to CGIAR Centers

Medium



S Fig. 20. Khapra Beetle (*Trogoderma granarium*) of sorghum: A. adults and B. larvae on the grains (Source: www.agspsv34.wa.gov.au).

Significance

Trogoderma granarium is a serious pest of stored products under hot dry conditions. Established infestations are difficult to control because of the beetle's ability to live without food for long periods of time and to survive on foods of low moisture content, its habit of crawling into tiny cracks and crevices and remaining there for long periods, and its relative tolerance to many surface insecticides and fumigants.

Symptoms

The khapra beetle is one of the world's most feared stored-product pests. The obvious signs of a khapra beetle infestation are the larvae and cast skins. Larvae and adults are best identified by microscopic examination. Larvae are mostly seen just before dusk, since they are more active at that time (Anonymous 1981).

Host

Larvae feed on a wide variety of stored products and dried foods. They prefer whole grain and cereal products such as *Triticum aestivum* (wheat), *Hordeum vulgare* (barley) and *Oryza sativa* (rice), but larvae have been recorded on the following: *Avena spp.* (oats), *Secale spp.* (rye), *Zea mays* (corn), dried blood, dried milk, fishmeal, *Arachis hypogea* (groundnut), flour, bran, malt, *Linum usitatissimum* (flax seed), *Medicago sativa* (alfalfa seed), *Lycopersicum esculantus* (tomato seed), *Phaseolus vulgaris* (pinto beans), *Vigna unguiculata* (blackeyed cowpeas), *Sorghum bicolor* (sorghum seed) and many other food products (Lindgren and Vincent 1959, Lindgren et al. 1955).

Geographic distribution

The distribution of khapra beetle extends from Myanmar (Burma) to West Africa and is limited by the 35° parallel to the north and the equator to the south. It has been introduced by commerce into some areas of similar climatic conditions (Anonymous 1981). The khapra beetle is found in all continents where grain and grain products are stored.

Biology and transmission

The adults are oblong-oval beetles, approximately 1.6 to 3.0 mm long and 0.9 to 1.7 mm wide. Males are brown to black with indistinct reddish brown markings on elytra. Females are slightly larger than males and lighter in

color. The head is small and deflexed with a short 11-segmented antenna. The antennae have a club of three to five segments, which fit into a groove in the side of the pronotum. The adults are covered with hairs. The eggs are milky white, turning pale yellowish with age, cylindrical, 0.7×0.25 mm, one end rounded, the other pointed and bearing spine-like projections. Larvae are uniformly yellowish white, except for the head and body hairs, which are brown. As the larvae increase in size, their body color changes to a golden or reddish brown, more body hairs develop, and the tail becomes proportionally shorter. Mature larvae are approximately 6 mm long and 1.5 mm wide. Adult khapra beetles have wings, but do not fly and feed very little. Mated females live from four to seven days, unmated females from 20 to 30 days, and males from seven to 12 days. Mating occurs about five days after emergence, and egg laying begins almost immediately at 40°C. Egg laying may begin at one to three days at cooler temperatures, but no eggs are produced at 20°C. Eggs hatch in three to 14 days after the female lays an average of 50 to 90 eggs that are loosely scattered in the host material. Complete development from egg to adult can occur from 26 to 220 days, depending upon temperature. Optimum temperature for development is 35°C. If the temperature falls below 25°C for a period of time or if larvae are very crowded, they may enter diapauses. They can survive temperatures below -8°C. In diapauses, the larvae can molt but are inactive and may remain in this condition for many years (Anonymous 1981).

Detection/indexing methods used in CGIAR

At ICRISAT

Dry seed examination using magnifying lens.

Treatment

High concentrations of fumigant (Aluminum phosphide) are maintained during the fumigation period to allow penetration into all cracks and crevices. In an eradication program, both fumigants and surface treatment (chlorpyrifos) are used in combination with preventive measures, eg, good sanitation practices and exclusion.

Procedures in CGIAR in case of positive test

At ICRISAT: Rejection and incineration of the infested seed samples

EPPO protocols

Not available

General references

Anonymous. 1981. Data sheets on quarantine organisms. *Trogoderma granarium* Everts. Pages 1-6 in European and Mediterranean Plant Protection Organization Bulletin 11 (1) Set 4, List A2.

Lindgren DL and **Vincent LE.** 1959. Biology and control of *Trogoderma granarium* Everts. Journal of Economic Entomology 52:312-319.

Lindgren DL, Vincent LE and **Krohne HE.** 1955. The khapra beetle, *Trogoderma granarium* Everts. Hilgardia 24:1-36.

CGIAR-published references on seed health

Nil

Pearl millet [*Pennisetum glaucum* (L.) R. Br.]

Bacteria

Pseudomonas syringae pv. *syringae* van Hall.

Synonyms

Pseudomonas syringae pv. *japonica*

Disease name

Brown spot or bacterial brown spot

Importance to CGIAR Centers

High

Significance

The diseases caused by this bacterium are very important throughout the world. For instance, bacterial brown spot occurs wherever beans are grown, and canker diseases of fruit trees caused by *P. syringae* pv. *syringae* are widespread and may be devastating, causing economical losses.

Symptoms

The symptoms first appear on the lower sides of the leaves as small, water-soaked spots. The spots enlarge, coalesce, and form larger areas that later become necrotic. The bacteria also enter the vascular tissues of the leaf and spread into the stem. The infected area, which is surrounded by a narrow zone of bright, lemon yellow tissue, turns brown, becomes rapidly necrotic, and through coalescence of several small spots, may produce large dead areas of various shapes. The disease produces identical symptoms on the stems, pods and seeds. In addition, light-cream or silver bacterial exudates are often produced on the lesions under moist conditions [Symptom similar to that in S Fig 1 (pg 58)].

Hosts

Multilateral hosts like graminacious and leguminacious plants.

Geographic distribution

Worldwide

Biology and transmission

Pseudomonas syringae pv. *syringae* is a rod shaped, gram-negative with polar flagella. *P. syringae* tests negative for arginine dihydrolase and oxidase activity, and forms the polymer levan on sucrose nutrient agar. It is known to secrete the lipodepsinonapeptide plant toxin syringomycin, and it owes its yellow fluorescent appearance when cultured in vitro on King's B medium to production of the siderophore pyoverdin. The pathogen is seed borne and it will spread through the infected seed from season to season (Gaudet and Kokko 1986, Venette et al. 1987). Diseases by *P. syringae* are favored by wet, cool conditions - optimum temperatures for disease development is around 12-25°C, although this can vary according to the pathovar involved. The pathogen is dispersed between plants via rain splash (Hirano and Upper 1990).

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection and agar plate method

Treatment

No suitable seed treatment to eradicate infection

Procedures in CGIAR in case of positive test

At ICRISAT: So far not detected at ICRISAT

EPPO protocols

Not available

General references

Gaudet DA and **Kokko EG**. 1986. Seedling disease of sorghum grown in southern Alberta caused by seedborne *Pseudomonas syringae* pv. *syringae*. Canadian Journal of Plant Pathology 8:208-217.

Hirano SS and **Upper CD**. 1990. Population biology and epidemiology of *Pseudomonas syringae* Annual Reviews in Phytopathology 28:155-177.

Venette JR, Lampa RS, Albaugh DA and Nayas JB. 1987. Presumptive procedure (dome test) for detection of seed borne bacterial pathogens in dry beans. *Plant Disease* 71:984-990.

CGIAR-published references on seed health

Mew TW and Misra JK, eds. 1994. *A Manual of Rice Seed Health Testing*. Manila, Philippines: International Rice Research Institute (IRRI). 113 pp.

Xanthomonas vasicola pv. *holcicola* (Elliott).

Synonyms

Bacterium holcicola, *Phytomonas holcicola*, *Pseudomonas holcicola*, *Xanthomonas campestris* pv. *holcicola*, *Xanthomonas holcicola*

Disease name

Bacterial leaf streak or bacterial streak

Importance to CGIAR Centers

High

Significance

The disease is important only occasionally during springtime under warm weather conditions and becomes less serious during hot and dry summer months.

Symptoms

First symptoms are narrow, water-soaked, transparent leaf streaks, 2-3 mm wide × 2-15 mm long, appearing as early as the second leaf stage of the seedling. Lesions soon turn red, become opaque, and at intervals may broaden into somewhat irregularly shaped oval spots with tan centers and narrow red margins. In severe cases, these coalesce to form long irregular streaks and blotches extending across all or much of the leaf blade, with dead tissue bordered by narrow, dark margins between the reddish-brown streaks. Abundant bacterial exudates are produced as light-yellow droplets, which dry to thin white or cream scales (Williams et al. 1978). [Symptom similar to that in S Fig. 2 (pg 60)].

Hosts

Panicum miliaceum (broomcorn millet), *Setaria italica* (foxtail millet), *Sorghum halepense* (aleppo grass), *Sorghum sudanense* (Sudan grass), *Sorghum bicolor* (common sorghum) and *Zea mays* (maize).

Geographic distribution

Xanthomonas vasicola pv. *holcicola* is prevalent worldwide. It is reported from USA, Argentina, Australia, Ethiopia, Gambia, India, Israel, Mexico, New Zealand, Niger, the Philippines, South Africa, Thailand, Romania, S Russia and Ukraine (Elliott 1930).

Biology and transmission

Xanthomonas vasicola pv. *holcicola* is both soil borne and seed borne, and is also transmitted by infected plant debris.

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection

Treatment

No seed treatment

Procedures in CGIAR in case of positive test

At ICRISAT: So far not detected

EPPO protocols

Not available

General references

Elliott C. 1930. Bacterial streak disease of sorghum. Journal of Agricultural Research 40:963-976.

Williams RJ, Frederiksen RA and Girard JC. 1978. Sorghum and Pearl Millet Disease Identification Handbook. Information Bulletin No. 2. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 88 pp.

CGIAR-published references on seed health

Nil

Xanthomonas campestris (Pammel) Dowson

Synonyms

Xanthomonas pennisiti, *Xanthomonas annamalaiensis*, *Xanthomonas rubrisorghii*

Disease name

Bacterial leaf streak

Importance to CGIAR Centers

High

Significance

Bacterial leaf streak is of minor importance.

Symptoms

Initial symptoms include narrow, water-soaked, transparent leaf streaks, 2-3 mm wide by 2-15 mm long, which generally appear from the second leaf stage of the seedlings. Lesions soon turn red, become opaque, and at intervals may broaden into somewhat irregularly shaped oval spots with tan centers and narrow red margins. In severe form, these coalesce to form long irregular streaks extending across the leaf blade. Abundant bacterial exudates are produced as light-yellow droplets, which dry to thin white or cream scales (Williams et al. 1978). [Symptom similar to that in S Fig. 2 (pg 60)].

Hosts

Panicum miliaceum (broomcorn millet), *Setaria italica* (foxtail millet), *Sorghum halepense* (aleppo grass), *Sorghum sudanense* (Sudan grass), *Sorghum bicolor* (common sorghum) and *Zea mays* (Qhobela and Claflin 1988).

Geographic distribution

It is reported from Nigeria and Senegal.

Biology and transmission

Bacterial colonies are yellow and mucoid on the nutrient agar medium. Bacterial cells are aerobic, motile, gram-negative, rod-shaped, and differ

pathologically, serologically and by membrane protein patterns from other pathovars of *X. campestris*. Cells measure $0.45 \times 2.25 \mu\text{m}$ and have one polar flagellum. Optimal growth occurs between 26 and 30°C (Rangaswami et al. 1961).

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection and agar plate method are used.

Treatment

No seed treatment is available.

Procedures in CGIAR in case of positive test

At ICRISAT: So far not detected

EPPO protocols

Not available

General references

Qhobela M and Claflin LE. 1988. Characterization of *Xanthomonas campestris* pv. *pennamericanum* pv. nov., causal agent of bacterial leaf streak of pearl millet. International Journal of Systematic Bacteriology 38:362-366.

Rangaswami G, Prasad NN and Eswaran KSS. 1961. Two new bacterial diseases of sorghum. Andhra Agricultural Journal 8:269-272.

Williams RJ, Frederiksen RA and Girard JC. 1978. Sorghum and Pearl Millet Disease Identification Handbook. Information Bulletin No. 2. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 88 pp.

CGIAR-published references on seed health

Nil

Fungi

Sclerospora graminicola (Sacc.) Schroet.

Synonyms

Sclerophthora macrospora

Disease name

Downy mildew or Green ear disease

Importance to CGIAR Centers

Medium

Significance

Yield losses upto 60% reported from India, and several countries in Africa (Singh et al. 1993).

Symptoms

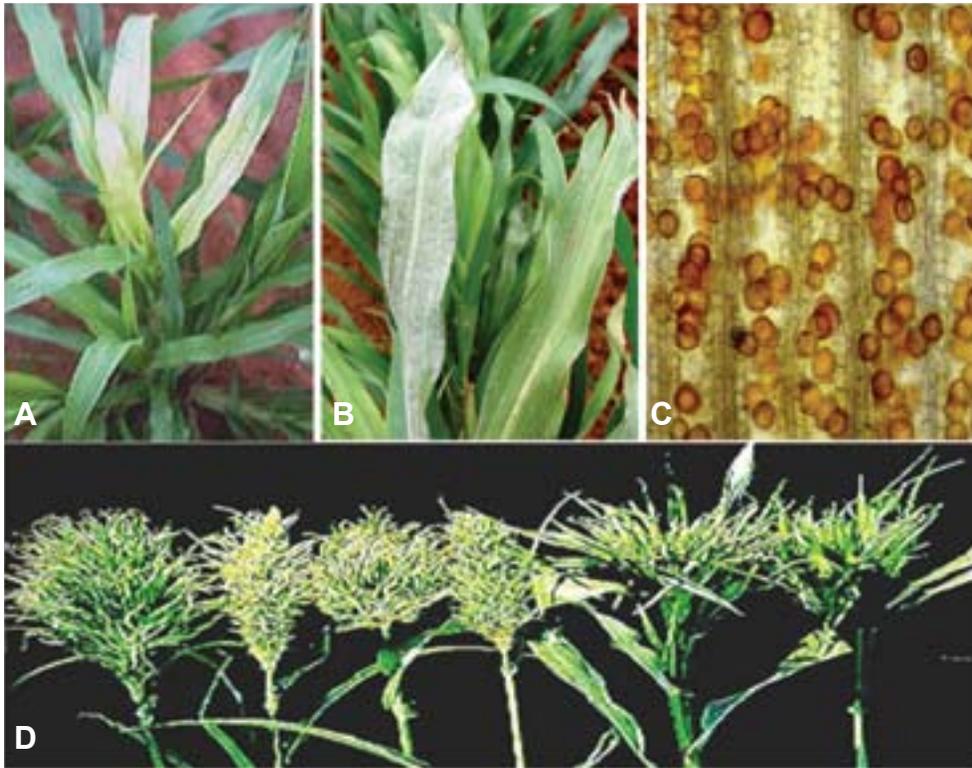
Leaf symptoms begin as chlorosis at the base of the leaf lamina and successive new leaves show a progression of greater leaf coverage. Under conditions of high humidity and moderate temperature, the infected chlorotic leaf area supports a massive asexual sporulation, generally on the abaxial surface of the leaves. Severely infected plants are generally stunted and do not produce panicles. The name 'green ear' stems from the appearance of green panicles due to transformation of floral parts into leafy structures, which can be total or partial (Singh et al. 1993).

Hosts

S. graminicola is specific to pearl millet.

Geographic distribution

Several countries in Asia and Africa such as Chad, Egypt, Gambia, Malawi, Mozambique, Niger, Nigeria, Zimbabwe, Senegal, South Africa. Also Mali, Burkina Faso, Ivory Coast, Sudan, Kenya, Uganda, Tanzania, Ghana, Togo, Zambia, and a few states in USA.



PM Fig. 1. Downy mildew (*Sclerospora graminicola*) of pearl millet: A. chlorosis on leaves; B. sporangial growth on lower surface of leaf; C. oospores and D. different malformed green ears (Source: ICRISAT IB No. 37).

Biology and transmission

Sclerospora graminicola produces two types of spores, asexual spores known as sporangia, and sexual spores known as oospores. The whitish downy growth of the pathogen on the leaf surface is the “asexual phase”, followed by the “sexual phase” in which oospores are produced within the leaf tissue. Sporangioophores are short, stout, determinate and dichotomously branched structures that emerge from systemically infected leaves through stomata. Sporangia are produced on sterigmata located at the tips of the sporangioophore branches. Sporangia are hyaline, thin walled, ellipsoid or broadly elliptic and papillate. Sporangia germinate indirectly by producing zoospores. The number of zoospores per sporangium vary from 1-12. Zoospores emerge through a pore produced by the release of the operculum. Zoospores germinate and produce infection in the host. The sexual phase

starts with the formation of the oospores in the host. Mature oospores are thick-walled, spherical, and brownish yellow, 22 to 35 μm in diameter. Oospores are resting spores and can survive for 8-10 years in the field, and cause the primary infection. The pathogen is soil borne and externally seed borne for causing the disease in the succeeding crop season. Secondary spread of the disease occurs through wind borne sporangia (Singh et al. 1993).

Detection/indexing methods used in CGIAR

At ICRISAT: Pre-export field inspection and seed washing for detection of oospores.

Treatment

Dry seed treatment with metalaxyl @ 2 g a.i. kg^{-1} seed

Procedures in CGIAR in case of positive test

At ICRISAT

Incineration of infected samples in the field, and rejection of seed samples if oospores are observed under seed washing test.

EPPO protocols

Not available

General references

Singh SD, King SB and Werder J. 1993. Downy mildew disease of pearl millet. Information Bulletin No. 37. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 36 pp.

CGIAR-published references on seed health

Ahmed KM and Ravinder Reddy Ch. 1993. A Pictorial guide to the identification of seed borne fungi of sorghum, pearl millet, finger millet, chickpea, pigeon pea and groundnut. Information Bulletin No. 34. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 200 pp.

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi Arid Tropics. 80 pp.

Claviceps fusiformis Loveless.

Synonyms

Claviceps microcephala

Disease name

Ergot or Sugary disease

Importance to CGIAR Centers

High

Significance

The disease assumes special importance because grain is contaminated by grain-replacing sclerotia, which contain alkaloids that affect the health of human beings and animals. Losses in grain yield due to this disease have been estimated as high as 58-70% in F₁ hybrids (Thakur and King 1988).

Symptoms

Ergot can be identified when creamy to pinkish mucilaginous droplets called 'honey dew' ooze from the infected florets on the panicles. These droplets contain numerous asexual conidia. Within 10-15 days these droplets dry out into hard, dark brown to black structures called sclerotia. These are larger than the seed and with a pointed apex, which protrude from the florets in place of the grain.

Hosts

Cenchrus ciliaris (buffel grass) and *Panicum antidotale* (blue panic grass)

Geographic distribution

The disease is distributed in India, Pakistan, and several countries in Africa, including Botswana, Burkina Faso, Gambia, Ghana, Malawi, Niger, Nigeria, Senegal, Somalia, Tanzania, Uganda, Zambia and Zimbabwe (Thakur and King 1988).

Biology and transmission

Sclerotia are elongated to round in shape, light pink to dark brown/dark in color, hard to brittle with cavities. These germinate by producing 1-17



PM Fig. 2. Ergot (*Claviceps fusiformis*) of pearl millet: A. honeydew stage; B. sclerotial stage and C. sclerotia (Source: ICRISAT IB No. 24).

fleshy, purplish stipes, 6-26 mm long. Each stipe bears at its apex a globular capitulum, which is light to dark brown with numerous perithecial projections. Perithecia are pyriform and are embedded in the somatic tissue in the peripheral region of the capitula. Asci are interspersed with paraphyses in the perithecia and emerge through ostioles. These asci are long and hyaline with apical pores. The thread-like ascospores are hyaline and nonseptate. These cause the initial infection in the field. The fungus produces two types of conidia— macro- and micro conidia. Macroconidia are hyaline, fusiform, unicellular, and germinate by producing 1-3 germ tubes from their ends or sides. Micro conidia are hyaline, globular, unicellular, and germinate by producing only one germ tube. Both macro- and microconidia are produced on the tips of the germ tubes that are produced in chains. Disease is spread through soil borne sclerotia, sometimes as contaminated seed with sclerotia

from season to season. Secondary spread occurs through wind borne conidia and also through rain splashes and insects (Thakur and King 1988).

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection, and seed examination for detecting the sclerotia using a magnifying lens.

Treatment

Nil

Procedures in CGIAR in case of positive test

At ICRISAT: Incineration of infected samples in the field, and rejection of seed samples if found positive in seed examination.

EPPO protocols

Not available.

General references

Thakur RP and King SB. 1988. Ergot disease of pearl millet. Information Bulletin no. 24. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 24 pp.

CGIAR-published references on seed health

Ahmed KM and Ravinder Reddy Ch. 1993. A Pictorial guide to the identification of seed borne fungi of sorghum, pearl millet, finger millet, chickpea, pigeon pea and groundnut. Information Bulletin No. 34. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 200 pp.

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Pyricularia grisea (Cke.) Sacc.

Synonyms

Pyricularia penniseti, *Pyricularia setaria*.

Disease name

Blast or Leaf blast or Brown leaf spot or *Pyricularia* leaf spot

Importance to CGIAR Centers

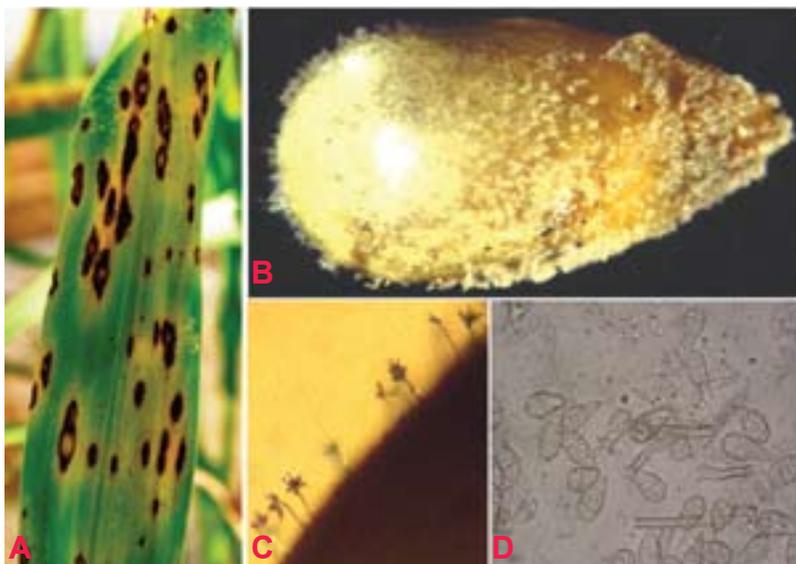
Medium

Significance

Leaf blast causes early death of seedlings under humid conditions. It causes the discoloration of the forage and there is a moderate to heavy reduction in grain and forage production.

Symptoms

Lesions on foliage are elliptical or diamond-shaped; approximately 2.5-3.5 × 1.5-2.5 mm. Lesion centers are grey and water-soaked when fresh but turn brown upon drying. Lesions are often surrounded by a chlorotic halo which will turn necrotic, giving the appearance of concentric rings.



PM Fig. 3. Blast (*Pyricularia grisea*) of pearl millet: A. leaf spot; B. mycelial growth on seed; C. conidiophore with conidia on seed (Source: ICRISAT IB No. 34) and D. conidia.

Hosts

Pennisetum glaucum (pearl millet), *Pennisetum purpureum* (napier grass).

Geographic distribution

In several countries in the world where warm and humid conditions prevail, blast appears on pearl millet over a period of time.

Biology and transmission

Conidia are pyriform, hyaline, and mostly 3-celled with a small appendage on the base cell. Conidia measure approximately $17.5\text{-}30.8 \times 5.9\text{-}8.8 \mu\text{m}$ (Mehta et al. 1953). Germination, appresoria formation, and invasion of host cells are more at 25°C (Yadava and Agnihotri 1980). Transmission occurs through wind borne conidia. It is also reported to be seed borne (Singh and Pavgi 1977).

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection and blotter test.

Treatment

Not known

Procedures in CGIAR in case of positive test

At ICRISAT: Incineration of infected samples in the field, and rejection of seed samples if found positive in blotter test.

EPPO protocols

Not available.

General references

Mehta PR, Singh B and Mathur SC. 1953. A new leaf spot disease of bajra (*Pennisetum typhoides* Staph and Hubbard) caused by a species of *Piricularia*. Indian Phytopathology 5:140-143.

Singh DS and Pavgi MS. 1977. Perpetuation of *Pyricularia penniseti* causing brown leaf spot of bajra. Indian Phytopathology 30:242-244.

Yadava RKS and Agnihotri JP. 1980. Epidemiology of *Pyricularia* leaf spot of bajra. Indian Phytopathology 33:150.

CGIAR-published references on seed health

Ahmed KM and Ravinder Reddy Ch. 1993. A Pictorial guide to the identification of seed borne fungi of sorghum, pearl millet, finger millet, chickpea, pigeon pea and groundnut. Information Bulletin No. 34. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 200 pp.

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Moesziomyces penicillariae (Bref.) Vanky.

Synonyms

Tolyposporium penicillariae, *Tolyposporium senegalense*

Disease name

Smut

Importance to CGIAR Centers

High

Significance

In general, grain loss of 5-20% has been reported (Chahal et al. 1994).

Symptoms

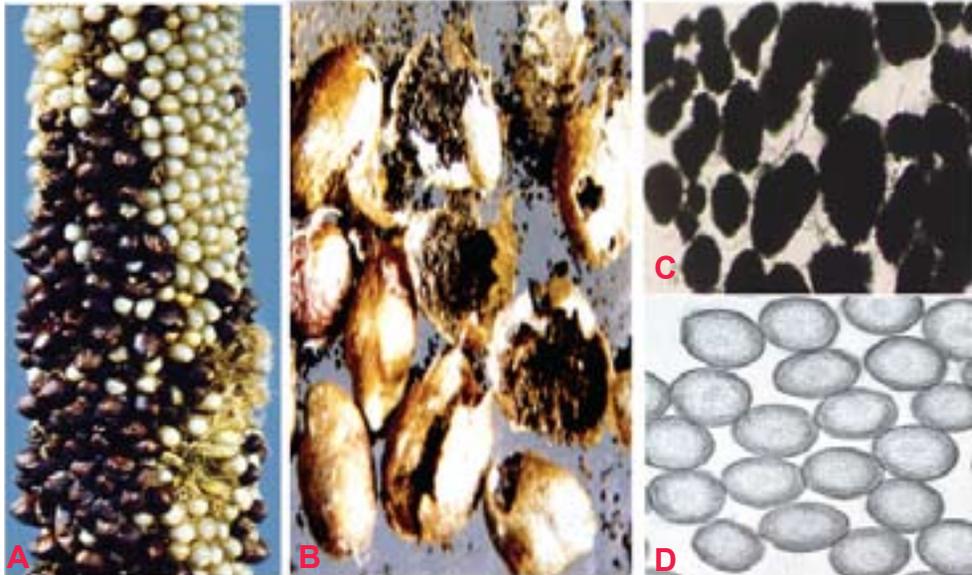
In the infected florets, the ovaries are converted into sori. The sori are larger than grains and appear as enlarged, oval to conical bodies projecting beyond the glumes in place of grains. Initially the sori are bright green but later turn brown or black. When the sori mature, the membrane ruptures and releases a brownish black mass of spores (Thakur and King 1988).

Host

Specific to pearl millet

Geographic distribution

USA, India, Zimbabwe, Senegal, Chad, Niger, Nigeria, Zambia, Sudan, Cameroon, Burkina Faso, Ghana, Mali and Tanzania (Rachie and Majmudar 1980).



PM Fig. 4. *Smut (Moesziomyces penicillariae) of pearl millet: A. smut sori on panicle (Source: ICRISAT IB No. 25); B. sori with teliospores (Source: Chahal et al. 1994); C. spore masses and D. spore balls (Source: ICRISAT IB No. 34).*

Biology and transmission

The teleutospores occur in compact, ball-like masses called spore balls. Spore balls are circular to near polyhedral. The number of teleutospores aggregated in balls varies from 200 to 1,400. Teleutospores are mostly angular to round, light brown in color and 7-12 μm in diameter. Teleutospores germinate and produce 4-celled promycelium with lateral and terminal sporidia. Variation in germination patterns of teleutospores occurs while they are held in the spore balls, and the sporidia are produced on branched hyphae in chains (Thakur and King 1988). These sporidia are the main propagules of the disease. The teleutospores are mostly wind borne for the secondary spread of the disease. Sometimes, the teleutospores are attached to the surface of the seed and act as primary source of inoculum. Teleutospores are also soil borne.

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection and seed washing test. A new method has been developed for elimination of oospores from contaminated seed.

Treatment

Spore balls (teleutospores) can be removed by salvaging the smut-contaminated seeds by mixing with sand and ethanol for 3 min while stirring.

Procedures in CGIAR in case of positive test

At ICRISAT: Incineration of infected samples in the field, and rejection of seed samples with positive test under seed washing test.

EPPO protocols

Not available.

General references

Chahal SS, Thakur RP and Mathur SB. 1994. Seed borne diseases and seed health testing of pearl millet. Copenhagen, Denmark: Danish Government Institute of Seed Pathology for developing countries. 72 pp.

Rachie KO and Majmudar JV. 1980. Pearl millet. University Park, Philadelphia, USA: Pennsylvania University press. 307 pp.

Thakur RP and King SB. 1988. Smut disease of pearl millet. Information Bulletin No. 25. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 17 pp.

CGIAR-published references on seed health

Ahmed KM and Ravinder Reddy Ch. 1993. A Pictorial guide to the identification of seed borne fungi of sorghum, pearl millet, finger millet, chickpea, pigeon pea and groundnut. Information Bulletin No. 34. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 200 pp.

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Bipolaris setariae (Saw.) Shoem.

Synonyms

Drechslera setariae, *Cochliobolus setariae*

Disease name

Leaf spot or leaf blight

Importance to CGIAR Centers

Medium

Significance

Infection at seedling stage results in death of plants and reduces crop stand in the field (Shetty et al. 1982). Infected plants produce discolored grains and seed of poor quality (Kameswara Rao et al. 2002).

Symptom

Foliar symptoms vary, as brown flecks, fine linear streaks, small oval spots; large irregular oval, oblong, or almost rectangular spots measuring 1-10 × 0.5-3 mm. Large fusiform lesions are sometimes produced. Lesions may expand and coalesce. Lesions may be solid dark brown but usually become tan or grayish brown with distinct dark brown border (Luttrell 1954).

Host

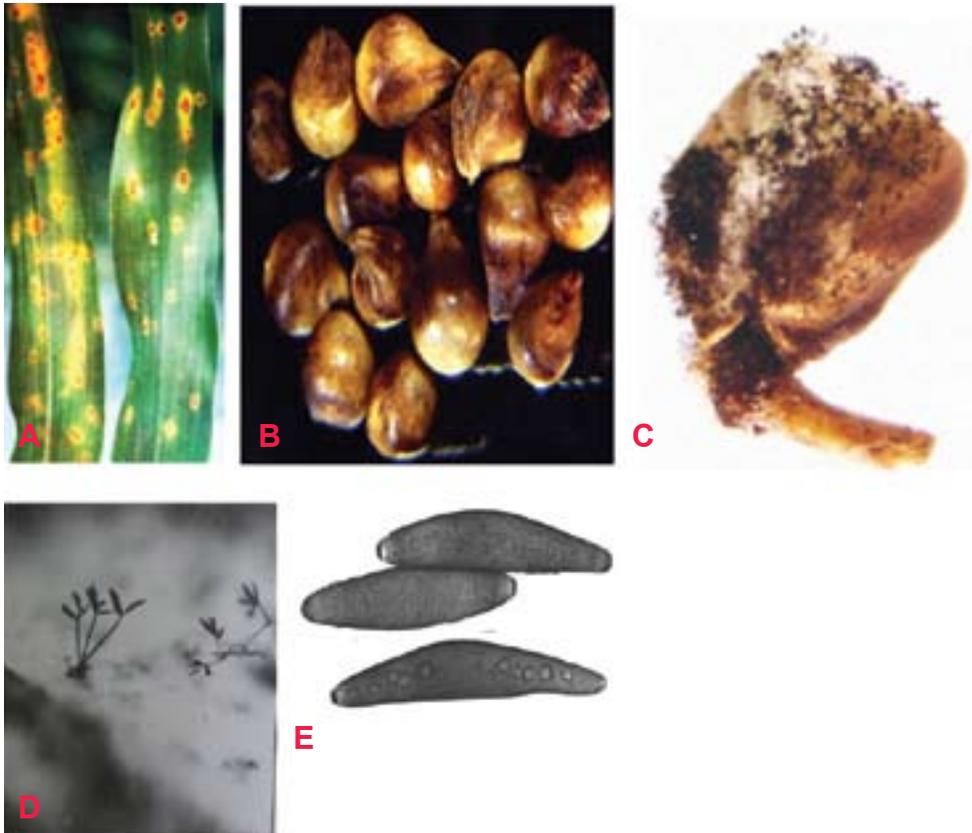
Pennisetum glaucum (pearl millet), *Pennisetum purpureum* (napier grass), *Panicum fasciculatum* Swartz (browntop millet), *Saccharum officinarum* (sugarcane), *Zea mays* (maize), *Sorghum bicolor* (sorghum), *Paspalum scrobiculatum* (little millet), *Panicum miliaceum* (kodo millet), *Hordeum vulgare* (barley), *Triticum aestivum* (wheat), *Avena sativa* (oats), *Imperata cylindrica* (Cogongrass) and *Cynodon dactylon* (bermudagrass).

Geographic distribution

Drechslera setariae is worldwide in distribution including USA, Hawaii, India, Japan, Zimbabwe and Zambia.

Biology and transmission

The mycelium is dark and individual hyphae are irregularly branched with rough surfaces. Conidiophores are mostly hypophyllous, simple, 2-8 septate,



PM Fig. 5. Leaf spot (*Bipolaris setariae*) of pearl millet: A. leaf spots (Source: Chahal et al. 1994); B. infected seed; C. fungal growth on seed; D. conidiophores with conidia and E. conidia (Source: ICRISAT IB No. 34).

erect, cylindrical, brown, slightly swollen at the base and geniculate at the apex. They are 72-199 μm in length and 5.6 to 9 μm in width. Conidia are acrogenous, 39-12 μm , 4-10 septate, ellipsoid, straight or slightly curved, pale to moderately dark brown and thin walled (Chahal et al. 1994). The pathogen is both soil borne and seed borne.

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection and blotter test (Girish et al. 2001)

Treatment

Rejection of the seed samples

Procedures in CGIAR in case of positive test

At ICRISAT: Incineration of infected samples in the field, and rejection of seed samples if found positive under blotter test.

EPPO protocols

Not available.

General references

Chahal SS, Thakur RP and Mathur SB. 1994. Seed borne diseases and seed health testing of pearl millet. Copenhagen, Denmark: Danish Government Institute of Seed Pathology for developing countries. 72 pp.

Girish AG, Singh SD, Chakrabarty SK, Prasada Rao RDVJ, Surender A, Varaprasad KS and Bramel PJ. 2001. Seed microflora of five ICRISAT mandate crops. *Seed Science and Technology Journal* 29:429-443.

Kameswara Rao N, Bramel Cox P, Reddy KN, Singh SD, Girish AG, Appa Rao S and Mahalakshmi V. 2002. Optimizing seed quality during germplasm regeneration in pearl millet. *Genetic Resources and Crop Evolution* 49:153-157. Netherlands: Kluwer Academic Publishers.

Luttrell ES. 1954. Diseases of pearl millet in Georgia. *Plant Disease Reporter* 38:507-514.

Shetty HS, Mathir SB, Neergaard P and Safeeula KM. 1982. *Drechslera setariae* in Indian pearl millet seeds, its seed-borne nature, transmission and significance. *Transactions of the British Mycological Society* 78:170-173.

CGIAR-published references on seed health

Ahmed KM and Ravinder Reddy Ch. 1993. A Pictorial guide to the identification of seed borne fungi of sorghum, pearl millet, finger millet, chickpea, pigeon pea and groundnut. Information Bulletin No. 34. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 200 pp.

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Insects

Plodia interpunctella Hubner.

Synonyms

Not known

Common name

Indian Meal Moth

Importance to CGIAR Centers

High

Significance

Indian Meal Moth is a common grain-feeding pest. It can infest a variety of products and is perhaps the most economically important insect pest of processed food. (www.elsevier.com/retrieve/pii). Infestations of *P. interpunctella* can cause direct product loss and indirect economic costs through pest control costs, quality losses and consumer complaints (Phillips et al. 2000).

Symptoms

Plodia interpunctella is an external feeder. The larvae continuously spin a silken web both inside and on top of the grain surface, and feed within the web. The webbing contains larval excreta (frass) and exuvia (cast skins), and gives an unpleasant odor to the infested commodity. The infested commodity is sometimes covered on the surface with a thick mat of silken webbing (Mohandass et al. 2007).



PM Fig. 6. Indian Meal Moth (*Plodia interpunctella*) of pearl millet (Source: ICRISAT IB No. 12).

Biology and transmission

Female moths lay between 60 and 400 eggs (Lyon 1991) on a grain surface. The eggs are ordinarily smaller than 0.5 mm and not sticky. They hatch in 2 to 14 days. The moth larvae are off-white with brown heads. When these larvae mature, they are usually about 12 mm long. The larval stage lasts from 2 to 41 weeks, depending on the temperature. Adult moths are 8-10 mm long with 16-20 mm wingspans. The outer half of their forewings is bronze, copper or dark gray in color, while the upper half are yellowish-gray, with a dark band at the intersection between the two. The entire life cycle may range from 30 to 300 days (Mohandass et al. 2007).

Hosts

Arachis hypogaea (groundnut), *Oryza sativa* (rice), *Prunus* (stone fruit), stored products (dried stored products), *Triticum aestivum* (wheat), *Zea mays* (maize), *Avena sativa* (oats), *Corylus*, *Helianthus annuus* (sunflower), *Hordeum vulgare* (barley), *Juglans regia* (Carpathian walnut), *Pistacia vera* (pistachio), *Prunus dulcis* (almond) and *Theobroma cacao* (cocoa).

Geographic distribution

Plodia interpunctella is cosmopolitan in distribution especially in warm climates. In cool temperate countries, it can survive in heated buildings.

Detection/indexing methods used in CGIAR

The primary detection method is through pheromone-based trapping of males (Phillips et al. 2000). The pheromone commonly referred to as 'ZETA' was one of the first commercial pheromones for stored-product insects, and the response of males to this pheromone has been well documented.

Treatment at ICRISAT

Fumigation with methyl bromide @ 32 g m⁻³ for 4 h followed by seed treatment with chlorpyrifos at 3 g kg⁻¹ seed (Ghanekar et al. 1996, Toews et al. 2006).

Procedures in CGIAR in case of positive test

At ICRISAT: Infested samples are rejected in case of positive test.

EPPO protocols

Not available.

General references

Ghanekar AM, Ranga Rao GV, Murthy KS, Surender A and Shaik Babu Saheb. 1996. Seed protectants for healthy exports. *Indian Journal of Plant Protection* 24:37-43.

Lyon WF. "Fact Sheet: Indianmeal Moth". Ohio State University. <http://ohioline.osu.edu/hyg-fact/2000/2089.html>. Retrieved on 2006-09-07.

Mohandass S, Arthur FH, Zhu KY and Throne JE. 2007. Biology and management of *Plodia interpunctella* (Lepidoptera: Pyralidae) in stored products. *Journal of Stored Products Research* 43:302-311.

Phillips TW, Berbert RC and Cuperus GW. 2000. Post-harvest integrated pest management. Pages 2690–2701 in *Encyclopedia of Food Science and Technology*, 2nd ed (Francis FJ, ed.). New York: Wiley Inc.

Toews MD, Campbell JF and Arthur FH. 2006. Temporal dynamics and response to fogging or fumigation of stored-product Coleoptera in a grain processing facility. *Journal of Stored Products Research* 42:480-498.

CGIAR-published references on seed health

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Sitotroga cerealella Olivier.

Synonyms

Tinea hordei

Common name

Angoumois Grain Moth

Importance to CGIAR Centers

High

Significance

Grain losses due to grain moth infestation have been recorded up to 50%. High temperature and lack of storage hygiene are the major factors resulting in insect infestation (Seifelnasr 1992).

Symptoms

Infestation can begin in the fields. In storage, the infestation is confined to the upper layer of the grains. The larva bores into the grain and remains there until it emerges as an adult from round emergence holes. The infested grain is completely hollowed out and filled with larval excreta.

Hosts

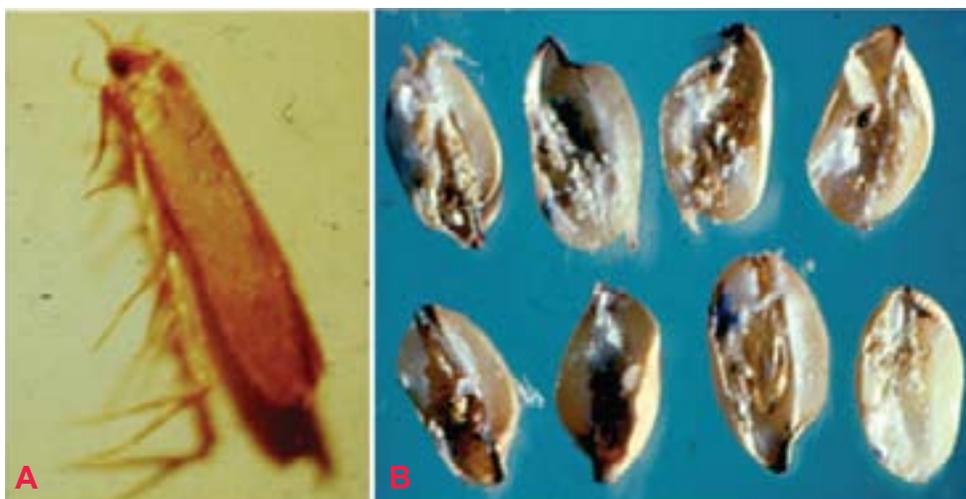
Avena sativa (oats), *Hordeum vulgare* (barley), *Oryza sativa* (rice), *Sorghum bicolor* (sorghum), *Secale cereale* (rye), *Triticum aestivum* (wheat), *Triticum spelta* (spelt) and *Zea mays* (maize).

Geographic distribution

It is cosmopolitan in distribution. It is one of the primary pests of stored cereal grain, but is also known to attack maize, wheat and barley in the storage godowns.

Biology

The female can lay up to 400 eggs that are deposited indiscriminately on or between the grains, on the panicles in the field, or in the storage area. The egg is white and oval, but soon turns bright red and hatches within a week. The tiny larva crawls about searching for a comparatively weak spot through



PM Fig. 7. Angoumois Grain Moth (*Sitotroga cerealella*) of pearl millet: A. adult and B. infested grains (Source: ICRISAT IB No. 12).

which it enters the grain, and feeds on the internal contents. The larval period is 2-3 weeks. The moth emerges within a week (Teetes et al. 1983).

Detection/indexing methods used in CGIAR

At ICRISAT: Dry seed examination

Treatment

Fumigation with methyl bromide @ 32 g m⁻³ for 4 h followed by seed treatment with chlorpyrifos at 3 g kg⁻¹ seed (Ghanekar et al. 1996).

Procedures in CGIAR in case of positive test

At ICRISAT: Highly infested samples are rejected

EPPO protocols

Not available.

General references

Ghanekar AM, Ranga Rao GV, Murthy KS, Surender A and Shaik Babu Saheb. 1996. Seed protectants for healthy exports. Indian Journal of Plant Protection 24:37-43.

Seifelnasr YE. 1992. Farmers' perceptions on management practices of insect pests on stored sorghum in southwestern Ethiopia. Crop Protection 26:1817-1825.

Teetes GL, Seshu Reddy KV, Leuschner K and House LR. 1983. Sorghum insect identification handbook. Information Bulletin No.12. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 125 pp.

CGIAR-published references on seed health

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Prostephanus truncatus Horn.

Synonyms

Dinoderus truncatus

Common name

Larger grain borer

Importance to CGIAR Centers

High

Significance

The grain damage by borer ranges from 19% to 38% and the mean dry weight loss between 5% and 20%. The quantity of grain dust produced weighed between 6 to 29 g kg⁻¹ grains (Shires 1977, Mailafiya et al. 2008).

Symptoms

Adults attack stored seed/grain with intact sheaths by boring into the base of the seed, making neat round holes. As they tunnel from grain to grain, large quantities of grain dust is generated. Adult females lay eggs in chambers bored at right angles to the main tunnels.

Hosts

Manihot esculenta (cassava), stored products (dried stored products), *Zea mays* (maize), *Dioscorea* (yam) and *Triticum aestivum* (wheat).

Geographic distribution

Prostephanus truncatus is indigenous in Central America, tropical South America, and the extreme south of the



PM Fig. 8. Larger Grain Borer (*Prostephanus truncatus*) of pearl millet (Source: www.agrsci.dk/plb/bembi/africa.com).

USA as a major pest. It is also distributed in Africa and Europe, and has restricted distribution in India (Farrell 2000).

Biology

The adult has the typical cylindrical bostrichid shape with body length of 3-4.5 mm. The declivity is flattened and steep, and has many small tubercles over its surface. The limits of the declivity, apically and laterally, are marked by a carina. The antennae are 10-segmented and have a loose three-segmented club; the 'stem' of the antenna is slender and clothed with long hairs and the apical club segment is as wide as, or wider than, the preceding segments. The larvae are white, fleshy and sparsely covered with hairs. They are parallel-sided, ie, they do not taper. The legs are short and the head capsule is small relative to the size of the body (Farrell 2000).

Detection/indexing methods used in CGIAR

At ICRISAT: Not detected

Treatment

Not suggested due to non-detection of the pest

Procedures in CGIAR in case of positive test

At ICRISAT: Infested samples are rejected

EPPO protocols

Not available.

General references

Farrell G. 2000. Dispersal, phenology and predicted abundance of the larger grain borer in different environments. *African Crop Science Journal* 8:337–343.

Mailafiya DM, Ayertey JN and Cudjoe AR. 2008. Damage and weight loss potential of *Prostephanus truncatus* Horn (Coleoptera: Bostrichidae) on sorghum grain: implication to cereal grain storage in sub-Saharan Africa. *International Journal of pure and applied sciences* 2:28-35.

Shires SW. 1977. The ability of *Prostephanus truncatus* (Horn) to damage and breed on several food commodities. *Journal of Stored Products Research* 13:205-208.

CGIAR-published references on seed health

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Tribolium castaneum Herbst.

Synonyms

Not known

Common name

Red Flour Beetle

Importance to CGIAR Centers

High

Significance

Important in stored pearl millet grain in several countries.

Symptoms

Infestation by adult beetles can be readily observed by the tunnels they leave when they move through the flour and other granular food products. Damage is particularly serious in grains such as rice and wheat, which have either been dehusked or processed into other products. When infestation is severe, these products turn grayish-yellow and become moldy, with a pungent odor. Infestation may also be apparent by the appearance of adults on the surface of the grains (Teetes et al. 1983).

Hosts

Arachis hypogaea (groundnut), *Avena sativa* (oats), *Bertholletia excelsa* (Brazil nut), *Hordeum vulgare* (barley), *Juglans* (walnuts), *Culinaris* (lentil), *Oryza sativa* (rice), *Phaseolus* (beans), *Phaseolus lunatus* (lima bean), *Pisum sativum* (pea), *Prunus dulcis* (almond), *Secale cereale* (rye), *Triticum* (wheat), *Triticum spelta* (spelt) and *Zea mays* (maize).



PM Fig. 9. Red Flour Beetle (*Tribolium castaneum*) of pearl millet: A. adult (Source: ICRISAT IB No. 12) and B. damaged grains.

Geographic distribution

T. castaneum is cosmopolitan in distribution, found infesting stored grain, seeds, flour, dried fruits and nuts (Teetes et al. 1983).

Biology and transmission

The adult is 2.3-4.4 mm long, rather flat, oblong and chestnut-brown (reddish-brown). It lays about 450 eggs in stored grain. The eggs are minute, cylindrical and white. The incubation period lasts for 5-12 days. The yellowish-white cylindrical grub is covered with fine hairs. The pupa is naked (without a cocoon), yellowish-white, becoming brown later and adults emerge in 3-7 days (Teetes et al. 1983).

Detection/indexing methods used in CGIAR

At ICRISAT

X-ray radiography is used for suspected samples because it offers a non-destructive test of seed samples. Dry seed is examined using a magnifying lens to separate the infested seed.

Treatment

Fumigation of the samples with methyl bromide by 32 gm^{-3} for 4 h followed by seed treatment with chlorpyrifos at 3 g kg^{-1} seed (Ghanekar et al. 1996).

Procedures in CGIAR in case of positive test

At ICRISAT: Rejection of infested seed samples in case of positive test

EPPO protocols

Not available.

General references

Ghanekar AM, Ranga Rao GV, Murthy KS, Surender A and Shaik Babu Saheb. 1996. Seed protectants for healthy exports. Indian Journal of Plant Protection 24:37-43.

Teetes GL, Seshu Reddy KV, Leuschner K and House LR. 1983. Sorghum insect identification handbook. Information Bulletin No. 12. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 125 pp.

CGIAR-published references on seed health

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Chickpea (*Cicer arietinum* L.)

Bacterium

Pseudomonas syringae Van Hall pv. *pisi* (Sackett) Young et al.

Synonyms

Pseudomonas pisi

Disease name

Bacterial blight

Importance to CGIAR Centers

Medium

Significance

Severe infections (reaching 100% disease incidence) and substantial crop losses have been reported from winter-sown peas in southern France, New Zealand and South Africa (Boelema 1972; Taylor 1972). The disease as such, however, does not appear to be of great economic importance in other parts of the world.

Symptoms

Symptoms appear on all aerial plant parts, including stipules, leaflets, petioles, stems, tendrils, flower buds and pods, but those on stems and stipules are most characteristic. Symptoms usually appear on the stem near the soil as water-soaked and later olive-green to purple-brown spots. The infection extends upwards to the stipules and leaflets, where veins turn brown to black and adjacent tissues become diseased in a fan-like pattern. The interveinal tissues may become water soaked and then yellowish to brown, finally drying out and becoming papery. Lesions on leaflets and pods begin as small, round, oval or irregular dark-green water-soaked spots at first, and later enlarge and coalesce but are sharply defined by the veins. Cream-colored bacterial ooze may be found on the lesion surface that, on drying, gives a glossy appearance. The leaflets later become yellowish and the spots brown and papery. Ripening pods become twisted and dry, lesions on them sunken and greenish-brown. Lesions on the pod may be limited to a narrow band on the sutures. Infected seeds show a water-soaked spot near

the hilum and/or are shrivelled, with a brown-yellow discoloration. Infection often takes place on sepals, spreading to the flowers, and flower buds may be killed before they open.

Hosts

Peas, including *Pisum sativum* var. *arvense*, are the principal hosts. Natural infection has also been found on *Lablab purpureus* (poor man's bean), *Lathyrus latifolius* (everlasting pea), *L. odoratus* (garden sweet pea) and *Vicia benghalensis* (purple vetch).

Geographic distribution

Bacterial blight is worldwide in distribution (Bulgaria, Greece, Hungary, Italy, Romania, USSR and Yugoslavia). Sporadic outbreaks have been recorded from Denmark, France, Germany, Morocco, the Netherlands, Switzerland, UK, Israel, Lebanon, India, Indonesia, Israel, Japan, Nepal, Kenya, Malawi, Morocco, South Africa, Tanzania, Zimbabwe, Bermuda, Canada, Mexico and USA).

Biology and transmission

Pseudomonas syringae pv. *psii* is a motile, gram-negative, non-spore-forming rod, 0.7×2-3 µm, with one to five polar flagella. Disease develops more readily on soils with high moisture content. Infections can occur through contact of diseased and healthy foliage and insects may have a role in transmission. The bacterium can survive on or within seeds for at least 10 months (Skoric 1927) and for several months on diseased plant debris in the field (Harris 1964).

Detection/indexing methods used in CGIAR

Detection of the pathogen in seeds is usually performed by soaking seeds in buffer at low temperature (4°C) for 4-16 h and subsequent isolation from the (centrifuged) soaking solution. For isolation from diseased tissues and seeds, King's B medium can be used, with supplement of boric acid, cephalixin and cycloheximide, if necessary (Mohan and Schaad 1987).

Treatment

Not known since it has not been detected at ICRISAT

Procedures in CGIAR in case of positive test

At ICRISAT: Incineration of the infected crop and rejection of the seed sample

EPPO protocols

EPPO recommends (OEPP/EPPO 1990) that pea seeds should come from a field or area free from *P. syringae* pv. *pisi*, or else that the seed crop should have been inspected. However, seed-testing techniques are now available (see Detection and inspection methods) that may prove useful.

General references

Boelema BH. 1972. Bacterial blight (*Pseudomonas pisi* Sackett) of peas in South Africa, with special reference to frost as a predisposing factor. Mededelingen Landbouwhogeschool Wageningen 72:1-87.

Harris DE. 1964. Bacterial blight of peas. Journal of Agriculture, Victoria Department of Agriculture 62:276-280.

Mohan SK and Schaad NW. 1987. Semiselective agar medium for isolating *Pseudomonas syringae* pv. *syringae* and pv. *phaseolicola* from bean seed. Phytopathology 77:1390-1395.

OEPP/EPPO. 1990. Specific quarantine requirements. EPPO Technical Documents No. 1008.

Skoric V. 1927. Bacterial blight of peas; overwintering, dissemination and pathological histology. Phytopathology 17:611-628.

Taylor JD. 1972. Races of *Pseudomonas pisi* and sources of resistance in field and garden peas. New Zealand Journal of Agricultural Research 15:441- 447.

CGIAR-published references on seed health

Nil

Fungi

Ascochyta rabiei (Pass.) Labr.

Synonyms

Dydimella pinedos, *Dydimella rabiei*

Disease name

Leaf blight or Stem blight or Pod blight or Ascochyta blight

Importance to CGIAR Centers

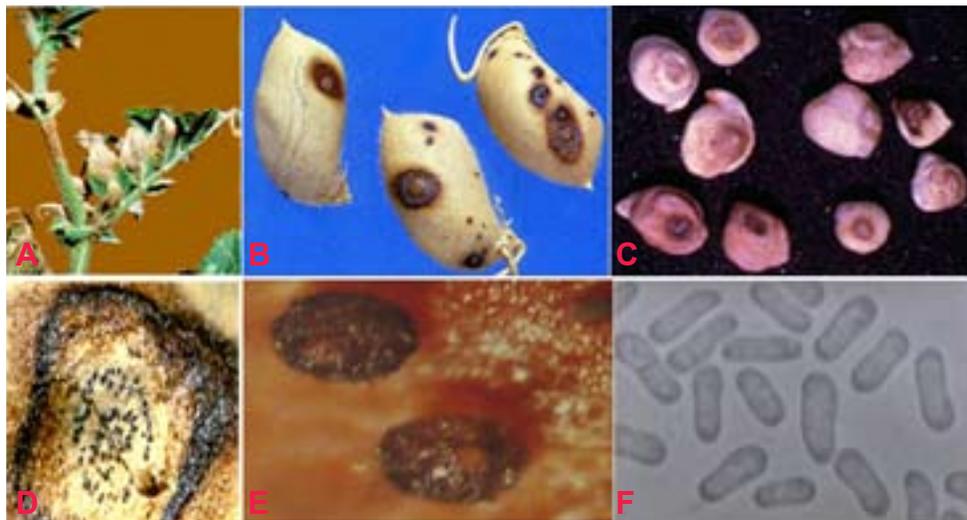
Medium

Significance

Yield losses have been reported up to 70% (Hagedorn 1984).

Symptoms

Symptoms appear on all aerial parts of the plants such as leaf, stem and pods. Disease appears at the early stage of the seedlings as dark brown lesions at the base of the stem. Affected seedlings may collapse and die



CP Fig. 1. *Ascochyta* blight (*Ascochyta rabiei*) of chickpea: symptoms on A. plant; B.pods; C. seeds; D. pycnidia on seed; E. pycnidia and F. conidia (Source: ICRISAT IB Nos. 28 and 34).

(damping-off). Initial symptoms include several water-soaked necrotic spots on the younger leaves of all the branches. At flowering and podding time symptoms appear as blighted patches and pycnidia are seen on the blighted patches. On the stem and petioles the lesions are obovate or elongate, and bear pycnidia. Fully developed lesions on pods are usually round, 0.5 cm in diameter, usually zonate and dark brown, without a definite margin. They may be circular or irregular in shape, with a darker centre. Infection spreads via the petiole to the stem causing girdling lesions. Flowers become spotted and pods poorly filled. Infection leads to post- and pre-emergence damping off, death or dwarfing of older plants and discoloration and shrinkage of seed (Nene et al. 1991).

Hosts

Pisum sativum (pea), *Cicer arietinum* (chickpea), *Lathyrus* (Vetchling), *Vigna mungo* (black gram), *Vigna umbellata* (Rice-bean) and *Vigna unguiculata* (cowpea).

Geographic distribution

Ascochyta blight is worldwide in distribution.

Biology and transmission

Pycnidia on stems, leaves, pods and seeds are solitary or gregarious, initially immersed becoming erumpent, dark brown to globose, black, 100×200 µm diameter, opening by papillate ostioles. Conidia are hyaline, slightly constricted at the septa, ellipsoid, guttulate, 1 septate (sometimes 2 or 3 septate), 8-16 × 3-4.5 µm. Asci are cylindrical to subclavate, short stipitate or sessile, 8-spored, 50-80 × 10-15 µm. Ascospores are irregularly biseriolate, hyaline, ellipsoid, guttulate, constricted at the septum, rounded at the ends, 12-18 × 4-8 µm. (Haware et al. 1986). Disease transmission occurs by water (conidia), air (ascospores), soil and host debris (in which the pathogen survives between crops) and also through seed.

Detection/indexing methods used in CGIAR

Keep the surface sterilized seeds (with 1% sodium hypochlorite for 10 min) on potato dextrose agar and incubate for 7 days at 22°C with 12 h photoperiod. Examine for typical colony characteristic of *A. rabiei* (Haware et al. 1986).

Recommendation

Serological test (Faris-Mokaiesh et al. 1995) involving DAS-ELISA suitable for the detection and quantification of *A. rabiei* in infected pea seeds.

Treatment

Seed treatment with thiabendazole at 3g kg⁻¹ seed is recommended (Reddy and Kababeh 1984).

Procedures in CGIAR in case of positive test

At ICRISAT: So far it has not been detected

EPPO protocols

Not known

General references

Faris-Mokaiesh S, Corbiere R, Lyons NF and Spire D. 1995. Evaluation of an enzyme-linked immunosorbent assay for detection of *Mycosphaerella pinodes* in pea seeds. *Annals of Applied Biology* 127:441-455.

Hagedorn DM. 1984. *Compendium of pea diseases*. St. Paul, MN. USA: APS Press.

Haware MP, Nene YL and Mathur SB. 1986. *Seedborne diseases of chickpea*. Technical Bulletin No. 1. Copenhagen, Denmark: Danish Government Institute of Seed Pathology for developing countries. 32 pp.

Nene YL, Reddy MV, Haware MP, Ganekar AM and Amin KS. 1991. *Field diagnosis of chickpea diseases and their control*. Information Bulletin No. 28, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 52 pp.

Reddy MV and Kababeh S. 1984. Eradication of *Ascochyta rabiei* from chickpea seed with thiabendazole. *International Chickpea Newsletter* 10:17-18.

CGIAR-published references on seed health

Ahmed KM and Ravinder Reddy Ch. 1993. *A Pictorial guide to the identification of seed borne fungi of sorghum, pearl millet, finger millet, chickpea, pigeonpea and groundnut*. Information Bulletin No. 34. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 200 pp.

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. *Germplasm exchange and quarantine of ICRISAT mandate crops*. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Fusarium oxysporum f. sp. *ciceri* (Padwick) Snyder & Hans.

Synonyms

Nil

Disease name

Fusarium wilt

Importance to CGIAR Centers

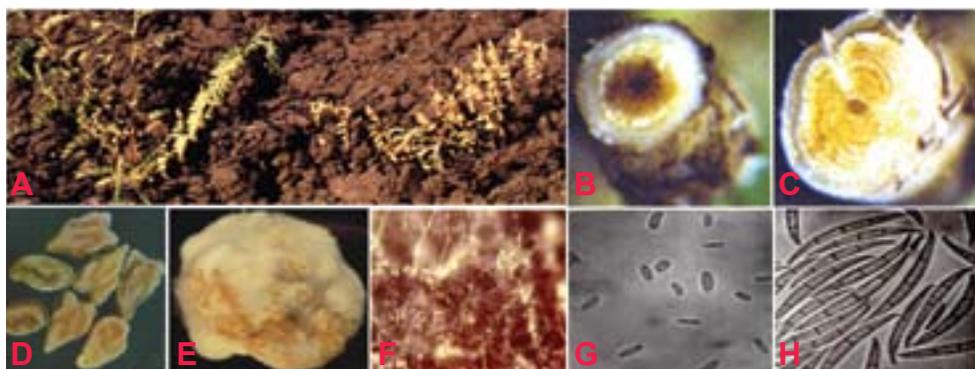
Low

Significance

Fusarium wilt is prevalent in most chickpea-growing countries and is a major disease of economic importance in Asian countries. Seeds harvested from infected plants are lighter and duller than those from healthy plants (Haware and Nene 1980).

Symptoms

Chickpea foliage develops a greyish-green chlorosis, typically affecting lower leaves first and extending up the plant. Leaves eventually take on a dull-yellow color, wilt and the plant collapses and dies. Adult plants wilt, with their petioles and rachises drooping. In some cases, there may be leaf vein clearing before wilt begins. Internally, the xylem tissues stain dark-brown to almost black. Wilting may initially affect only one side of the plant.



CP Fig. 2. *Fusarium wilt* (*Fusarium oxysporum* f. sp. *ciceri*) of chickpea: A. wilting symptom; B. and C. xylem discoloration in infected plant; D. infected seeds; E. mycelial growth on seed; F. mycelium with conidia (powdery dots); G. microconidia and H. macroconidia (Source: ICRISAT IB Nos. 28 and 34).

Hosts

Cicer arietinum (chickpea), *Cajanus cajan* (pigeonpea), *Lens culinaris* ssp. *culinaris* (lentil) and *Pisum sativum* (pea).

Geographic distribution

Fusarium wilt is a serious disease of chickpea in India, Iran, Pakistan, Nepal, Burma, Spain, Tunisia, Mexico, Morocco, Algeria and Syria (Haware 1990).

Biology and transmission

F. oxysporum f.sp. *ciceri* can survive for many years either in soil as chlamydospores or as a saprobe in plant debris. Microconidia are borne on simple short conidiophores arising laterally on the hyphae. These are oval to cylindrical, straight to curved, and $5-15 \times 2-5 \mu\text{m}$, collecting in small slimy droplets. Macroconidia are 1-7 (mostly 3-5) septate, $25-55 \times 2.5-6 \mu\text{m}$, fusiform, curved, with a tapering, pointed, sometimes hooked, apical cell and distinctly pedicellate basal cell. Macroconidia arising from phialides are similar to those forming microconidia except that they are often in clusters, borne on irregularly branching cells. In some strains macroconidia are sparse, in others, abundantly produced in pinkish sporodochial conidiomata. Chlamydospores are globose, hyaline $7-15 \mu\text{m}$ diameter, usually forming abundantly in mature colonies, terminal or intercalary, single or in small groups or chains. Conidia are dispersed by water flow, rain splash and by movement of infected soil or plant material, especially seed. Following infection of host roots, the fungus crosses the cortex and enters the xylem tissues. It then spreads rapidly up through the vascular system, becoming systemic in the host tissues, and may directly infect the seed.

Detection/indexing methods used in CGIAR

At ICRISAT

Pre export field inspection and blotter test. For confirmation of the fungus, agar plate method is used. The agar plate method includes surface sterilization of the seeds with 2.5% sodium hypochlorite for 2 min, plating the seeds on Czapeks agar (amended with 500 mg PCNB, 25g malachite green, 750 mg strepto-penicillin, and 2 g yeast extract/liter), and incubating the seeds at 20°C under a 12 h NUV/12 h dark light cycle for 8 days (Haware et al. 1978).

Treatment

Seed treatment with 1.5 g kg⁻¹ seed with benomyl + thiram (1:1 vol.) (Haware et al. 1978)

Procedures in CGIAR in case of positive test

Rejection of the infected seed sample

EPPO protocols

Not available

General references

Haware MP. 1990. Fusarium wilt and other important diseases of chickpea in Mediterranean area. CIHEAM-Options Mediterraneennes Seminar Series No.9:61-64.

Haware MP and Nene YL. 1980. Influence of wilt at different stages on the yield loss in chickpea. Tropical Grain Legume Bulletin 19:38-44.

Haware MP, Nene YL and Rajeshwari R. 1978. Eradication of *Fusarium oxysporum f. sp. ciceri* transmitted in chickpea seed. Phytopathology 68:1364-1367.

CGIAR-published references on seed health

Ahmed KM and Ravinder Reddy Ch. 1993. A Pictorial guide to the identification of seed borne fungi of sorghum, pearl millet, finger millet, chickpea, pigeonpea and groundnut. Information Bulletin No. 34. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 200 pp.

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Phomopsis longicolla Hobbs.

Synonyms

Nil

Disease name

Phoma blight

Importance to CGIAR Centers

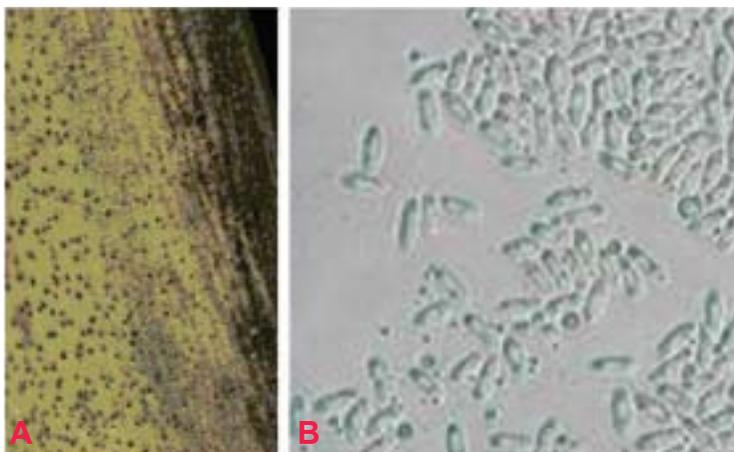
Low

Significance

Seed germination can be reduced by as much as 90% (Kmetz et al. 1978) since it is a seed borne disease. About 40% yield losses have been reported when infected seeds were planted (Wall et al. 1983).

Symptoms

Infected seedlings become blighted and die. Those that survive have colorless or bright red to orange cotyledonary lesions that range in size from pinpoint to lesions that cover the whole cotyledon. Small reddish brown streaks, 1.5 cm long, form on hypocotyls. Senescent tissues are covered with minute, black pycnidia, usually arranged linearly on stems. Pycnidia are scattered on dry, poorly developed pods. They may also occur on mature



CP Fig. 3. *Phoma blight* (*Phomopsis longicolla*) of chickpea: A. lesion with pycnidia and B. pycnidiospores (Source: www.bspp.org.uk/publications/newdisease).

Pods. Severely infected seeds are shriveled, badly cracked, and frequently covered by white mycelium. Infected seeds could be a means of introducing the pathogen into new areas (Garzonio and McGee 1983).

Hosts

Glycine max (soybean), *Abelmoschus esculentus* (okra), *Abutilon theophrasti* (China jute), *Allium cepa* (onion), *Allium sativum* (garlic), *Arachis hypogaea* (groundnut), *Alysicarpus vaginalis* (alyce clover), *Capsicum frutescens* (chilli), *Kummerowia striata* (common lespedeza), *Lotus corniculatus* (bird's-foot trefoil), *Lupinus* (lupins), *Lycopersicon esculentum* (tomato), *Phaseolus acutifolius* (tepariy bean), *Phaseolus coccineus* (bean (runner)), *Phaseolus lunatus* (lima bean), *Phaseolus vulgaris* (common bean), *Pisum sativum* (pea), *Trifolium pratense* (purple clover) and *Vigna unguiculata* (cowpea).

Geographic distribution

Widely distributed in Asia, Africa, Europe, America and Oceania.

Biology and transmission

Fungal colonies are colorless, with black, spreading stromata. Pycnidia are black, solitary or aggregated, unilocular or multilocular, with prominent necks more than 200 µm long. Alpha conidia are hyaline, ellipsoid to fusiform, guttulate, and 5-9 × 1.5-3.5 µm. Beta conidia, which are rarely formed, are hyaline and filiform, sometimes curved at the end.

Detection/indexing methods used in CGIAR

At ICRISAT: So far it has not been detected at ICRISAT

Treatment

So far not available

Procedures in CGIAR in case of positive test

Incineration of the infected crop and rejection of the infected seed samples

EPPO protocols

Not available

General references

Kmetz KT, Schmitthenner AF and Ellett CW. 1978. Soybean seed decay: prevalence of infection and symptom expression caused by *Phomopsis* sp., *Diaporthe phaseolorum* var. *sojae*, and *D. phaseolorum* var. *caulivora*. *Phytopathology* 68:836-840.

Wall MT, McGee DC and Burris JS. 1983. Emergence and yield of fungicide-treated soybean seed differing in quality. *Journal of Agronomy* 75:969-973.

Garzonio DM and McGee DC. 1983. Comparison of seeds and crop residues as sources of inoculum for pod and stem blight of soybeans. *Plant Disease* 67:1374-1376.

CGIAR-published references on seed health

Ahmed KM and Ravinder Reddy Ch. 1993. A Pictorial guide to the identification of seed borne fungi of sorghum, pearl millet, finger millet, chickpea, pigeonpea and groundnut. Information Bulletin No. 34. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 200 pp.

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Phoma medicaginis Malbr. & Roum.

Synonyms

Nil

Disease name

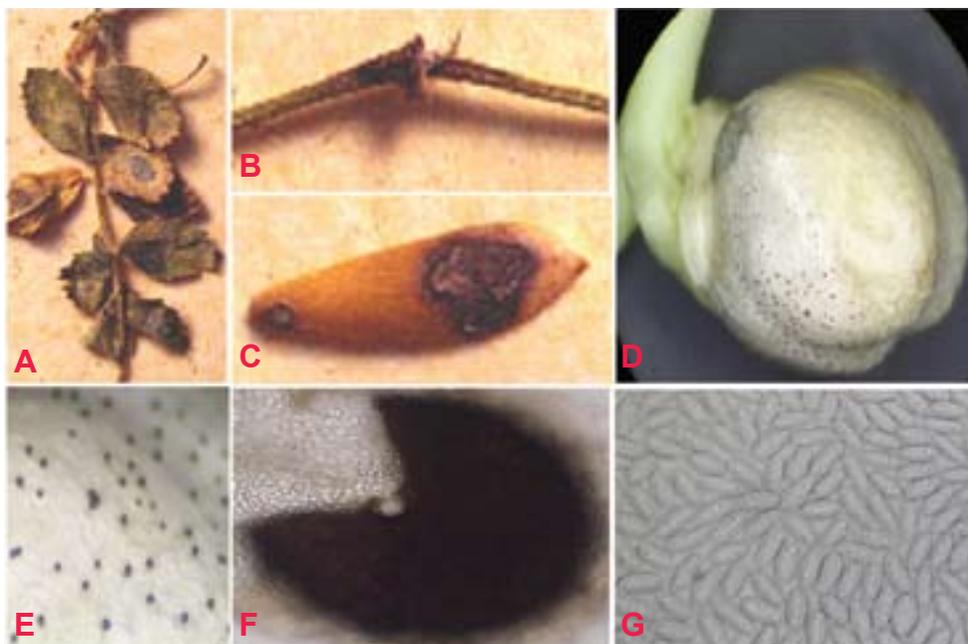
Phoma leaf blight, Chickpea leaf spot

Importance to CGIAR Centers

High

Significance

Phoma leaf blight is of minor importance in India and elsewhere in the world (Haware and Nene 1981).



CP Fig. 4. Leaf spot (*Phoma medicaginis*) of chickpea: symptoms on A. leaf; B. twig; C. pod (Source: ICRISAT IB No. 28); D. pycnidia embedded in seed; E. pycnidia; F. mature pycnidium releasing pycnidiospores and G. pycnidiospores.

Symptoms

Phoma leaf blight affects the crop in the reproductive stage. The field symptom is the occurrence of patches of drying plants. Lesions are irregular, light brown on the leaves, stems and pods with dark margins. Dark, minute, submerged pycnidia are irregularly scattered in the infected tissue. Seeds from the infected plants are discolored and shriveled (Nene et al. 1991).

Hosts

Glycine max (soyabean), *Abelmoschus esculentus* (okra), *Abutilon theophrasti* (China jute), *Allium cepa* (onion), *Allium sativum* (garlic), *Arachis hypogaea* (groundnut), *Alysicarpus vaginalis* (alyce clover), *Capsicum frutescens* (chilli), *Kummerowia striata* (common lespedeza), *Lotus corniculatus* (bird's-foot trefoil), *Lupinus* (lupins), *Lycopersicon esculentum* (tomato), *Melilotus alba*, *Phaseolus acutifolius* (teparty bean), *Phaseolus coccineus* (bean (runner)), *Phaseolus lunatus* (lima bean), *Phaseolus vulgaris* (common bean), *Pisum sativum* (pea), *Strophostyles helvola* (annual wooly-bean), *Trifolium pratense* (purple clover) and *Vigna unguiculata* (cowpea).

Geographic distribution

It is a minor disease reported from Australia, Bangladesh, India and USA.

Biology and transmission

The mycelium is dark gray to black. Hyphae are thick, branched and have rough surfaces. Pycnidia arise singly or in aggregate masses with extremely variable shapes, 200-300 µm in diameter, usually globose to subglobose. Conidia are hyaline to pale yellow, aseptate, straight, $4.5-8.0 \times 2-3$ µm and guttulate. Chlamydospores are small, thick, dark brown to black, spherical to irregular with smooth to rough surfaces. They may be terminal or intercalary, formed in chains (Nene and Reddy 1987). Disease spreads through infected seed from location to location.

Detection/indexing methods used in CGIAR

AT ICRISAT: Pre export field inspection and blotter test are used

Treatment

Not available

Procedures in CGIAR in case of positive test

Incineration of the infected crop and rejection of the infected seed samples

EPPO protocols

Not available

General references

Haware MP and **Nene YL**. 1981. Phoma blight – a new disease of chickpea. *Plant disease* 65:282.

Nene YL, Reddy MV, Haware MP, Ganekar AM and **Amin KS**. 1991. Field diagnosis of chickpea diseases and their control. Information Bulletin No. 28, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics, 52 pp.

Nene YL and **Reddy MV**. 1987. Chickpea diseases and their control. Pages 233-270 *in* The Chickpea (Saxena MC and Singh KB, eds.). Wallingford, Oxon, UK: CAB International.

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Botrytis cinerea Pers. Ex Fr.

Synonyms

Nil

Disease name

Botrytis gray mold

Importance to CGIAR Centers

Low

Significance

Botrytis gray mold is the most important disease of chickpea in the eastern Terai region of Nepal and is responsible for the complete failure of the crop with estimated yield loss of 15% in farmers' fields (Chaurasia and Joshi 2001). More than 80% crop loss has been reported in Bangladesh and north-western India. However, under favorable conditions yield loss up to 95% have been reported (Pande et al. 2002).

Symptoms

Botrytis gray mold is usually seen at flowering. Symptoms develop on the stems, flowers, leaves and pods as gray or dark brown lesions. The gray fungal growth is evident on the flowers and the petioles if observed in the early morning. Drooping of the affected tender terminal branches is a common field symptom. In cloudy weather, flower drop and rotting of plant parts are common. Under favorable weather conditions brown spots develop on the leaflets and circular to elongated spots form on the branches. Sometimes,



CP Fig. 5. *Botrytis gray mold (Botrytis cinerea) of chickpea: A. infected plant without pods; B. grayish colony on twig; C. lesions on leaf and flower; D. pods; E. seeds; F. fungal growth on seed; G. conidiophore with cluster of conidia and H. conidia (Source: ICRISAT IB Nos. 28 and 34).*

tiny black sclerotial masses appear on the dead tissue. On the infected plants, either no seed set or only shriveled seeds appear. On infected pods, lesions are water-soaked and irregular in shape, and black sclerotial bodies are seen (Haware et al. 1992).

Hosts

Vitis vinifera (grapevine), *Chrysanthemum × morifolium* (chrysanthemum (florists')), *Malus pumila* (apple), *Pyrus communis* (European pear), *Phaseolus* (beans), *Brassicaceae* (cruciferous crops), *Allium cepa* (onion), *Cucumis sativus* (cucumber), *Helianthus annuus* (sunflower), *Hibiscus cannabinus* (kenaf), *Lactuca sativa* (lettuce), *Linum usitatissimum* (flax), *Lycopersicon esculentum* (tomato), *Pisum sativum* (pea), *Rosa* (roses),

Allium fistulosum (Welsh onion), *Arachis hypogaea* (groundnut), *Brassica rapa subsp. pekinensis* (Pe-tsai), *Carthamus tinctorius* (safflower), *Chrysanthemum* (daisy), *Cicer arietinum* (chickpea), *Calendula officinalis* (Pot marigold), *Capsicum* (peppers), *Phaseolus vulgaris* (common bean), *Sesbania cannabina* (corkwood tree), *Solanum melongena* (aubergine), *Triticum aestivum* (wheat), *Vicia faba* (broad bean), *Vicia sativa* (common vetch) and *Zinnia elegans* (Zinnia).

Geographic distribution

Botrytis gray mold is a serious disease in parts of Bangladesh, India, Nepal and Pakistan. It has also been reported from Argentina, Australia, Canada and Chile.

Biology and transmission

The mycelium of *B. cinerea* is septate, brown, hyphae being 8-16 μ wide. The conidiophores are light brown, septate, erect, and their tips are slightly enlarged bearing small and pointed sterigmata. The conidia are hyaline, 1-celled, oval and are formed in clusters on short sterigmata. The conidia in mass are ash-gray in color, and measure 4-20 \times 4-16 μ . The disease is transmitted by the seed borne fungus from location to location.

Detection/indexing methods used in CGIAR

Pre export field inspection and blotter test.

Treatment

Seed treatment with a mixture of 25% carbendazim and 50% thiram at 2.5 g kg⁻¹ seed (Pande et al. 2002).

Procedures in CGIAR in case of positive test

AT ICRISAT: Rejection of the infected seed samples

EPPO protocols

Not available

General references

Chaurasia PCP and **Joshi S.** 2001. Management of Botrytis gray mold of chickpea at Tarahara, Nepal. Nepal Agricultural Research Journal 4 & 5:37-41.

Haware MP, Faris DG and Gowda CLL (eds.). 1992. Botrytis gray mold of chickpea: summary proceedings of the BARI/ICRISAT Working Group Meeting to discuss Collaborative Research on Botrytis Gray Mold of chickpea, 4-8 March 1991, Joydebpur, Bangladesh. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 23 pp.

Pande S, Singh G, Narayana Rao J, Bakr MA, Chaurasia PCP, Joshi S, Johanson C, Singh SD, Kumar J, Rahman MM and Gowda CLL. 2002. Integrated management of botrytis gray mold of chickpea. Information Bulletin No. 61. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 32 pp.

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Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Colletotrichum dematium (Pers ex Fr) Grove

Synonyms

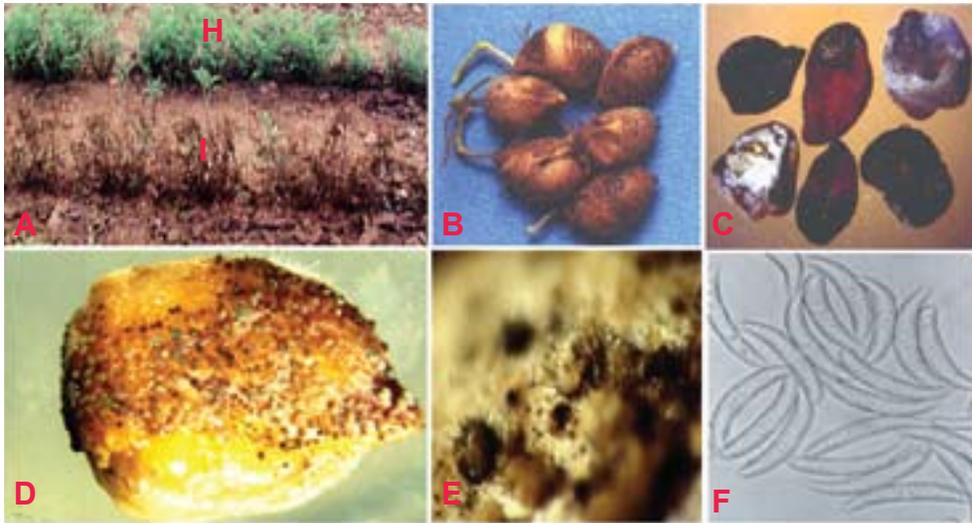
Colletotrichum bakeri, *Colletotrichum brassica*, *Colletotrichum lysimachiae*, *Colletotrichum pucciniophilum*, *Colletotrichum sanguisorbae*, *Colletotrichum volutella*, *Dinemasporium dianthi*, *Ellisiellina volutella*, *Sphaeria dematium*, *Vermicularia bakeri*, *Vermicularia dematium*, *Vermicularia dianthi*, *Vermicularia echinata*, *Vermicularia lagunensis*, *Vermicularia lysimachia*, *Vermicularia volutella*

Disease name

Anthracnose or Colletotrichum blight

Importance to CGIAR Centers

Low



CP Fig. 6. Anthracose (*Colletotrichum dematium*) of chickpea: symptoms on A. plant, infected row (I), healthy row (H); B. pods; C. seed; D. mycelial growth on seed; E. acervuli on seed with setae and F. conidia (Source: ICRISAT IB Nos. 28 and 34).

Significance

Anthracnose is of minor importance in chickpea growing areas.

Symptoms

Small water-soaked yellowish spots appear on the lower leaves, which later turn into circular brown lesions with yellow margin 1 to 3 mm in diameter. In some cases, lesions enlarge rapidly, become irregular and cover the entire leaflet, and extend to the stipules and stems. Lesions on pods are circular to elongate, sunken at the center. Plants wilt and dry due to severe infection, and plants killed by this disease lie scattered in the field (Nene et al. 1991).

Hosts

Allium cepa (onion), *Allium sativum* (garlic), *Arachis hypogaea* (groundnut), *Beta vulgaris* (beetroot), *Helianthus annuus* (sunflower), *Vicia faba* (broad bean), *Abelmoschus esculentus* (okra), *Cicer arietinum* (chickpea), *Capsicum annuum* (bell pepper), *Crotalaria juncea* (sunn hemp), *Glycine max* (soybean), *Lablab purpureus* (hyacinth bean), *Lycopersicon esculentum* (tomato), *Vigna radiata* (bean, mung), *Vigna mungo* (black gram), *Spinacia oleracea* (spinach), *Cyamopsis tetragonoloba* (clusterbean), *Gomphrena globosa* (Globe amaranth), *Medicago sativa* (lucerne), *Ricinus communis* (castor bean) and *Amaranthus hybridus* (green amaranth).

Geographic distribution

Colletotrichum dematium is worldwide in distribution, especially in several countries of Europe, Asia, Africa and Oceania.

Biology and transmission

White mycelium is seen on infected plant parts, and sometimes acervuli with black setae are also seen. Acervuli are circular, erumpent, dark brown to black, which scatters throughout the infected part or are aggregated, and in groups. Acervuli release conidia in pale yellow to gray masses. The color of the acervular masses is pale to bright orange. Within the acervular masses numerous thick black, erect hair like spines or setae are seen. Setae are longer than the acervular masses. Conidia are hyaline, single-celled, measure 2.5-4×15-32 μm, fusoid and tapered at both ends. The disease is transmitted through infected seed and soil borne inoculum (Ahmed and Ravinder Reddy 1993).

Detection/indexing methods used in CGIAR

Pre-export field inspection and blotter test

Treatment

A minor disease and does not require any specific control measure.

Procedures in CGIAR in case of positive test

At ICRISAT: Incineration of infected plants and rejection of infected samples

EPPO protocols

Not available

General references

Nene YL, Reddy MV, Haware MP, Ganekar AM and Amin KS. 1991. Field diagnosis of chickpea diseases and their control. Information Bulletin No. 28. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 52 pp.

CGIAR-published references on seed health

Ahmed KM and Ravinder Reddy Ch. 1993. A Pictorial guide to the identification of seed borne fungi of sorghum, pearl millet, finger millet, chickpea, pigeonpea and groundnut. Information Bulletin No. 34. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 200 pp.

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Insects

Callosobruchus analis Fabricius.

Synonyms

Bruchus analis, *Bruchus glaber*, *Bruchus jekelii*, *Bruchus obliquus*, *Bruchus ciceri*, *Callosobruchus glaber*, *Callosobruchus jekelii*

Disease name

Stored grain pest

Importance to CGIAR Centers

Medium



CP Fig. 7. Stored grain pest (*Callosobruchus analis*) of chickpea: A. adult (Source: www.invasive.org/brows/detail=066007) and B. damaged grains with white eggs and floppy windows (Source: ICRISAT IB No. 42).

Significance

Infested chickpea lose their viability and are unfit for human consumption. In Africa, Asia and Oceania, *C. analis* is considered a pest of economic importance for stored-legume grains (Southgate 1979).

Symptoms

Chickpea pods are seldom infested in the field. The pests attack nearly mature and dried pods during storage. The round exit hole and the white eggs on the pod wall are conspicuous. Infested stored seed can be recognized by the eggs on the seed surface, and the round exit holes with the 'flap' of seed coat.

Hosts

Cicer arietinum (chickpea), *Cajanus cajan* (pigeonpea) and other grain legumes.

Geographic distribution

Callosobruchus analis is widespread in Asia.

Biology and transmission

Adults are small, 3 mm long brown beetles with black spots on the elytra. Eggs are laid on the seed surface. Larvae feed and pupate entirely within the seed. One generation is completed in 4-5 weeks (Ranga Rao and Shanower 1999).

Detection/indexing methods used in CGIAR

Dry seed examination and X-ray radiography are used for detection of the bruchides.

Treatment

At ICRISAT: Fumigation with methyl bromide @ 32 g m⁻³ for 4 h followed by seed treatment with chlorpyrifos 3 g kg⁻¹ seed (Ghanekar et al. 1996).

Procedures in CGIAR in case of positive test

Removal of the infested seeds followed by seed treatment with chlorpyrifos at 3 g kg⁻¹ seed

EPPO protocols

Not available.

General references

Ghanekar AM, Ranga Rao GV, Murthy KS, Surender A and Shaik Babu Saheb. 1996. Seed protectants for healthy exports. Indian Journal of Plant Protection 24:37-43.

Ranga Rao GV and Shanower TG. 1999. Identification and Management of Pigeonpea and Chickpea Insects Pests in Asia. Information Bulletin No. 57. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 96 pp.

Southgate BJ. 1979. Biology of the Bruchidae. Annual Review of Entomology 24:449-473.

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Trogoderma granarium Everts.

Synonyms

Trogoderma afrum, *Trogoderma khapra*, *Trogoderma quinquefasciata*

Common name

Khapra beetle

Importance to CGIAR Centers

High

Significance

Trogoderma granarium is a serious pest of stored products under hot dry conditions. Established infestations are difficult to control because of the beetle's ability to live without food for long periods of time and to survive on foods of low moisture content, its habit of crawling into tiny cracks and crevices and remaining there for long periods, and its relative tolerance to many surface insecticides and fumigants.



CP Fig. 8. Khapra Beetle (*Trogoderma granarium*) of chickpea: A. adults and B. larvae and damaged grains (Source: www.agspsrv34.agric.wa.gov.au).

Symptoms

The khapra beetle is one of the world's most feared stored-product pests. The obvious signs of a khapra beetle infestation are the larvae and cast skins. Larvae and adults are best identified by microscopic examination. Larvae are most likely to be seen just before dusk, since they are more active at that time (Anonymous 1981).

Host

Larvae feed on a wide variety of stored products and dried foods. They prefer whole grain and cereal products such as *Triticum aestivum* (wheat), *Hordeum vulgare* (barley), and *Oryza sativa* (rice), but larvae have been recorded on the following: *Avena spp.* (oats), *Secale spp.* (rye), *Zea mays* (corn), dried blood, dried milk, fishmeal, *Arachis hypogaea* (groundnuts), flour, bran, malt, *Linum usitatissimum* (flax seed), *Medicago sativa* (alfalfa seed), *Lycopersicum esculantum* (tomato seed), *Phaseolus vulgaris* (pinto beans), *Vigna unguiculata* (blackeyed cowpeas), *Sorghum bicolor* (sorghum seed) and many other food products (Lindgren and Vincent 1959, Lindgren et al. 1955).

Geographic distribution

The distribution of khapra beetle extends from Myanmar (Burma) to West Africa and is limited by the 35° parallel to the north and the equator to the south. It has been introduced by commerce into some areas of similar climatic conditions (Anonymous 1981). The khapra beetle is found in all continents where grain and grain products are stored.

Biology and transmission

The adults are oblong-oval beetles, approximately 1.6 to 3.0 mm long and 0.9 to 1.7 mm wide. Males are brown to black with indistinct reddish brown markings on elytra. Females are slightly larger than males and lighter in color. The head is small and deflexed with a short 11-segmented antenna. The antennae have a club of three to five segments, which fit into a groove in the side of the pronotum. The adults are covered with hairs. The eggs are milky white, turning pale yellowish with age, cylindrical, 0.7×0.25 mm, one end rounded, the other pointed and bearing spine-like projections. Larvae are uniformly yellowish white, while the head and body hairs are brown. As the larvae increase in size, their body color changes to a golden or reddish brown, more body hairs develop, and the tail becomes proportionally shorter. Mature larvae are approximately 6 mm long and 1.5 mm wide. Adult khapra beetles have wings, but apparently do not fly and feed very little. Mated females live from four to seven days, unmated females from 20 to 30 days, and males from seven to 12 days. Mating occurs about five days after emergence, and egg laying begins almost immediately at 40°C. Egg laying may begin at one to three days at cooler temperatures, but no eggs are produced at 20°C. Eggs hatch in three to 14 days after the female lays an average of 50 to 90 eggs that are loosely scattered in the host material. Complete development from egg to adult can occur from 26 to 220 days, depending upon temperature. Optimum temperature for development is 35°C. If the temperature falls below 25°C for a period of time or if larvae are very crowded, they may enter diapauses. They can survive temperatures below -8°C. In diapauses, the larvae can molt but are inactive and may remain in this condition for many years (Anonymous 1981).

Detection/indexing methods used in CGIAR

At ICRISAT: Dry seed examination using magnifying lens

Treatment

High concentrations of fumigant (Aluminum phosphide) are maintained during the fumigation period to allow penetration into all cracks and crevices. In an eradication program, both fumigants and surface treatment (chlorpyrifos) are used in combination with preventive measures such as good sanitation practices and exclusion.

Procedures in CGIAR in case of positive test

At ICRISAT: Rejection and incineration of the infested seed samples

EPPO protocols

EPPO A2 list: No. 121

Control. Methyl bromide fumigation gives good control for a wide range of commodities. Effective control in the structure of buildings and ships requires high concentrations maintained over the fumigation period to enable the gas to penetrate into cracks and crevices. A list of dosage schedules may be found in EPPO quarantine procedure No. 12 (OEPP/EPPO 1982). Phosphine can also be used against *T. granarium*; dosage schedules are given by OEPP/EPPO (1984). In India, the use of deoiled neem (*Azadirachta indica*) seed powder mixed into wheat was found to be an effective and cheap method to control the pest in stored wheat (Singh and Kataria 1986). The use of carbon dioxide was also reported to be effective in India (Srivastava 1985). As an alternative to the fumigation of cereals with methyl bromide or other pesticides, the use of a heat treatment has been reported to be very effective against the khapra beetle (Fleurat-Lessard 1985). An exposure to 60°C for 30 min resulted in 100% mortality of all stages of *T. granarium* (Ismail et al. 1988).

Phytosanitary risk. *T. granarium* is an A2 quarantine organism for EPPO (OEPP/EPPO 1981), and is also of quarantine concern for CPPC, COSAVE, JUNAC, NAPPO and OIRSA. The continued occurrence of *T. granarium* on produce imported from countries where it is indigenous, and the potential for spread due to increasing use of dry cargo containers and roll-on roll-off road transport, make it a continued threat to EPPO countries. This not only applies to the risk of establishment in heated buildings in areas of unfavorable climate, but also to parts of Greece, Italy, Spain and Russia on the fringes of the natural range, where it is not known to be established. A minimum period of 4 months with an average temperature of 20°C is considered necessary for *T. granarium* to be a pest. In addition, it should be recalled that other continents take severe measures against *T. granarium*; the presence of the pest in an EPPO country would be a significant additional constraint to its exports.

Phytosanitary measures. EPPO (OEPP/EPPO 1990) recommends that it is preferable not to require a phytosanitary certificate for stored products, but rather to inspect consignments on import and take appropriate post-entry action, for example, treatment following EPPO Quarantine Procedures Nos 12 or 18 (OEPP/EPPO 1982, 1984).

General references

Anonymous. 1981. Data sheets on quarantine organisms. *Trogoderma granarium* Everts. Pages 1-6 in European and Mediterranean Plant Protection Organization Bulletin 11 (1) Set 4, List A2.

Fleurat-Lessard F. 1985. Les traitements thermiques de desinfestation des cereals et des produits céréaliers: possibilité d'utilisation pratique et domaine d'application. *Bulletin OEPP/EPPO* 15:109-118.

Ismail AY, Abid SH and Mawlood NA. 1988. Effect of high temperature on the mortality of the red flour beetle *Tribolium confusum* and khapra beetle *Trogoderma granarium*. *Zanco* 1:35-42.

Lindgren DL and Vincent LE. 1959. Biology and control of *Trogoderma granarium* Everts. *Journal of Economic Entomology* 52:312-319.

Lindgren DL, Vincent LE and Krohne HE. 1955. The khapra beetle, *Trogoderma granarium* Everts. *Hilgardia* 24:1-36.

OEPP/EPPO. 1981. Data sheets on quarantine organisms No. 121, *Trogoderma granarium*. *Bulletin OEPP/EPPO Bulletin* 11 (1).

OEPP/EPPO. 1982. Quarantine procedures No. 12. Methyl bromide fumigation of stored products. *Bulletin OEPP/EPPO Bulletin* 12 (Special issue on EPPO recommendations on fumigation standards):30-31.

OEPP/EPPO. 1984. Quarantine procedures No. 18. Phosphine fumigation of stored products. *Bulletin OEPP/EPPO Bulletin* 14:598-599.

OEPP/EPPO. 1990. Specific quarantine requirements. *EPPO Technical Documents* No. 1008.

Singh RP and Kataria PK. 1986. Deoiled neem kernel powder as protectant of wheat seeds against *Trogoderma granarium* Everts. *Indian Journal of Entomology* 48:119-120.

Srivastava JL. 1985. Use of controlled atmosphere for the control of stored product insects. Pages 202-207 in Behavioral and physiological approaches in pest management (Regupathy A and Jayaraj S, eds.). Coimbatore, Agriculture University, Tamil Nadu, India.

CGIAR-published references on seed health

Nil

Pigeonpea (*Cajanus cajan* L.)

Bacteria

Pseudomonas syringae pv. *lisi* (Sackett) Young et al.

Synonyms

Pseudomonas lisi

Disease name

Bacterial blight

Importance to CGIAR Centers

Medium

Significance

Severe infection and substantial crop losses have been reported from winter-sown peas in southern France, New Zealand and South Africa (Boelema 1972, Taylor 1972). The disease as such, however, does not appear to be of great economic importance in Europe.

Symptoms

Symptoms usually appear on the stem near the soil as water-soaked and later olive-green to purple-brown spots. The infection extends upwards to the stipules and leaflets, where veins turn brown to black and adjacent tissues become diseased in a fan-like pattern. The interveinal tissues may become water soaked and then turn yellowish to brown, finally drying out and becoming papery. Lesions on leaflets and pods begin as small, round, oval or irregular dark-green water-soaked spots at first, and later enlarge and coalesce but are sharply defined by the veins. Cream-colored bacterial ooze may be found on the lesion surface that, on drying, gives a glossy appearance. The leaflets later become yellowish and the spots brown and papery. Ripening pods become twisted and dry, lesions on them are sunken and greenish-brown. Lesions on the pod may be limited to a narrow band on the sutures. Infected seeds show a water-soaked spot near the hilum and/or are shrivelled, with a brown-yellow discoloration. Infection often takes place on sepals, spreading to the flowers, and flower buds may be killed before they open.

Hosts

Pisum sativum var. *arvense* (peas) is the principal host. Natural infection has also been recorded on *Lablab purpureus* (hyacinth bean), *Lathyrus latifolius* (Everlasting-pea or sweet-pea Everlasting), *L. odoratus* (sweet pea) and *Vicia benghalensis* (purple vetch).

Geographic distribution

Bacterial blight is worldwide in distribution, especially in Bulgaria, Greece, Hungary, Italy, Romania, USSR and Yugoslavia. Sporadic outbreaks have been recorded from Denmark, France, Germany, Morocco, the Netherlands, Switzerland, UK, Israel, Lebanon, India, Indonesia, Japan, Nepal, Kenya, Malawi, Morocco, South Africa, Tanzania, Zimbabwe, Bermuda, Canada, Mexico and USA.

Biology and transmission

Pseudomonas syringae pv. *pisi* is a motile, gram-negative, non-spore-forming rod, 0.7×2-3 µm, with one to five polar flagella. Disease has been observed to develop more readily on soils with high moisture content. Infections can occur through contact of diseased and healthy foliage and insects may have a role in transmission. The bacterium can survive on or within seeds for at least 10 months (Skoric 1927) and for several months on diseased plant debris in the field (Harris 1964).

Detection/indexing methods used in CGIAR

At ICRISAT

Detection of the pathogen in seeds is usually performed by soaking ground pea seeds in buffer at low temperature (4°C) for 4-16 h and subsequent isolation from the (centrifuged) soaking solution. For isolation from diseased tissues and seeds, King's medium B can be used, with supplement of boric acid, cephalixin and cycloheximide if necessary (Mohan and Schaad 1987).

Treatment

Not known since it has not been detected at ICRISAT

Procedures in CGIAR in case of positive test

At ICRISAT: Incineration of the infected crop and rejection of the seed samples.

EPPO protocols

EPPO (OEPP/EPPO 1990) recommends that pea seeds should come from a field or area free from *P. syringae* pv. *pisii*, or else that the seed crop should have been inspected. However, seed-testing techniques are now available to detect the bacteria.

General references

Boelema BH. 1972. Bacterial blight (*Pseudomonas pisi* Sackett) of peas in South Africa, with special reference to frost as a predisposing factor. Mededelingen Landbouwhogeschool Wageningen 72:1-87.

Harris DE. 1964. Bacterial blight of peas. Journal of Agriculture, Victoria Department of Agriculture 62:276-280.

Mohan SK and Schaad NW. 1987. Semiselective agar medium for isolating *Pseudomonas syringae* pv. *syringae* and pv. *phaseolicola* from bean seed. Phytopathology 77:1390-1395.

OEPP/EPPO. 1990. Specific quarantine requirements. EPPO Technical Documents No. 1008.

Skoric V. 1927. Bacterial blight of peas; overwintering, dissemination and pathological histology. Phytopathology 17:611-628.

Taylor JD. 1972. Races of *Pseudomonas pisi* and sources of resistance in field and garden peas. New Zealand Journal of Agricultural Research 15:441- 447.

CGIAR-published references on seed health

Nil

Fungi

Colletotrichum cajani Rangel.

Synonyms

Nil

Disease name

Anthracnose

Importance to CGIAR Centers

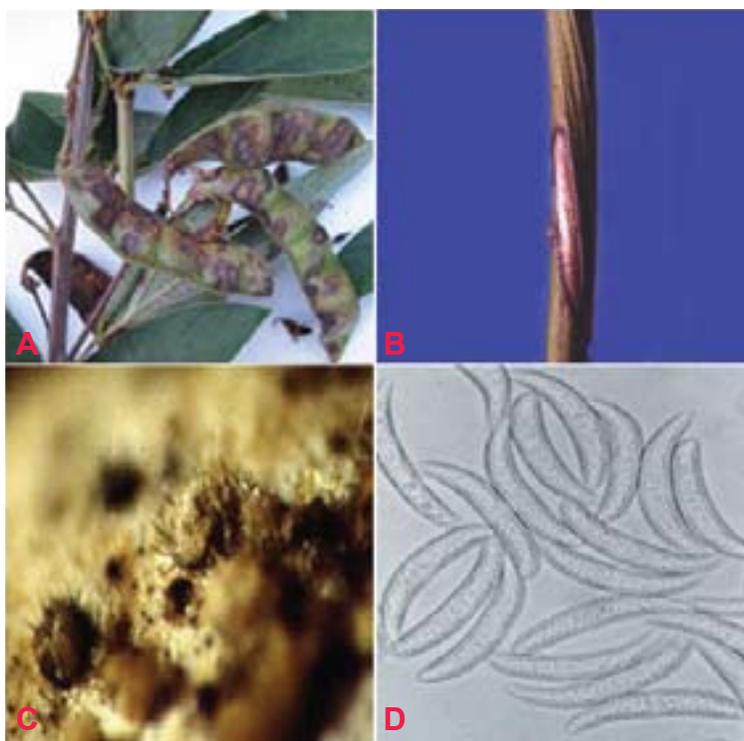
High

Significance

Anthrachnose is destructive and infects leaves, pods and seeds especially during the period of heavy rainfall. The losses are mainly due to dropping of pods at a young stage and discoloration and decay of some or all the seeds in the infected pods. In a harvest of affected crop, 86% pods have been found to be infected with 36% unmarketable seeds (Tucker 1927).

Symptoms

The typical symptoms are sunken spots on pods due to drying up and collapse of the cells in the center. Pink sticky spore masses that develop during the moist weather, which have an ulcer like appearance, are also present. The main symptoms include spots on pods and leaves, blackening and shrinking of veins of infected leaves and their premature fall. The infected pods become distorted, abort and die. Affected young pods drop and all the



Anthrachnose (Colletotrichum cajani) of pigeonpea:
A. lesions on plant and pods (Source: www.agrociencia-panama.blogspot.com); B. lesion on stem; C. acervuli on seed and D. conidia (Source: ICRISAT IB Nos. 34 and 42).

seeds in the infected pods are discolored and decayed. Anthracnose spots appear as irregular, brown to grayish stem lesions containing dark, scattered acervuli. Severe infection leads to drying and death of infected branches. Minute spots with dark margins and gray centers scattered with acervuli are also common on the leaves and pods of infected plants (Reddy et al. 1993).

Hosts

Many ornamental plants and leguminacious weeds.

Geographic distribution

The disease was first reported from Brazil in 1927 and subsequently from several other countries such as Puerto Rico, India, USA, Venezuela and Zambia (Nene et al. 1996).

Biology and transmission

The conidia are cylindrical, broadly elliptical or irregular with rounded ends and $12-17 \times 3.5-7.2 \mu$ in size. The setae are numerous, and are curved, septate and $100 \times 3.5 \mu$ in size. Appressoria apparently analogous to chlamydospores may be as it is and were observed after 2 months on PDA and steamed pigeonpea pods. The pathogen has been associated with seeds of pigeonpea and is considered as the quarantine important pathogen (Nirula 1980).

Detection/indexing methods used in CGIAR

At ICRISAT: Pre-export field inspection and blotter test are used

Treatment

Rejection of the infected seed samples

Procedures in CGIAR in case of positive test

AT ICRISAT: Rejection of the infected seed samples

EPPO protocols

Not available.

General references

Nene YL, Sheila VK and Sharma SB. 1996. A world list of chickpea and pigeonpea pathogens. 5th edition. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 27 pp.

Nirula KK. 1980. Quarantine to seed exchange at the ICRISAT. Seed Pathology News 13:11-12.

Reddy MV, Raju TN, Sharma SB, Nene YL and McDonald D. 1993. Handbook of pigeonpea diseases. Information Bulletin No. 42. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 64 pp.

Tucker CM. 1927. Pigeonpea anthracnose. Journal of Agricultural Research 34:589-596.

CGIAR-published references on seed health

Nil

Alternaria alternata (Fries) Keissler.

Synonyms

Alternaria fasciculata, *Alternaria rugosa*, *Alternaria tenuis*, *Macrosporium fasciculatum*, *Torula alternate*.

Disease name

Alternaria blight or Leaf spot

Importance to CGIAR Centers

Medium

Significance

In the late sown, pre-rabi pigeonpea crop, Alternaria blight has been identified as a potential problem in some states of India (Reddy et al. 1993).

Symptoms

Alternaria alternata causes circular necrotic spots on leaves that develop quickly forming typical concentric rings. The lesions appear on aerial plant parts including pods. They cause severe blighting of the leaves and defoliation and drying of infected branches (Reddy et al. 1993).



PP Fig. 1. *Alternaria blight (Alternaria alternata) of pigeonpea: A. leaf spot; B. leaf blight (Source: ICRISAT IB No. 42); C. fungal growth on seed (Source: ICRISAT IB No. 34); D. conidia on seed and E. conidia (Source: ICRISAT IB Nos. 34 and 42).*

Hosts

Over 380 hosts have been recorded in the USDA Systematic Botany and Mycology Fungus-Host Distribution Database <http://nt.ars-grin.gov/>. It is an opportunistic pathogen on numerous hosts causing leaf spots, rots and blights on many plant parts. It can also cause upper respiratory tract infections in AIDS patients^[1] and asthma in people with sensitivity.

Geographic distribution

Alternaria blight is distributed in India, Kenya and Puerto-Rico (Reddy et al. 1993).

Biology and transmission

Mycelium of the pathogen is usually light olive green to brown. Hyphae are dark brown, thick, septate and branched. Conidiophores are pale brown to olive brown, 25-60×3-3.5 µm in size and straight or flexuous. Individual conidiophores arise directly from substrate forming bushy heads consisting of 4-8 large catenate conidia chains. Secondary conidiophores are generally short and 1-celled. Conidia are pale brown to light brown, obclavate to obpyriform or ellipsoid, have a short conical beak at the tip, or are sometimes beakless. Surface of conidia is smooth to verruculose, 20-63×9-18 µm in size. Conidia are septate with several (1-5) vertical and 3-8 transverse septa. The fungus sporulates well under warm and humid conditions (Kannaiyan and Nene 1977). *Alternaria alternata* has been found to be internal seed borne and the infection was detected in all parts of the seed (Girish et al. 2007).

Detection/indexing methods used in CGIAR

At ICRISAT: Pre-export field inspection and blotter test are used.

Treatment

Seed treatment with the mixture of iprodione 25% + carbendazim 25% (1:1 by vol.) at 2 g a.i. kg⁻¹ seed (Girish et al. 2007).

Procedures in CGIAR in case of positive test

AT ICRISAT: Seed treatment with the mixture of benomyl + thiram (1:1) at 3 g kg⁻¹ seed.

EPPO protocols

Not available.

General references

Girish AG, Sowjanya YV, Chakrabarty SK and Thakur RP. 2007. Studies on seedborne nature and management of *Alternaria alternata* and *A. brassicae* in pigeonpea. Indian Journal of Plant Protection 35:128-130.

Kannaiyan J and Nene YL. 1977. Alternaria leaf spot of pigeonpea. Tropical Grain Legumes Bulletin 9:34.

Reddy MV, Raju TN, Sharma SB, Nene YL and McDonald D. 1993. Handbook of pigeonpea diseases. Information Bulletin No. 42. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 64 pp.

CGIAR-published references on seed health

Ahmed KM and Ravinder Reddy Ch. 1993. A Pictorial guide to the identification of seed borne fungi of sorghum, pearl millet, finger millet, chickpea, pigeonpea and groundnut. Information Bulletin No. 34. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 200 pp.

Lasiodiplodia theobromae (pat.) Griffin & Maubl.

Synonyms

Botryodiplodia ananassae, *Botryodiplodia elasticae*, *Botryodiplodia theobromae*, *Botryodiplodia tuberculata*, *Chaetodiplodia grisea*, *Diplodia ananassae*, *Diplodia theobromae*, *Lasiodiplodia nigra*, *Lasiodiplodia tuberculata*, *Lasiodiplodiella triflorae*, *Macrophoma vestita*

Disease name

Blight

Importance to CGIAR Centers

Medium

Significance

Lasiodiplodia theobromae affects a very wide range of crops, particularly at the post-harvest stage. Infected seeds have reduced germination (Ellis et al. 1978).

Symptoms

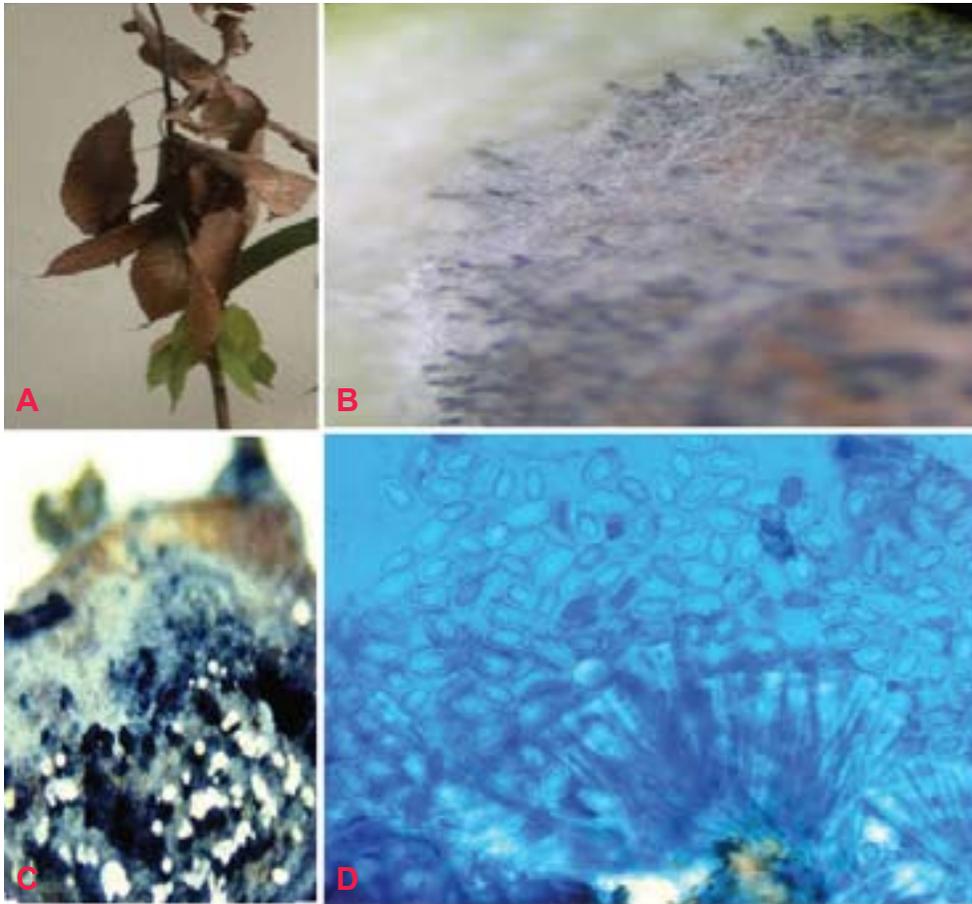
Seed rotting and seedling blight.

Hosts

Citrus aurantiifolia (lemon), *Theobroma cacao* (cocoa), *Arachis hypogaea* (groundnut), *Gossypium* (cotton), *Musa* (banana), *Mangifera indica* (mango), *Zea mays* (maize), *Allium* spp. (onions, garlic, leek, etc), *Ananas comosus* (pineapple), *Capsicum annuum* (bell pepper), *Dioscorea* (yam), *Cajanus cajan* (pigeonpea), *Glycine max* (soyabean), *Ipomoea batatas* (sweet potato), *Manihot esculenta* (cassava), *Nicotiana tabacum* (tobacco), *Oryza sativa* (rice), *Saccharum officinarum* (sugarcane), *Sorghum bicolor* (sorghum), *Vigna unguiculata* (cowpea) and *Vitis vinifera* (grapevine).

Geographic distribution

Lasiodiplodia theobromae is worldwide in distribution especially in Africa, Asia, the western hemisphere and Oceania.



PP Fig. 2. PP Fig. 3. *Blight (Lasiodiplodia theobromae) of pigeonpea: A. lesions on plant (Source: www.bspporg.uk.com); B. pycnidia on seed; C. black and white conidial ooze on seed (Source: ICRISAT IB No. 34) and D. single celled immature conidia.*

Biology and transmission

Colonies of the pathogen on oatmeal agar are grayish or mouse grey to black, fluffy with abundant aerial mycelium, reverse fuscous black to black. Pycnidia appear on the infected leaves, stems and fruits. Pycnidia are immersed and thick-walled, and aggregated in clusters immersed in a stroma frequently up to 5 mm wide, erumpent, often with a distillate papillate ostiole (Punithalingam 1976). Conidiophores are hyaline, simple, sometimes septate, rarely branched, cylindrical, arising from the inner layers of cells lining the conidiomatal cavity. Conidia are initially aseptate, hyaline,

granulose, subovoid to ellipsoid-oblong, thick-walled, base truncate. Mature conidia are one-septate, cinnamon to fawn, often longitudinally striate, 18-30×10-15 µm. Paraphyses are hyaline, cylindrical, sometimes septate, up to 50 µm long. Seed borne nature of *L. theobromae* was reported in about 29% of the seeds of pigeonpeas (Richardson 1990).

Detection/indexing methods used in CGIAR

At ICRISAT: Pre-export field inspection and blotter method

Treatment

Seed treatment with a mixture of benomyl + thiram (1:1) at 3 g kg⁻¹ seed.

Procedures in CGIAR in case of positive test

AT ICRISAT: Seed treatment with a mixture of benomyl + thiram (1:1) at 3 g kg⁻¹ seed.

EPPO protocols

Not available.

General references

Ellis MA, Paschal EH, Ravalo EJ and Rosaria E. 1978. Effect of growing location on internally seed-borne fungi, seed germination and field emergence of pigeon pea in Puerto Rico. *J. Agric. Univ. P.R* 62:355-360.

Punithalingam E. 1976. *Botryodiplodia theobromae*, No. 519 in *Descriptions of Pathogenic Fungi and Bacteria*. Wallingford, UK: CAB International.

Richardson MJ. 1990. *An Annotated List of Seed-borne Diseases*. 4th edn. Zurich, Switzerland: International Seed Testing Association.

CGIAR-published references on seed health

Ahmed KM and Ravinder Reddy Ch. 1993. A Pictorial guide to the identification of seed borne fungi of sorghum, pearl millet, finger millet, chickpea, pigeonpea and groundnut. Information Bulletin No. 34. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 200 pp.

Nematode

Heterodera cajani Koshy.

Synonyms

Heterodera vigni

Disease name

Pearly root

Importance to CGIAR Centers

Low

Significance

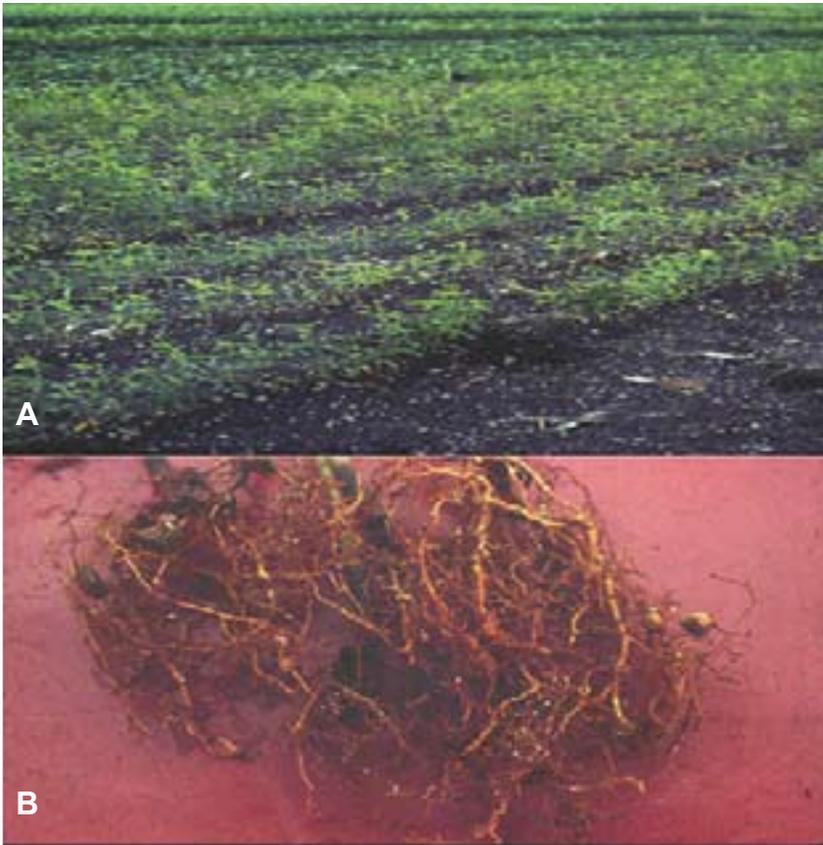
Yield losses of over 30% and 28% reduction in plant growth have been reported (Sharma et al. 1993).

Symptoms

Heterodera cajani is primarily a root-parasite. The most important characteristic symptom is the presence of cysts on the root surface. Identification of “pearly root” caused by the presence of white females is a useful symptom of *H. cajani* infestation in pigeonpea at the vegetative stage (Sharma 1993). The symptoms of nematode injury include stunting, reduced leaf lamina size and yellowing on cotyledonary leaves (Gaur and Singh 1977). Flowers and pods are reduced in size and number and the root system may also be poorly developed. Foliage symptoms are generally not apparent even in heavily infested soils, but a reduction in height and vigor of the infected plants can be discerned by careful comparison with healthy plants.

Hosts

Cajanus cajan (pigeonpea), *Cyamopsis tetragonoloba* (cluster bean), *Lablab purpureus* (hyacinth bean), *Vigna aconitifolia* (aconite-leaved kidney beans), *Vigna radiata* (bean, mung), *Vigna mungo* (black gram), *Phaseolus vulgaris* (common bean), *Pisum sativum* (pea), *Sesamum indicum* (sesame) and *Vigna unguiculata* (cowpea) (Sharma and Nene 1985).



PP Fig. 3. Pearly root (*Heterodera cajani*) of pigeonpea: A. symptoms in field and B. root damage symptoms (Source: ICRISAT IB No. 42).

Geographic distribution

Heterodera cajani has been reported from Egypt, India and Pakistan. It is widespread in sandy-loam soils in northern India and in black cotton soils in western and southern India (Reddy et al. 1993, Varaprasad et al. 1997).

Biology and transmission

The adult females are lemon-shaped and sedentary in habit, and remain attached to roots semi-endoparasitically. These are white to slightly brown, with a neck and posterior cone-like elevation on which the vulva is situated; turn into a cyst of same size and shape. The posterior part of body protruding outside the root usually appears with a small rounded egg sac attached to it. The cephalic region has two annules; the second is larger than the first. The stylet is of medium strength, in two equal parts; basal knobs round to slightly

anteriorly flattened. The median esophageal bulb is large rounded, with well developed valve plates. The excretory pore is placed posterior behind the median bulb. Esophageal glands extend over the intestine. Ovaries are paired and convoluted. Uterus with several eggs fills most of the body. Vulva is a large transverse slit on a cone-shaped elevation of the body. Anus is close to vulva. An egg sac is present. The size of egg sacs varies between 0.5-2 times the size of cyst. Egg sacs are yellow, occasionally purple. Few to 200 eggs (average 54) are found in the egg sacs (Koshy and Swarup 1971). Eggs may be retained inside the female body but many are laid in a gelatinous matrix forming egg sacs. Eggs are oval, 95-115 µm long, and 37-48 µm wide. Eggshell is hyaline, without surface markings. Morphological characteristics of 2nd-, 3rd- and 4th-stage juveniles of *H. cajani*, *H. avenae* and *H. mothi* are described and compared by Taya and Bajaj (1986). Males are vermiform.

Detection/indexing methods used in CGIAR

AT ICRISAT: Pre-export field inspection

Treatment

Not available

Procedures in CGIAR in case of positive test

AT ICRISAT: Rejection of the seed samples

EPPO protocols

Not available.

General references

Gaur HS and **Singh I.** 1977. Pigeonpea cyst nematode, *Heterodera cajani*, associated with the moong crop in the Punjab State. Journal of Research, Punjab Agricultural University 14:509.

Koshy PK and **Swarup G.** 1971. Investigations on the life history of the pigeon-pea cyst nematode, *Heterodera cajani*. Indian Journal of Nematology 1:44-51.

Reddy MV, **Raju TN**, **Sharma SB**, **Nene YL** and **McDonald D.** 1993. Handbook of pigeonpea diseases. Information Bulletin No. 42. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 64 pp.

Sharma SB and **Nene YL.** 1985. Additions to host range of pigeonpea cyst nematode, *Heterodera cajani*. International Pigeonpea Newsletter 4:42.

Sharma SB. 1993. Pearly root of pigeonpeas caused by *Heterodera cajani*. Indian Journal of Nematology 21:169.

Sharma SB, Nene YL, Reddy MV and McDonald D. 1993. Effect of *Heterodera cajani* on biomass and grain yield of pigeon pea on vertisol in pot and field experiments. Plant Pathology 42:163-167.

Taya AS and Bajaj HK. 1986. Larval stages of *Heterodera avenae* Woll, *H. cajani* Koshy and *H. mothi* Khan and Husain. Indian Journal of Nematology 16:160-162.

Varaprasad KS, Sharma SB and Loknathan TR. 1997. Nematode constraints to pigeonpea and chickpea in Vidarbha region of Maharashtra in India. International Journal of Nematology 7:152-157.

CGIAR-published references on seed health

Nil

Insects

Callosobruchus analis Fabricius.

Synonyms

Bruchus analis, *Bruchus glaber*, *Bruchus jekelii*, *Bruchus obliquus*, *Bruchus ciceri*, *Callosobruchus glaber*, *Callosobruchus jekelii*

Disease name

Stored grain pest

Importance to CGIAR Centers

Medium

Significance

Infested pigeonpea lose their viability and are unfit for human consumption. In Africa, Asia and Oceania, *C. analis* is considered a pest of economic importance for stored-legume grains (Southgate 1979).

Symptoms

Pigeonpea pods are seldom infested in the field. The pests attack nearly mature and dried pods during storage. The round exit hole and the white eggs on the pod wall are conspicuous. Infested stored seed can be recognized



PP Fig. 4. Stored grain pest (*Callosobruchus analis*) of pigeonpea: A. adult (Source: www.invasive.org/brows/detail=066007); B. infested pods and C. infested seed and white eggs (Source: ICRISAT IB No. 26).

by the eggs on the seed surface, and the round exit holes with the 'flap' of seed coat.

Hosts

Cicer arietinum (chickpea), *Cajanus cajan* (pigeonpea) and other grain legumes.

Geographic distribution

Callosobruchus analis is widespread in Asia.

Biology and transmission

Adults are small, 3 mm long brown beetles with black spots on the elytra. Eggs are laid on the seed surface. Larvae feed and pupate entirely within the seed. One generation is completed in 4-5 weeks (Ranga Rao and Shanower 1999).

Detection/indexing methods used in CGIAR

Dry seed examination and X-ray radiography are used for detection of the bruchides.

Treatment

At ICRISAT: Fumigation with methyl bromide @ 32 g m⁻³ for 4 h followed by seed treatment with chlorpyrifos 3 g kg⁻¹ seed (Ghanekar et al. 1996).

Procedures in CGIAR in case of positive test

Removal of the infested seeds followed by seed treatment with chlorpyrifos at 3 g kg⁻¹ seed.

EPPO protocols

Not available.

General references

Ghanekar AM, Ranga Rao GV, Murthy KS, Surender A and Shaik Babu Saheb. 1996. Seed protectants for healthy exports. Indian Journal of Plant Protection 24:37-43.

Ranga Rao GV and Shanower TG. 1999. Identification and Management of Pigeonpea and Chickpea Insect Pests in Asia. Information Bulletin No. 57, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 96 pp.

Southgate BJ. 1979. Biology of the Bruchidae. Annual Review of Entomology 24:449-473.

CGIAR-published references on seed health

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Trogoderma granarium Everts.

Synonyms

Trogoderma afrum, *Trogoderma khapra*, *Trogoderma quinquefasciata*

Common name

Khapra beetle

Importance to CGIAR Centers

High



PP Fig. 5. Khapra Beetle (*Trogoderma granarium*) of pigeonpea: A. adults and B. larvae and damaged grains (Source: www.agpsprv34.agric.wa.gov.au).

Significance

Trogoderma granarium is a serious pest of stored products under hot dry conditions. Established infestations are difficult to control because of the beetle's ability to live without food for long periods of time and to survive on foods of low moisture content, its habit of crawling into tiny cracks and crevices and remaining there for long periods, and its relative tolerance to many surface insecticides and fumigants.

Symptoms

The khapra beetle is one of the world's most feared stored-product pests. The obvious signs of a khapra beetle infestation are the larvae and cast skins. Larvae and adults are best identified by microscopic examination. Larvae are mostly seen just before dusk, since they are more active at that time (Anonymous 1981).

Host

Larvae feed on a wide variety of stored products and dried foods. They prefer whole grain and cereal products such as *Triticum aestivum* (wheat), *Hordeum vulgare* (barley), and *Oryza sativa* (rice), but larvae have been recorded on the following: *Avena spp.* (oats), *Secale spp.* (rye), *Zea mays* (corn), dried blood, dried milk, fishmeal, *Arachis hypogaea* (groundnut), flour, bran, malt, *Linum usitatissimum* (flax seed), *Medicago sativa* (alfalfa seed), *Lycopersicum esculantum* (tomato seed), *Phaseolus vulgaris* (pinto beans), *Vigna unguiculata* (blackeyed cowpeas), *Sorghum bicolor* (sorghum seed) and many other food products (Lindgren and Vincent 1959, Lindgren et al. 1955).

Geographic distribution

The distribution of khapra beetle extends from Myanmar (Burma) to West Africa and is limited by the 35° parallel to the north and the equator to the south. It has been introduced by commerce into some areas of similar climatic conditions (Anonymous 1981). The khapra beetle is found in all continents where grain and grain products are stored.

Biology and transmission

The adults are oblong-oval beetles, approximately 1.6 to 3.0 mm long and 0.9 to 1.7 mm wide. Males are brown to black with indistinct reddish brown markings on elytra. Females are slightly larger than males and lighter in color. The head is small and deflexed with a short 11-segmented antenna. The antennae have a club of three to five segments, which fit into a groove in the side of the pronotum. The adults are covered with hairs. The eggs are milky white, turning pale yellowish with age, cylindrical, 0.7×0.25 mm, one end rounded, the other pointed and bearing spine-like projections. Larvae are uniformly yellowish white, except for the head and body hairs, which are brown. As the larvae increase in size, their body color changes to a golden or reddish brown, more body hairs develop, and the tail becomes proportionally shorter. Mature larvae are approximately 6 mm long and 1.5 mm wide. Adult khapra beetles have wings, but do not fly and feed very little. Mated females live from four to seven days, unmated females from 20 to 30 days, and males from seven to 12 days. Mating occurs about five days after emergence, and egg laying begins almost immediately at 40°C. Egg laying may begin at one to three days at cooler temperatures, but no eggs are produced at 20°C. Eggs hatch in three to 14 days after the female lays an average of 50 to 90 eggs that are loosely scattered in the host material. Complete development from egg to adult can occur from 26 to 220 days, depending upon the temperature. Optimum temperature for development is 35°C. If the temperature falls below 25°C for a period of time or if larvae are very crowded, they may enter diapauses. They can survive temperatures below -8°C. In diapauses, the larvae can molt but are inactive and may remain in this condition for many years (Anonymous 1981).

Detection/indexing methods used in CGIAR

At ICRISAT: Dry seed examination using magnifying lens

Treatment

High concentrations of fumigant (Aluminium phosphide) are maintained during the fumigation period to allow penetration into all cracks and crevices. In an eradication program, both fumigants and surface treatment (chlorpyrifos) are used in combination with preventive measures, eg, good sanitation practices and exclusion.

Procedures in CGIAR in case of positive test

At ICRISAT: Rejection and incineration of the infested seed samples

EPPO protocols

Not available.

General references

Anonymous. 1981. Data sheets on quarantine organisms. *Trogoderma granarium* Everts. Pages 1-6 in European and Mediterranean Plant Protection Organization Bulletin 11 (1) Set 4, List A2.

Lindgren DL and Vincent LE. 1959. Biology and control of *Trogoderma granarium* Everts. Journal of Economic Entomology 52:312-319.

Lindgren DL, Vincent LE and Krohne HE. 1955. The khapra beetle, *Trogoderma granarium* Everts. Hilgardia 24:1-36.

CGIAR-published references on seed health

Nil

Groundnut (*Arachis hypogaea* Linn.)

Bacterium

Ralstonia solanacearum (Smith) Yabuuchi et al.

Synonyms

Bacterium solanacearum, *Burkholderia solanacearum*, *Pseudomonas solanacearum*

Disease name

Bacterial wilt

Importance to CGIAR Centers

Medium

Significance

Bacterial wilt is a major constraint to groundnut production in China, Indonesia and Vietnam. Yield losses of 10 to 30% commonly occur and can reach over 60% in heavily infested fields (Mehan et al. 1994).

Symptoms

Wilt symptoms can be seen 2-3 weeks after planting. The first sign of disease is a slight drooping or curling of one or more leaves. In more advanced stages, the plants may bend over at the tip, appear dry, and eventually turn brown, wither, and die. Infected plants have discolored and rotten roots and pods. The diagnostic characteristics of this disease are the dark brown discoloration in the xylem and pith, and the streaming of 'bacterial ooze' (Mehan et al. 1994).

Hosts

Arachis hypogaea (groundnut), *Capsicum* spp. (chilies), *Gossypium hirsutum* (Cotton), *Ipomoea batatas* (sweet potato), *Lycopersicon esculentum* (tomato), *Manihot esculenta* (cassava), *Musa* spp. (banana), *Nicotiana* spp. (tobacco), *Solanum melongena* (brinjal), *Solanum tuberosum* (potato) and *Zingiber officinale* (zinger).



GN Fig. 1. Bacterial wilt (*Ralstonia solanacearum*) of groundnut: drooping and curling of leaves (Source: ICRISAT IB No. 50).

Geographic distribution

Bacterial wilt is global in distribution, and mostly prevalent in several countries of Asia, Africa and North America.

Biology and transmission

Ralstonia solanacearum is an aerobic, non-spore-forming, rod shaped, gram-negative bacterium. The bacterial cells measure approximately $0.5 \times 1.5 \mu$. Virulent isolates are mainly non-flagellate and non-motile. Avirulent isolates usually bear 1-4 polar flagellae and are highly motile. Common fimbriae are often present in both virulent and avirulent isolates. Although it does not produce fluorescent pigments, it produces a brown diffusible pigment on a variety of agar media containing tyrosine. The bacterium grows at a wide range of temperatures from 25 to 35°C. The bacterium is mainly disseminated through infested soil, water and infected seed (Anitha et al. 2003).

Detection/indexing methods used in CGIAR

At ICRISAT

Direct plating of 4-week old leaf-twigs, leaf-bits and seed on Tetrazolium chloride agar (TZCA) medium is used to detect the wilt pathogen in groundnut (Prasada Rao et al. 2000, Anitha et al. 2004).

Treatment

Not available

Procedures in CGIAR in case of positive test

At ICRISAT: Incineration of the infected plants and rejection of the seed samples

EPPO protocols

Not available.

General references

Anitha K, Gunjotikar GA, Chakrabarty SK, Singh SD, Sarath Babu B, Prasada Rao RDVJ and Varaprasad KS. 2003. Interception of bacterial wilt, *Burkholderia solanacearum* in groundnut germplasm imported from Australia. Journal of Oilseeds Research 20:101-104.

Anitha K, Chakrabarty SK, Girish AG, Prasada Rao RDVJ and Varaprasad KS. 2004. Detection of bacterial wilt infection in imported groundnut germplasm. Indian Journal of Plant Protection 32:147-148.

Mehan VK, Liao BS, Tan YJ, Robinson-Smith A, McDonald D and Hayward AC. 1994. Bacterial wilt of groundnut. Information Bulletin No. 35. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 28 pp.

Prasada Rao RDVJ, Gunjotikar GA, Chakrabarty SK, Varaprasad KS, Singh SD and Bramel-Cox PJ. 2000. Detection of *Ralstonia solanacearum* in seeds of wild *Arachis* spp. imported from Brazil. Indian Journal of Plant Protection 28:51-56.

CGIAR-published references on seed health

Nil

Fungi

Verticillium dahliae Kleb.

Synonyms

Verticillium albo-atrum var. *chlamydosporale*, *Verticillium albo-atrum* var. *dahliae*, *Verticillium albo-atrum* var. *medium*, *Verticillium dahliae* f. *chlamydosporale*, *Verticillium dahliae* f. *medium*, *Verticillium ovatum*, *Verticillium tracheiphilum*

Disease name
Verticillium wilt

Importance to CGIAR Centers
High

Significance

Verticillium dahliae affects many important crops including peanut and causes losses of economic significance in many countries.

Symptoms

Early symptoms usually appear at the flowering stage and include marginal chlorosis of the leaves, loss of leaf turgidity and leaf curling. Leaf symptoms are generally yellowing and leaflet necrosis, followed by wilting and defoliation. The roots of the infected plants have brown discoloration of the



GN Fig. 2. *Verticillium wilt (Verticillium dahliae) of groundnut: marginal chlorosis, leaf curling, tiger striping and yellowing of leaves (Source: ICRISAT IB No. 36).*

vascular tissues. Occasionally plants die, and the roots of the dead plants are severely rotted (Subrahmanyam et al. 1992).

Hosts

Verticillium dahliae has a very wide host range among economically important crops such as *Gossypium* (cotton), *Solanum tuberosum* (potato), *Solanum melongena* (aubergine), *Capsicum annuum* (bell pepper), *Olea europaea* subsp. *europaea* (olive), *Brassica napus* var. *napus* (rape), *Fragaria ananassa* (strawberry), *Humulus lupulus* (hop), *Lycopersicon esculentum* (tomato), *Medicago sativa* (lucerne), *Mentha* (mints), *Arachis hypogaea* (groundnut), *Armoracia rusticana* (horseradish), *Brassica oleracea* var. *gemmifera* (Brussels sprouts), *Pistacia vera* (pistachio), *Prunus* (stone fruit) and *Vitis vinifera* (grapevine).

Geographic distribution

Verticillium dahliae is worldwide in distribution, including Asia, Africa, Europe, USA and Australia.

Biology and transmission

Verticillium dahliae is a moderately to fast-growing fungus with little to moderate aerial mycelium and a regular margin, turning black from the centre after a week due to production of microsclerotia. Conidiophores are verticillate and conidiogenous cells subtended in whorls (2-3 per node), and are erect and hyaline. Conidia are ellipsoidal, hyaline, mostly one-celled and produced at the tips of narrow, pointed sterigmata. Conidia are 2.5-6×1.5-3.0 µm in size. Conidia are produced in succession to form moist spore balls at the tips of conidiogenous cells, giving characteristic appearance to conidiophore in culture. Microsclerotia are of irregular shape and size (50-200×15-100 µm), dark brown to black and globose. The fungus survives in soil as microsclerotia that germinate in response to root exudates. The hyphae or germinating conidia penetrate the cortex of young roots and the fungus grows into the stele. In the xylem vessels, the pathogen spreads by mycelial growth, and also by the production of conidia, which get into the transpiration stream. Microsclerotia are formed in senescing diseased tissues. The pathogen is disseminated throughout the field soil by farm equipment, wind and water movement and by infected seed.

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection and blotter test are used.

Treatment

Not available

Procedures in CGIAR in case of positive test

At ICRISAT: Incineration of the infected plants and rejection of the infected seed samples

EPPO protocols

EPPO A2 list: No. 85

Detection. Use of DNA hybridization probes (Robb et al. 1990) and ELISA test for *V. albo-atrum* are in use in France for testing certified pelargonium (OEPP/EPPO 1992).

Phytosanitary risk. EPPO has listed hop-infecting strains of *V. albo-atrum* and *V. dahliae* as A2 quarantine pests (OEPP/EPPO 1982), but no other regional plant protection organization has done so. Regulatory control may remain appropriate, but may take on the character of a certification scheme for planting material.

Phytosanitary measures. EPPO recommends (OEPP/EPPO 1990) that hop planting material should come from a field where verticillium wilt has not occurred in the last 5 years and that consignments and their mother plants should have been found free from the disease in the last growing season. Such measures are as relevant in a national certification scheme as for international phytosanitary certification.

General references

OEPP/EPPO. 1982. Data sheets on quarantine organisms No. 85, Hop-infecting strains of *Verticillium albo-atrum* and *V. dahliae*. *Bulletin*, OEPP/EPPO Bulletin 12 (1).

OEPP/EPPO. 1990. Specific quarantine requirements. EPPO Technical Documents No. 1008.

OEPP/EPPO. 1992. Certification schemes No. 3. Pathogen-tested material of pelargonium. OEPP/EPPO Bulletin 22:285-296.

Robb J, Hu X, Schmidt J and Nazar R. 1990. DNA hybridization probes for the identification and quantification of *V. dahliae* and *V. albo-atrum*. Page 97 in Abstracts of the Proceedings of 5th International Verticillium Symposium, Leningrad, USSR.

Subrahmanyam P, Wongkaew S, Reddy DVR, Demski JW, McDonald D, Sharma SB and Smith DH. 1992. Field diagnosis of groundnut diseases. Information Bulletin No. 36, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 84 pp.

CGIAR-published references on seed health

Nil

Colletotrichum dematium (Pers.) Grove.

Synonyms

Colletotrichum bakeri, *Colletotrichum brassicae*, *Colletotrichum lysimachiae*, *Colletotrichum pucciniophilum*, *Colletotrichum sanguisorbae*, *Colletotrichum volutella*, *Dinemasporium dianthi*, *Ellisiellina volutella*, *Sphaeria dematium*, *Vermicularia bakeri*, *Vermicularia dematium*, *Vermicularia dianthi*, *Vermicularia echinata*, *Vermicularia lagunensis*, *Vermicularia lysimachiae*, *Vermicularia volutella*.

Disease name

Anthracnose

Importance to CGIAR Centers

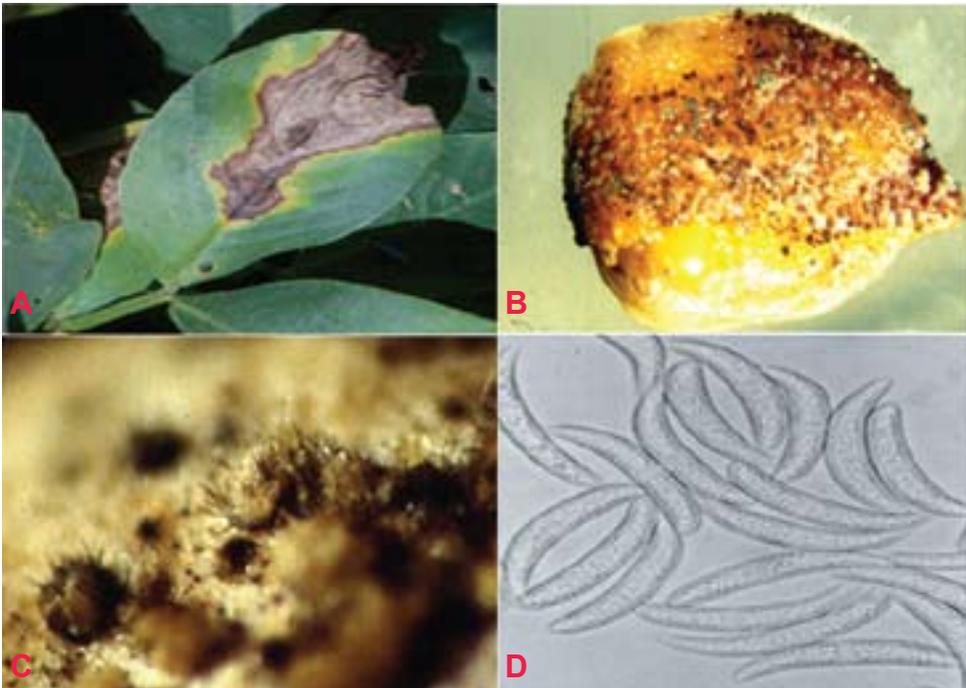
Low

Significance

Anthracnose in peanut is of minor importance.

Symptoms

Symptoms appear as wedge-shaped lesions on the leaflet tips. Lesions may also develop on the leaflet margins leading to marginal blight. The periphery of the advancing margins of the lesion is surrounded by the yellow zone. The necrotic tissue becomes dark brown and tends to fragment along the leaflet margins. The disease may also extend to stipules and stems. Fruiting bodies (acervuli) are visible through a hand lens, and are abundant on infected leaf tissue (Subrahmanyam et al. 1992).



GN Fig. 3. Anthracnose (*Colletotrichum dematium*) of groundnut: A. wedge-shaped lesions on the leaflet; B. fungal growth on seed; C. acervuli with setae on seed and D. conidia (Source: ICRISAT IB Nos. 34 and 36).

Hosts

Allium cepa (onion), *Allium porrum* (leek), *Allium sativum* (garlic), *Arachis hypogaea* (groundnut), *Beta vulgaris* (beetroot), *Helianthus annuus* (sunflower), *Piper betle* (betel pepper), *Vicia faba* (broad bean), *Voandzeia subterranea* (bambara groundnut), *Abelmoschus esculentus* (okra), *Allium* (onions, garlic, leek, etc), *Cicer arietinum* (chickpea), *Capsicum annum* (bell pepper), *Crotalaria juncea* (sunn hemp), *Glycine max* (soyabean), *Lablab purpureus* (hyacinth bean), *Lycopersicon esculentum* (tomato), *Vigna radiata* (bean, mung), *Vigna mungo* (black gram), *Spinacia oleracea* (spinach).

Geographic distribution

Colletotrichum dematium is worldwide in distribution, especially in India, Niger, Nigeria, Sudan, Senegal, Taiwan, Tanzania, Thailand, Uganda and USA.

Biology and transmission

Mycelium of *C. dematium* is hyaline, it produces circular, erumpent, dark brown to black acervuli. These acervuli are scattered on the infected pods, aggregated or in groups. Acervuli exude spores in pale to smoke-gray masses. Numerous thick, black, erect setae are interspersed within the acervuli. Conidia are hyaline, 1-celled and $2.5-4.0 \times 15-32 \mu\text{m}$ in size. They are fusoid and bluntly tapered at both ends (Ahmed and Ravinder Reddy 1993).

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection and blotter test are used

Treatment

Not available

Procedures in CGIAR in case of positive test

At ICRISAT: Rejection of seed samples in case of positive test

EPPO protocols

Not available.

General references

Ahmed KM and Ravinder Reddy Ch. 1993. A Pictorial guide to the identification of seed borne fungi of sorghum, pearl millet, finger millet, chickpea, pigeonpea and groundnut. Information Bulletin No. 34. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 200 pp.

Subrahmanyam P, Wongkaew S, Reddy DVR, Demski JW, McDonald D, Sharma SB and Smith DH. 1992. Field diagnosis of groundnut diseases. Information Bulletin No. 36, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 84 pp.

CGIAR-published references on seed health

Nil

Rhizoctonia bataticola (Tassi) E.J. Butler [*Macrophomina phaseolina* (Tassi) Goid]

Synonyms

Botryodiplodia phaseoli, *Dothiorella cajani*, *Dothiorella phaseoli*, *Dothiorella philippinensis*, *Fusicoccum cajani*, *Macrophoma cajani*, *Macrophoma corchori*, *Macrophoma phaseoli*, *Macrophoma phaseolina*, *Macrophoma sesami*, *Macrophomina phaseoli*, *Macrophomina philippinensis*, *Rhizoctonia lamellifera*, *Sclerotium bataticola*, *Tiarosporella phaseoli*, *Tiarosporella phaseolina*.

Disease name

Root rot or Charcoal rot

Importance to CGIAR Centers

High

Significance

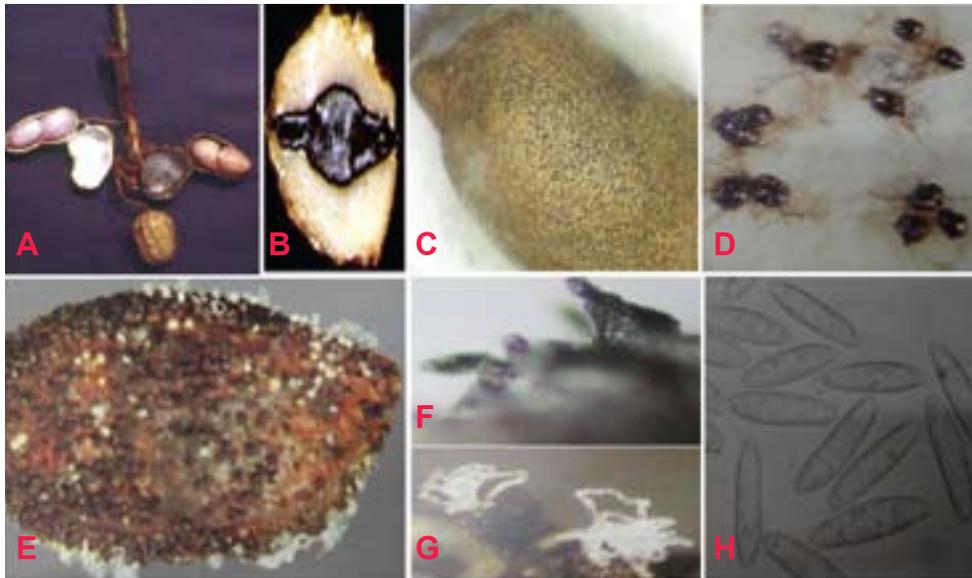
Charcoal rot is economically important across a broad range of crops throughout the world, particularly in regions that experience hot, dry conditions during the growing period. Yield losses in groundnut of 100, 94 and 63% have been reported when disease appeared at the pre-emergence, pre-pod and pod-filling stages, respectively (Sharma and Bhowmik 1986).

Symptoms

Water-soaked lesions appear on the hypocotyl near the soil surface. The lesions enlarge, become dull brown, girdle the hypocotyl, and kill the plants. Lesions on the roots appear water-soaked at first, but infected tissues eventually have a dull, light-brown appearance. Later, affected areas become covered with sclerotia. Roots become rotten and blackened with shredding of the taproot. The dead tissues rot and turn black, as sclerotia of the fungus develop profusely. Infected pegs and pods also rot and become covered with sclerotia.

Hosts

Many crop plants including *Allium cepa* (onion), *Allium sativum* (garlic), *Arachis hypogaea* (groundnut), *Beta vulgaris* var. *saccharifera* (sugarbeet), *Brassica oleracea* var. *botrytis* (cauliflower), *Cajanus cajan* (pigeonpea),



GN Fig. 4. Charcoal rot (*Rhizoctonia bataticola*) of groundnut: A. water soaked necrotic lesions on pods; B. infected cotyledon; C. infected seed with sclerotia; D. sclerotia; E. pycnidia and conidial ooze on seed; F. pycnidia; G. conidial ooze and H. conidia of *Macrophomina phaseolina* (Source: ICRISAT IB Nos. 34 and 36).

Carthamus tinctorius (safflower), *Cicer arietinum* (chickpea), *Cyamopsis tetragonoloba* (clusterbean), *Coriandrum sativum* (coriander), *Capsicum annuum* (bell pepper), *Cucumis melo* (melon), *Cucumis sativus* (cucumber), *Curcuma longa* (turmeric), *Crocus sativus* (saffron), *Glycine max* (soyabean), *Helianthus annuus* (sunflower), *Nicotiana tabacum* (tobacco), *Oryza sativa* (rice), *Pennisetum glaucum* (pearl millet), *Vigna radiata* (bean, mung), *Vigna mungo* (black gram), *Phaseolus vulgaris* (common bean), *Sorghum bicolor* (common sorghum), *Vigna unguiculata* (cowpea) and *Zea mays* (maize)

Geographic distribution

Rhizoctonia bataticola is worldwide in distribution.

Biology and transmission

Sclerotia are black, smooth, hard and 0.1-1 mm diameter, and occur within roots, stems, leaves and fruits. Conidiomata are pycnidial, dark-brown, and either solitary or gregarious on leaves and stems; they are immersed, becoming erumpent, 100-200 µm diameter, opening by an apical ostiole; the conidiomatal wall is multicellular with heavily pigmented, thick-walled cells

on the outermost side. Conidiophores are hyaline, short and obpyriform to cylindrical, 5-13×4-6 µm. Conidia are hyaline, ellipsoid to obovoid, 14-30×5-10 µm (Ahmed and Ravinder Reddy 1993). *R. bataticola* or *M. phaseolina* was detected in the seed coat, cotyledons and embryo of groundnut (Chakrabarty et al. 2005). It survives under different temperatures from -18°C to 20°C (Singh et al. 2003).

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection and blotter test.

Treatment

Seed treatment with a mixture of carbendazim and thiram (1:1) at 2 g a.i. kg⁻¹ seed

Procedures in CGIAR in case of positive test

At ICRISAT: If the seed colonization is <20%, seed treatment with a mixture of carbendazim and thiram (1:1) at 2 g a.i. kg⁻¹ is used, and seed samples having >20% colonization are rejected.

EPPO protocols

Not available.

General references

Ahmed KM and Ravinder Reddy Ch. 1993. A Pictorial guide to the identification of seed borne fungi of sorghum, pearl millet, finger millet, chickpea, pigeonpea and groundnut. Information Bulletin No. 34. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 200 pp.

Chakrabarty SK, Girish AG, Anitha K, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Detection, seedborne nature, disease transmission and eradication of seedborne infection by *Rhizoctonia bataticola* (Taub.) Butler in groundnut. Indian Journal of Plant Protection 33:85-89.

Sharma RC and Bhowmik TP. 1986. Estimation of yield losses in *groundnut* due to *Macrophomina phaseolina* (Tassi) Goid. Indian Journal of Plant Pathology 4:108-112.

Singh SD, Girish AG, Kameswar Rao N, Bramel PJ and Subhash Chandra. 2003. Survival of *Rhizoctonia bataticola* in groundnut seed under different storage conditions. Seed Science and technology Journal 31:169-175.

CGIAR-published references on seed health

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Viruses

Peanut mottle virus (PMoV).

Synonym

Peanut green mosaic virus, Peanut chlorotic mottle virus

Disease name

Peanut mottle

Importance to CGIAR Centers

High

Significance

PMoV causes substantial yield losses in many parts of the world. In some southeast Asian countries, losses up to 30-48% have been reported, and in the Indian subcontinent the virus is a potential threat to groundnut production (Reddy 1991, Prasada Rao et al. 1996).

Symptoms

Leaf symptoms on groundnuts include mild dark-green mosaic or mottle, crinkled leaflet margins and depressed interveinal tissue. Occasional leaf necrosis and deformation, chlorotic spots and stunting are also observed. Infected seeds are often malformed and discolored (Abdelsalam et al. 1987).

Hosts

Arachis chacoense (wild groundnut), *Phaseolus vulgaris* (common bean), *Lupinus angustifolius* (lupins), *Vigna radiata* (mung bean), *Pisum sativum* (pea), *Glycine max* (soybean) and forage legumes.



GN Fig. 5. Peanut mottle (*Peanut mottle virus*) of groundnut: symptoms of irregular dark green islands and interveinal depression (Source: ICRISAT IB No. 36).

Geographic distribution

PMoV is worldwide in distribution, including East Africa, southeast Asia, India, the Philippines, Taiwan, Malaysia, South America and southeast USA (Reddy 1991).

Biology and transmission

PMoV has flexuous, filamentous, non-enveloped particles ranging from 723 to 763 nm in length and 12 nm in diameter (Pietersen and Garnett 1992). Infected groundnuts are considered to be the primary source of PMoV (Prasada Rao et al. 1993), and other leguminous crops growing nearby become infected from this crop. In addition to being mechanically transmissible, PMoV is also transmitted in a non-persistent manner by several species of aphid, including *Aphis craccivora*, *Aphis gossypii*, *Hyperomyzus lactucae*, *Myzus persicae*, *Rhopalosiphum maidis* and *Rhopalosiphum padi* (Pietersen and Garnett 1992). PMoV is seed borne up to 20% in groundnuts (Bashir et al. 2000). Adams and Kuhn (1977) reported that seed transmission is due to the presence of the virus in the embryo.

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection and ELISA (Sudarshan and Reddy 1989) are used

Treatment

Not known

Procedures in CGIAR in case of positive test

At ICRISAT: Rejection of seed samples in case of positive test

EPPO protocols

Not available.

General references

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CGIAR-published references on seed health

Nil

Peanut stripe virus (PStV)

Synonym

Nil

Disease name

Peanut stripe

Importance to CGIAR Centers

Low

Significance

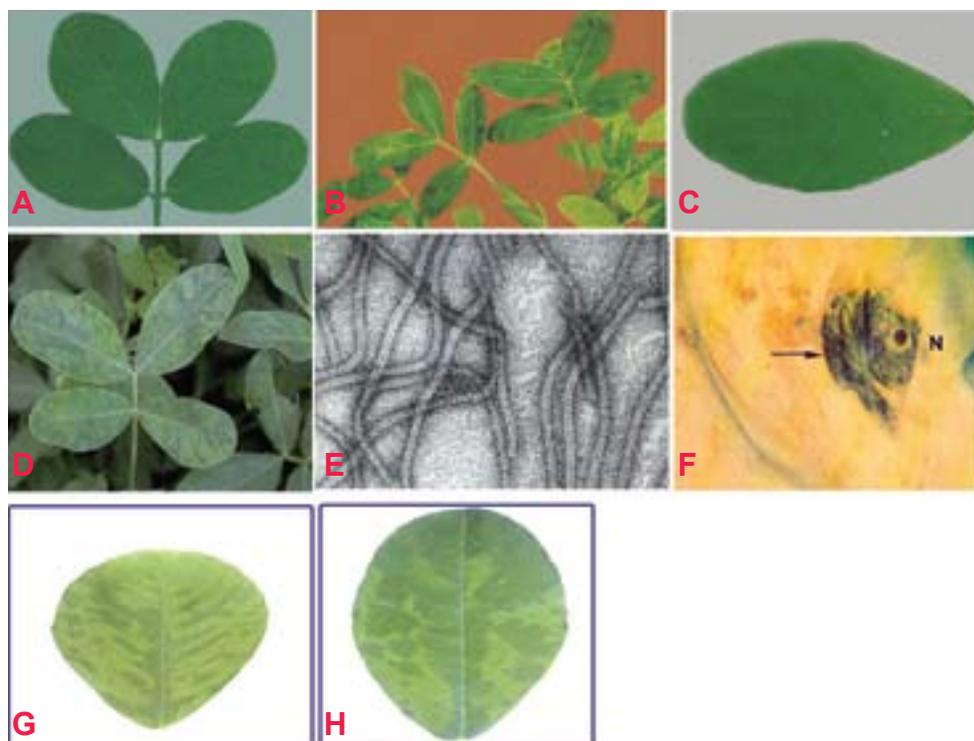
PStV has been reported to cause about 50% incidence in China (Xu et al. 1994). In Gujarat, India, the disease incidence has been recorded up to 40% (Varma et al. 1994). In southeast Asia, high incidences of up to 38% have been reported in Indonesia (Middleton and Saleh 1988) and the Philippines (Adalla and Natural 1988). PStV infection has a highly variable effect on groundnut yield, depending on the test conditions, cultivar and the virus isolate.

Symptoms

Symptoms on groundnut plants vary, depending on virus isolate and groundnut cultivar. For most isolates, the initial symptoms appear as chlorotic flecks or rings on young quadrifoliate. The plants are slightly stunted. Subsequently, the older leaves show symptoms that are more specific to the isolate: mild mottle, blotch, stripe, chlorotic ring mottle, chlorotic line pattern, oak leaf pattern or necrosis (Wongkaew and Dollet 1990). The symptoms normally persist throughout plant development. The 'stripe' [V-shaped or herringbone pattern] and 'necrotic' isolates, which are seen less often, can severely stunt the plants if they infect them early.

Hosts

Arachis hypogaea (groundnut), *Glycine max* (soyabean), *Lupinus albus* (lupine), *Medicago sativa* (lucerne), *Vigna radiata* (mung bean), *Sesamum indicum* (sesame), *Vigna unguiculata* (cowpea), *Cassia occidentalis* (coffee senna), *Cassia tora* (foetid cassia), *Centrosema pubescens* (Centro), *Calopogonium caeruleum*, *Crotalaria pallida* (smooth crotalaria), *Desmodium* (tick clovers), *Indigofera* (indigo), *Pueraria phaseoloides* (tropical kudzu), *Cassia obtusifolia* (sicklepod) and *Stylosanthes biflora* (Pencil flower).



GN Fig. 6. Peanut stripe (*Peanut stripe virus*) of groundnut: A. stripe and green banding symptoms; B. striping and mosaic (oak leaf pattern) symptoms in older leaves; C. chlorotic flecks; D. chlorotic ring mottle symptoms; E. electron micrograph ($\times 257000$); F. subdivision-IV type inclusive body (arrow) adjacent to the nucleus (N) in PStV infected leaflet; G. necrotic stripes and H. mild mottle and blotch (Source: ICRISAT IB Nos. 36 and 38).

Geographic distribution

PStV is widespread in groundnut-growing areas throughout east and south Asia. It was first detected in India in 1987 (Demski et al. 1993). It also occurs in all groundnut growing areas of Indonesia, Malaysia, Myanmar, the Philippines, Thailand and Vietnam (Demski et al. 1993).

Biology and transmission

PStV particles are filamentous flexuous rods, approx. 752 nm long and 12 nm in diameter. Each particle consists of single protein pieces of 33,500 daltons. The genome is a single stranded (ss) positive-sense RNA molecule of about 9,500 nucleotides. The particles are relatively stable and can be stained with 2% phosphotungstate or ammonium molybdate pH 6.5 (Demski et al. 1993). The virus is transmitted by several species of aphids in a non-

persistent manner, which is also the only means of disease spread under field conditions. *Aphis craccivora* is the major vector for the transmission of PSTV. Apart from *A. craccivora*, *Myzus persicae*, *A. gossypii* and *Hysteroneura setariae* have been shown to be highly efficient PSTV vectors for the transmission of the disease. PSTV transmission through groundnut seed can be as high as 37% in artificially inoculated plants (Demski et al. 2004). Under natural conditions, however, the transmission frequency is up to 7%. PSTV seed transmission frequency can be influenced by the virus isolate, groundnut cultivar and environment. The virus can be detected in both the embryo and the cotyledon, but not in the seed testa.

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection and ELISA (Sudarshan and Reddy 1989) are used

Treatment

Not known

Procedures in CGIAR in case of positive test

At ICRISAT: Rejection of seed samples in case of positive test

EPPO protocols

Not available.

General references

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CGIAR-published references on seed health

Nil

Peanut stunt virus (PSV)

Synonym

Robinia mosaic virus, Black locust true mosaic virus, Clover blotch virus

Disease name

Peanut stunt

Importance to CGIAR Centers

High

Significance

In the 1960s, PSV was a problem in Virginia, North Carolina and Georgia, but it is not of economic importance for groundnut production in the USA. However, PSV sporadically causes a high incidence of peanut stunt disease in Hebei, Henan and Liaoning provinces in China (Xu et al.1992).



GN Fig. 7. *Peanut stunt (Peanut stunt virus) of groundnut: dwarfing symptoms of branches (Source: ICRISAT IB No. 36).*

Symptoms

Symptoms vary depending on the host plant and the strain of the virus. In groundnuts, there are various degrees of stunting, shortening of the petioles, reduced leaf size, mild mottling and malformation of pods. Seeds from infected plants appear deformed, frequently with a split pericarp wall, and have poor viability.

Hosts

PSV naturally infects several leguminous host species - *Arachis hypogaea* (groundnut), *Vicia faba* (broad bean), *Glycine max* (soybean), *Pisum sativum* (pea), *Vigna unguiculata* (cowpea), *Lupinus luteus* (yellow lupin), *Nicotiana tabacum* (tobacco), *Lycopersicon esculentum* (tomato) and *Datura stramonium* (devils trumpet).

Geographic distribution

PSV is worldwide in distribution, including several countries in Europe (France, Hungary, Italy, Poland and Spain; in Asia (China, Georgia, Japan, Korea and India); in Africa (Morocco and Sudan) and also in USA (Subrahmanyam et al. 1992).

Biology and transmission

PSV particles are isometric or polyhedral, with a diameter of ca 25-30 nm. The coat protein of PSV contains a single polypeptide with an apparent molecular weight of about 26 kDa. PSV has a positive-sense tripartite genome (designated RNAs 1, 2 and 3 in order of decreasing size). In addition to the genomic RNAs, the virions also encapsulate a fourth RNA (called RNA 4), which is a subgenomic RNA that functions as mRNA for the viral-coat protein (Naidu et al. 1995). Three types of native particles exist, each consisting of the same protein shell, yet containing different RNA species. One type of particle contains genomic RNA 1, another contains RNA 2 and the third contains genomic RNA 3 and subgenomic RNA 4. However, all the particles have the same sedimentation coefficient (S_{20,w}). All three genomic RNAs, but not subgenomic RNA 4, are essential for infection. Certain naturally occurring PSV isolates also encapsidate a satellite RNA (satRNA) molecule with its genomic and subgenomic RNAs (Naidu et al. 1995). PSV-associated satRNAs are linear, single-stranded RNA molecules, ranging in size from 391 to 393 nucleotides. PSV satRNA has essentially no sequence homology with its helper virus (ie, PSV) genomic RNAs (Collmer et al. 1985). Depending

on the PSV strain and host species involved, satRNAs can modulate the symptoms caused by PSV (Naidu et al. 1992). PSV supports the replication of its satRNAs but not those associated with cucumber mosaic virus. PSV is transmitted in nature by insect vectors - *Aphis craccivora*, *A. spiraecola* and *Myzus persicae*. It is transmitted in a non-persistent manner. PSV can also be transmitted by mechanical inoculation. PSV is transmitted in a small percentage (0.1%) through groundnut seeds (Kuhn 1969).

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection, double-antibody-sandwich (DAS)-ELISA and an indirect ELISA are used to detect PSV (Bharathan et al. 1984).

Treatment

Not known

Procedures in CGIAR in case of positive test

At ICRISAT: Incineration of the infected plants and rejection of the infected seeds

EPPO protocols

Not available

General references

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CGIAR-published references on seed health

Nil

Peanut clump virus (PCV).

Synonym

Indian Peanut Clump Virus (IPCV)

Disease name

Peanut clump

Importance to CGIAR Centers

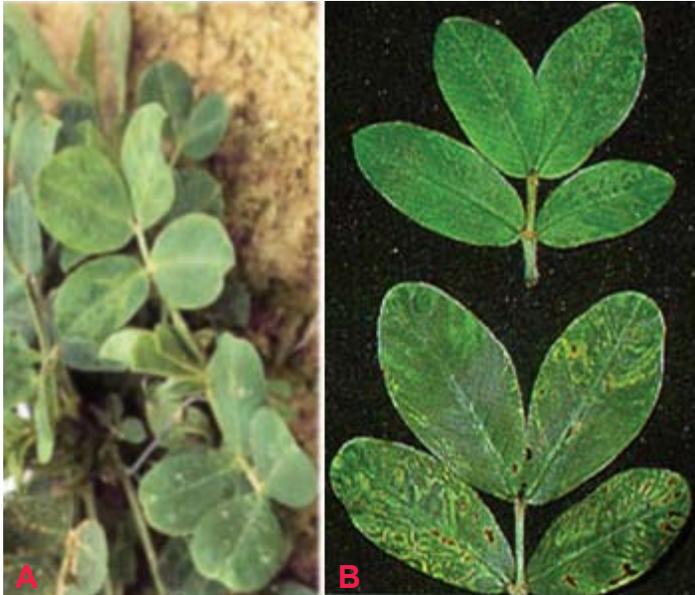
High

Significance

PCV infected plants do not produce pods, and yield losses in groundnut grown in light sandy soils are as high as 60% even in late infected crops (Reddy et al. 1988).

Symptoms

Plants affected by clump disease are conspicuous in the field because of their severe stunting and dark green appearance. Initial symptoms appear on young leaflet as mottling, mosaic and chlorotic rings, but later turn dark green with or without faint mottling as the leaves mature. Early infected plants become severely stunted. Late infected plants may not show conspicuous stunting but appear dark green with faint mottling on younger leaflets. In late infected plants, clumping may be restricted to a few branches. Infected plants become bushy and produce several flowers. Early infected plants may not produce any pods and late infected plants may produce poorly developed pods (Reddy et al. 1988). These plants often occur in patches and the disease reoccurs in the same area of the groundnut field in successive years.



GN Fig. 8. Peanut clump (Peanut clump virus) of groundnut: A. mosaic and mottling symptoms; B. darker green and faint mottling older leaves and chlorotic rings (Source: ICRISAT IB No. 36).

Hosts

PCV causes disease in *Triticum* (wheat), *Hordeum vulgare* (barley), *Saccharum officinarum* (sugarcane), *Capsicum spp* (chili), and *Cajanus cajan* (pigeonpea). It also infects *Sorghum bicolor* (sorghum), *Zea mays* (maize), *Oryza sativa* (rice), *Brassica juncea* (mustard), *Glycine max* (soybean) and *Vigna radiata* (mung bean), but these hosts do not exhibit symptoms (Thouvenel and Fauquet 1981).

Geographic distribution

The disease affects groundnut in several countries in western Africa, including Burkina Faso, Ivory Coast and Senegal, several countries of Asia, including India and Pakistan, and also in South Africa (Delfosse et al. 1995).

Biology and transmission

IPCW particle dimensions in leaf dip preparations are $184 \pm 8 \times 24 \pm 2$ nm in uranyl acetate and 169 ± 5 and $239 \pm 13 \times 20 \pm 1$ nm in phosphotungstate (Thouvenel and Fauquet 1981). In IPCW-Ludhiana strain, 175 nm particles

contain RNA-2 (1.35×10^6 mol. wt) and 235 nm particles contain RNA-1 (1.84×10^6 mol. wt). Both particles induce local lesions in bean tissues. IPCV isolates from India have been grouped into 3 distinct serotypes - IPCV-H (Hyderabad), IPCV-D (Durgapura) and IPCV-L (Ludhiana). Complementary DNA hybridization tests have shown that isolates D, H and L of IPCV are related to each other but not to furoviruses (Robinson and Reddy 1985). IPCV is seed transmitted up to 11% in groundnut and also through seeds of finger millet, pearl millet, foxtail millet, wheat and maize. IPCV has been transmitted by *Polymyxa graminis* (Ratna et al. 1991).

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection, Double antibody sandwich ELISA (DAS-ELISA) and Nucleic acid hybridization (Reddy et al. 1985) tests are used.

Treatment

Seed treatment is not available but the disease is satisfactorily controlled by adopting appropriate cultural practices over a period of time.

Procedures in CGIAR in case of positive test

At ICRISAT: Incineration of the infected crop and rejection of the infected seeds are used in case of positive test.

EPPO protocols

Not available.

General references

Delfosse P, Bashir M, Malik SN and Reddy AS. 1995. Survey of groundnut viruses in Pakistan. *International Arachis Newsletter* 15:51-52.

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CGIAR-published references on seed health

Nil

Nematodes

Ditylenchus destructor Thorne.

Synonym

Not available

Common name

Potato tuber nematode or potato rot nematode

Importance to CGIAR Centers

Medium

Significance

It has been a problem in all the groundnut-producing areas of South Africa (Jones and De Waele 1988). It is suspected that the population in South Africa may be a separate ecotype or pathotype and may be confined to groundnuts.

Symptoms

The most common symptoms include stunting and chlorosis of affected plants. Hulls of groundnuts show black discoloration, which appear first along the longitudinal veins. The kernels are shrunken. The infected testae are brown to black and the embryo shows a brown discoloration (Jones and De Waele 1988).

Host

Potatoes (*Solanum tuberosum*) are the main host of *D. destructor*, but the nematode can also occasionally be found on bulbous *Trifolium spp.* (clover), *Daucus carota* (carrots), *Arachis hypogaea* (groundnut) and *Allium sativum* (garlic). Overall, some 70 crops and weeds and a similar number of fungus species have been recorded as hosts (Thorne 1961).

Geographical distribution

Ditylenchus destructor is worldwide in distribution. It occurs in EPPO region (Albania, Austria, Belarus, Belgium, Bulgaria, Czech Republic, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Romania, Russia (European), Slovakia, Spain, Sweden, Switzerland, Turkey and UK); in Asia (Azerbaijan, China, Iran, Japan, Kazakhstan, Saudi Arabia, Tajikistan, Turkey, Uzbekistan); in South Africa; in North America (Canada, Mexico and USA); in South America; in Oceania (Australia and New Zealand).

Biology and transmission

Adults of *D. destructor* are minute worm-like animals, 0.8-1.4 mm in length and 23-47 μm in diameter. Considerable morphometric variation occurs in adults according to their host and/or age. Males and females are similar in general appearance. In females, the ost-vulval sac extends about three-quarters of the distance to the anus, and the tail has a narrow rounded terminus. Males have ventrally curved, anteriorly expanded spicules. There are four juvenile stages (the first preceding hatching of the egg), superficially similar to adults, but differing in size and in lacking developed reproductive organs. Unlike the closely related species *D. dipsaci*, *D. destructor* is unable to withstand excessive desiccation, and for this reason it is usually more important in cool and moist soils. Without a resistant resting stage, the species overwinters in soil as adults or larvae and may even multiply by feeding on alternative weed hosts (eg, *Mentha arvensis*, *Sonchus arvensis*) and on fungal mycelium. It may also possibly overwinter as eggs. These hatch in the spring and larvae are immediately able to parasitize hosts. Egg hatch at 28°C begins 2 days after egg laying, with an average interval of 4.4 days between egg laying and hatch, and development from egg to adult takes between 6 and 7 days (Hooper 1973).

Detection/indexing methods used in CGIAR

At ICRISAT: Pre export field inspection and seed washing to detect the nematodes.

Treatment

Seed dressing of groundnut prior to planting with thiram or benomyl wettable powder gives very good control (Fujimura et al. 1989).

Procedures in CGIAR in case of positive test

At ICRISAT: Incineration of the infested crop and rejection of the seed samples.

EPPO protocols

Ditylenchus destructor was considered to be an EPPO A2 quarantine pest (OEPP/EPPO 1978) but was deleted from the quarantine list in 1984 because of its minor importance and very wide distribution throughout the EPPO region, in particular in those areas where it would be likely to cause crop damage.

General references

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Thorne G. 1961. Principles of nematology. New York, USA: McGraw-Hill Book Co. Inc. 533 pp.

CGIAR-published references on seed health

Nil

Aphelenchoides arachidis Bos.

Synonym

Nil

Common name

Groundnut testa nematode

Importance to CGIAR Centers

High

Significance

Nematode infection does not suppress yield, but causes serious qualitative damage and predisposes seeds to fungal infection by *Fusarium* sp., *Macrophomina phaseolina*, *Rhizoctonia solani* and *Sclerotium rolfsii*. These infected seeds are under-graded and unmarketable (Bridge and Hunt 1985, Minton and Baujard 1990, Stokes 1980).

Symptoms

Aphelenchoides arachidis occurs as an endoparasite on the tissues of the pods, testas, roots and hypocotyls. Testas infected with *A. arachidis* are thicker and more uneven than normal testas. Heavily infected seeds had translucent testas shortly after removal of the fully mature pods. These seeds are also a lighter brown and have darker vascular strands within testas (Stokes 1980).

Host

Arachis hypogaea (peanut) is the principal host; other agronomic crops and weeds can be infected without showing any symptoms or damage. These hosts include *Zea mays* (maize), *Oryza sativa* (rice), *Saccharum officinarum* (sugarcane) and unidentified grasses (CABI 2001).

Geographical distribution

This nematode has been reported only from Nigeria.

Biology and transmission

Females of *Aphelenchoides arachidis* are characterized by a lateral field marked by two incisures, a stylet 11-12 µm long with distinct knobs, a

postvulval uterine sac extending to half the vulva-anus distance, and a sub-cylindroid tail with a bluntly rounded terminus provided by a mucro. The nematode develops and reproduces in the seed coat (testa), and also in the pod, root and hypocotyl tissues causing discoloration, necrosis and brown stripes within the testas. The nematode-infected seeds appear shrunken and dark. This pest can survive in low numbers in pods and seeds (Bridge and Hunt 1985). The nematode is disseminated by infected peanut hulls and seeds. Because of its limited distribution (Nigeria), *A. arachidis* has not caused major economic losses, but this pest can become a major economic pest if introduced in large peanut-producing areas (Minton and Baujard 1990).

Detection/indexing methods used in CGIAR

At ICRISAT: Seed washing test is used to detect the nematode.

Treatment

Hot water treatment at 60°C for 5 minutes eliminates the nematode (Stokes 1980).

Procedures in CGIAR in case of positive test

At ICRISAT: Incineration of the plants and rejection of the seed samples in case of positive test.

EPPO protocols

Not available.

General references

Bridge J and Hunt DJ. 1985. *Aphelenchoides arachidis*. CIH description of plant parasitic nematodes Set 8, No. 116:3. St. Albans, UK: Commonwealth Institute of Helminthology.

CAB International. 2001. *Aphelenchoides arachidis*. In Crop protection compendium, global module, 3rd edition. Wallingford, UK: CAB International.

Minton NA and Baujard P. 1990. Nematode parasites of peanuts. Pages 285-320 in Plant parasitic nematodes in tropical and subtropical agriculture (Luc M, Sikora RA and Bridge J, eds.). Wallingford, UK: CAB International.

Stokes DE. 1980. The effects of the testa nematode, *Aphelenchoides arachidis*, on peanuts. Nematology Circular No. 68. Gainesville, FL, USA: Florida Department of Agriculture and Consumers Services, Division of Plant Industry.

CGIAR-published references on seed health

Nil

Insects

Caryedon serratus Olivier.

Synonym

Caryedon gonagra, *Caryedon fuscus*, *Caryedon languidus*, *Pachymerus sicutensis*, *Caryedon sicutensis*, *Caryedon acaciae*, *Pachymerus conger*, *Bruchus serratus*, *Caryedon gonager*, *Caryoborus gonagra*, *Pachymerus gonagra*, *Caryoborus gonager*, *Caryoborus serratus*, *Pachymerus serratus*

Common name

Peanut bruchid beetle, groundnut bruchid, tamarind weevil, groundnut borer or seed beetle

Importance to CGIAR Centers

High

Significance

Caryedon serratus is a serious pest of stored groundnuts, particularly when these are still in their shells. The damage caused is particularly significant when the nuts are destined for confectionary purposes.

Symptoms

The translucent milky-white eggs are attached to the pod wall. After hatching, the larvae burrow straight through the egg shell and the pod wall, and start eating the seed. The first sign of attack is the appearance of 'windows' cut into the pod wall by the larvae to allow the adult to leave the pod after emerging from the pupal cocoon. Fully grown larvae sometimes come out through the exit holes made by the previous generations. They often live in the storage sacks and pupate in large numbers at the bottom of the pile of sacks. By this stage, the groundnut seeds are severely damaged for human consumption or oil expulsion (Wightman and Ranga Rao 1993).

Host

Arachis hypogaea (groundnut), stored products (dried stored products), *Elaeis guineensis* (African oil palm), *Gossypium* (cotton), *Phaseolus* (beans), *Theobroma cacao* (cocoa) and *Tamarindus indica* (Indian tamarind).



GN Fig. 9. Peanut Bruchid Beetle (*Caryedon serratus*) of groundnut: A. milky-white eggs on the pod; B. windows cut into the pod wall by the larvae and C. adult (Source: ICRISAT IB No. 39).

Geographical distribution

Caryedon serratus is of Asian origin, but is distributed to many tropical and subtropical regions of the world (Southgate 1979). Although it is especially prevalent in the warm and hot parts of Asia, north-eastern and West Africa, the West Indies, Hawaii, and parts of South and Central America as far north as Mexico, it is a serious pest of stored groundnuts only in West Africa.

Biology and transmission

The eggs of *C. serratus* are translucent, white, oval, approximately 1 mm long and 0.5 mm wide (Davey 1958). The larvae are scarabeiform and sparsely hairy. They usually leave the pods of their host before pupation. Pupae are creamy white, glabrous, about 5 mm long (Cox 1996). *C. serratus* is a large robust bruchid, which, in commerce, is almost always associated with groundnuts or tamarinds. It has a reddish-brown cuticle, densely clothed with grey-brown setae, but with dark, irregular markings on the elytra. The pygidium in the female is fully visible from above. Body length is 3.5-7.4 mm. It is almost entirely covered dorsally by golden scale-like setae. Antennae are 5 to 10 serrate with 2-4 segments impressed basally. Head is with prominent and median carina. Pronotum is subconical, evenly convex dorsally, reddish-fuscous to testaceous, irregularly punctured, with fine bead around all margins, except for anterior angles. Elytra are one-and-a-half times as long as broad, punctate-striate, testaceous to dark reddish-fuscous, usually with darker maculaton. Metafemora are strongly thickened, with ventral, comb-like row of one large, sub median tooth followed by 8-12 small teeth. Metatibiae are strongly curved, but simple, without either ventral, sub basal tubercle or two small, unequal, ventroapical calceriae (Prevett 1967). The optimum conditions for development are 30-33°C and 70-90% RH, under

which conditions the development period is 41-42 days. Breeding can take place between 23 and 35°C (Davey 1958).

Detection/indexing methods used in CGIAR

At ICRISAT: Dry seed examination using magnifying lens and X-ray radiography are used.

Treatment

Fumigation with methyl bromide @ 32 g m⁻³ for 4 h followed by seed treatment with chlorpyrifos 3 g kg⁻¹ seed (Ghanekar et al. 1996).

Procedures in CGIAR in case of positive test

At ICRISAT: Removal of the infested seeds followed by seed treatment

EPPO protocols

Not available.

General references

Cox ML. 1996. The pupae of Chrysomeloidea. Pages 119-265 in *Chrysomelidae Biology*, vol. 1: The Classification, Phylogeny and Genetics (Jolivet PHA, Cox ML, eds.). Amsterdam, The Netherlands: SPB Academic Publishing.

Davey PM. 1958. The groundnut bruchid, *Caryedon gonagra* (F.). *Bulletin of Entomological Research*, 49(2):385-404.

Ghanekar AM, Ranga Rao GV, Murthy KS, Surender A and Shaik Babu Saheb. 1996. Seed protectants for healthy exports. *Indian Journal of Plant Protection* 24:37-43.

Prevett P. 1967. The larva of *Caryedon serratus* (Ol.), the groundnut seed beetle (Coleoptera: Bruchidae). *Journal of Stored Products Research* 3:117-127.

Southgate BJ. 1979. Biology of the Bruchidae. *Annual Review of Entomology* 24:449-473.

Whiteman JA and Ranga Rao GV. 1993. A groundnut insect identification handbook for India. Information Bulletin No. 39. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 64 pp.

CGIAR-published references on seed health

Nil

Tribolium castaneum Herbst.

Synonyms

Not known

Common name

Red flour beetle or rust-red flour beetle

Importance to CGIAR Centers

Low

Significance

Red flour beetles attack stored grain products such as flour, cereals, meal, crackers, beans, spices, pasta, cake mix, dried pet food, dried flowers, chocolate, nuts, seeds and even dried museum specimens. These beetles have chewing mouthparts, but do not bite or sting. The red flour beetle may elicit an allergic response, but is not known to spread disease and does not feed on or damage the structure of a home or furniture. These beetles are the most important pests of stored products in the home and grocery stores.

Symptoms

Infestation by adult beetles can be readily observed by the tunnels they leave when they move through the flour and other granular food products. When infestation is severe, these products turn grayish-yellow and become moldy, with a pungent odor. Infestation may also be apparent by the appearance of adults on the surface of the seeds (Whiteman and Ranga Rao 1993).

Hosts

Arachis hypogaea (groundnut), *Avena sativa* (oats), *Bertholletia excelsa* (Brazil nut), *Hordeum vulgare* (barley), *Juglans* (walnuts), *Lens culinaris* (lentil), *Oryza sativa* (rice), *Phaseolus* (beans), *Phaseolus lunatus* (lima bean), *Pisum sativum* (pea), *Prunus dulcis* (almond), *Secale cereale* (rye), *Triticum* (wheat), *Triticum spelta* (spelt), *Zea mays* (maize).

Geographic distribution

The rust-red flour beetle, originally of Indo-Australian origin, has a cosmopolitan distribution but occurs more in warmer climates. Its distribution is mainly in Africa, Australasia – Oceania, Central and South America,



GN Fig. 10. Red Flour Beetle (*Tribolium castaneum*) of groundnut: A. adult and B. damaged seed (Source: ICRISAT IB No. 39).

Europe, northern Asia, Mediterranean Basin, South and Southeast Asia, USA and Canada. It is found in stored grain, seeds, flour, dried fruits, nuts (Teetes et al. 1983).

Biology and transmission

The adult is 3-4 mm long, oblong and brown in color. It lays about 450 eggs, distributed among the pods and seeds. The eggs are minute, cylindrical and white. The eggs hatch in 3-4 days, and the slender cylindrical larvae start feeding on the seed. Pupation takes place in the produce without a cocoon. The pupal period may last for 7-10 days, and the adult can live up to 18 months. The developmental period from egg to adult may require about 20 days at 30°C with about 70%RH (Whiteman and Ranga Rao 1993).

Detection/indexing methods used in CGIAR

At ICRISAT: X-ray radiography is used for suspected samples because it offers a non-destructive method. Dry seed examination is carried out using a magnifying lens to separate the infested seed.

Treatment procedures in CGIAR in case of positive test

At ICRISAT: Fumigation of the samples with methyl bromide @ 32 g m⁻³ for 4 h followed by treatment with chlorpyrifos at 3 g kg⁻¹ seed (Ghanekar et al. 1996). Infested samples are rejected.

EPPO protocols

Not available.

General references

Ghanekar AM, Ranga Rao GV, Murthy KS, Surender A and Shaik Babu Saheb. 1996. Seed protectants for healthy exports. Indian Journal of Plant Protection 24:37-43.

Teetes GL, Seshu Reddy KV, Leuschner K and House LR. 1983. Sorghum insect identification handbook. Information Bulletin No. 12. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 125 pp.

Whiteman JA and Ranga Rao GV. 1993. A groundnut insect identification handbook for India. Information Bulletin No. 39. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 64 pp.

CGIAR-published references on seed health

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Trogoderma granarium Everts.

Synonym

Trogoderma afrum, *Trogoderma khapra*, *Trogoderma quinquefasciata*

Common name

Khapra beetle

Importance to CGIAR Centers

High

Significance

Trogoderma granarium is a serious pest of stored products under hot dry conditions. Established infestations are difficult to control because of the beetle's ability to live without food for long periods of time and to survive on foods of low moisture content, its habit of crawling into tiny cracks and crevices and remaining there for long periods, and its relative tolerance to many surface insecticides and fumigants.

Symptoms

The khapra beetle is one of the world's most feared stored-product pests. The obvious signs of a khapra beetle infestation are the larvae and cast skins. Larvae and adults are best identified by microscopic examination. Larvae are mostly seen just before dusk, since they are more active at that time (Anonymous 1981).

Host

Larvae feed on a wide variety of stored products and dried foods. They prefer whole grain and cereal products such as *Triticum aestivum* (wheat), *Hordeum vulgare* (barley) and *Oryza sativa* (rice), but larvae have been recorded on the following: *Avena spp.* (oats), *Secale spp.* (rye), *Zea mays* (corn), dried blood, dried milk, fishmeal, *Arachis hypogaea* (groundnut), flour, bran, malt, *Linum usitatissimum* (flax seed), *Medicago sativa* (alfalfa seed), *Lycopersicum esculantum* (tomato seed), *Phaseolus vulgaris* (pinto beans), *Vigna unguiculata* (blackeyed cowpeas), *Sorghum bicolor* (sorghum seed) and many other food products (Lindgren and Vincent 1959, Lindgren et al. 1955).



GN Fig. 11. Khapra Beetle (*Trogoderma granarium*) of groundnut: A. adults and B. larvae on seeds (Source: www.agspsrv34.agric.wa.gov.au).

Geographic distribution

The distribution of khapra beetle extends from Myanmar (Burma) to West Africa and is limited by the 35° parallel to the north and the equator to the south. It has been introduced by commerce into some areas of similar climatic conditions (Anonymous 1981). The khapra beetle is found in all continents where grain and grain products are stored.

Biology and transmission

The adults are oblong-oval beetles, approximately 1.6 to 3.0 mm long and 0.9 to 1.7 mm wide. Males are brown to black with indistinct reddish brown markings on elytra. Females are slightly larger than males and lighter in color. The head is small and deflexed with a short 11-segmented antenna. The antennae have a club of three to five segments, which fit into a groove in the side of the pronotum. The adults are covered with hairs. The eggs are milky white, turning pale yellowish with age, cylindrical, 0.7×0.25 mm, one end rounded, the other pointed and bearing spine-like projections. Larvae are uniformly yellowish white, except head and body hairs which are brown. As the larvae increase in size, their body color changes to a golden or reddish brown, more body hairs develop, and the tail becomes proportionally shorter. Mature larvae are approximately 6 mm long and 1.5 mm wide. Adult khapra beetles have wings, but do not fly and feed very little. Mated females live from four to seven days, unmated females from 20 to 30 days, and males from seven to 12 days. Mating occurs about five days after emergence, and egg laying begins almost immediately at 40°C. Egg laying may begin at one to three days at cooler temperatures, but no eggs are produced at 20°C. Eggs hatch in three to 14 days after the female lays an average of 50 to 90 eggs that are loosely scattered in the host material. Complete development from egg to adult can occur from 26 to 220 days, depending upon temperature. Optimum temperature for development is 35°C. If the temperature falls below 25°C for a period of time or if larvae are very crowded, they may enter diapauses. They can survive temperatures below -8°C. In diapauses, the larvae can molt but are inactive and may remain in this condition for many years (Anonymous 1981).

Detection/indexing methods used in CGIAR

At ICRISAT: Dry seed examination using magnifying lens

Treatment

High concentrations of fumigant (Aluminium phosphide) are maintained during the fumigation period to allow penetration into all cracks and crevices. In an eradication program, both fumigants and surface treatment (chlorpyrifos) are used in combination with preventive measures, such as good sanitation practices and exclusion.

Procedures in CGIAR in case of positive test

At ICRISAT: Rejection and incineration of the infested seed samples

EPPO protocols

Not available.

General references

Anonymous. 1981. Data sheets on quarantine organisms. *Trogoderma granarium* Everts. Pages 1-6 in European and Mediterranean Plant Protection Organization Bulletin 11 (1) Set 4, List A2.

Lindgren DL and Vincent LE. 1959. Biology and control of *Trogoderma granarium* Everts. Journal of Economic Entomology 52:312-319.

Lindgren DL, Vincent LE and Krohne HE. 1955. The khapra beetle, *Trogoderma granarium* Everts. Hilgardia 24:1-36.

CGIAR-published references on seed health

Nil

Finger millet (*Eleusine coracana* L.)

Bacteria

Pseudomonas syringae pv. *syringae*.

Synonyms

Pseudomonas syringae pv. *japonica*

Disease name

Brown spot or bacterial brown spot

Importance to CGIAR Centers

High

Significance

The disease is very important throughout the world where finger millet is grown.

Symptoms

Symptoms first appear on the lower surface of the leaves as small, water-soaked spots. The spots enlarge, coalesce, and form larger areas that later become necrotic. The bacteria also enter the vascular tissues of the leaf and spread into the stem. The infected area, which is surrounded by a narrow zone of bright, lemon yellow tissue, turns brown, becomes rapidly necrotic, and through coalescence of several small spots, may produce large dead areas of various shapes. The disease produces identical symptoms on the stems, pods and seeds. In addition, light-cream or silver bacterial exudates are often produced on the lesions under moist conditions. [Symptom similar to that in S Fig1 (pg 58)].

Hosts

Multilateral hosts like graminaceous and leguminaceous plants.

Geographic distribution

Pseudomonas syringae pv. *syringae* is worldwide in distribution. www.faqs.org/abstracts/Biological-sciences/Distribution-of-Pseudomonas-syringae-pathovars.

Biology and transmission

Pseudomonas syringae pv. *syringae* is a rod shaped, gram-negative with polar flagella. It tests negative for arginine dihydrolase and oxidase activity, and forms the polymer levan on sucrose nutrient agar. It is known to secrete the lipodepsinonapeptide plant toxin syringomycin, and it owes its yellow fluorescent appearance when cultured *in vitro* on King's B medium to production of the siderophore pyoverdin (Goszczyńska and Serfontein 1998). The pathogen is seed borne and spreads through the infected seed from season to season (Gaudet and Kokko 1986, Venette et al. 1987).

Detection/indexing methods used in CGIAR

At ICRISAT: Pre-export field inspection and agar plate method are used.
www.apsnet.org/pd/SEARCH

Treatment

No suitable seed treatment to eradicate infection

Procedures in CGIAR in case of positive test

At ICRISAT: So far not detected at ICRISAT

EPPO protocols

Not available.

General references

Gaudet DA and **Kokko EG**. 1986. Seedling disease of sorghum grown in southern Alberta caused by seed borne *Pseudomonas syringae* pv. *syringae*. Canadian Journal of Plant Pathology 8:208-217.

Venette JR, **Lampa RS**, **Albaugh DA** and **Nayes JB**. 1987. Presumptive procedure (dome test) for detection of seed borne bacterial pathogens in dry beans. Plant Disease 71:984-990.

Goszczyńska T and **Serfontein JJ**. 1998. Milk-Tween agar, a semi selective medium for isolation and differentiation of *Pseudomonas syringae* pv. *Syringae*, *Pseudomonas syringae* pv. *phaseolicola* and *Xanthomonas axonopodis* pv. *phaseoli*. Journal of Microbiological Methods 32:65-72.

CGIAR-published references on seed health

Mew TW and **Misra JK** (eds.). 1994. A Manual of Rice Seed Health Testing. Manila, Philippines: International Rice Research Institute (IRRI). 113 pp.

Xanthomonas vasicola pv. *holcicola* Elliott.

Synonyms

Bacterium holcicola, *Phytomonas holcicola*, *Pseudomonas holcicola*, *Xanthomonas campestris* pv. *holcicola*, *Xanthomonas holcicola*

Disease name

Bacterial leaf streak or bacterial streak

Importance to CGIAR Centers

High

Significance

Bacterial streak is of minor importance on finger millet.

Symptoms

Symptoms caused by the pathogen are narrow, water-soaked, transparent leaf streaks, 2-3 mm wide by 2-15 mm long, appearing as early as the second leaf stage of the seedling. Lesions soon turn red, become opaque, and at intervals may broaden into somewhat irregularly shaped oval spots with tan centers and narrow red margins. In severe attacks, lesions coalesce to form long irregular streaks and blotches extending across all or much of the leaf blade, with dead tissue bordered by narrow, dark margins between the reddish-brown streaks. Abundant bacterial exudate is produced as light-yellow droplets, which dry to thin white or cream scales (Williams et al. 1978) [Symptom similar to that in S Fig 2 (pg 60)].

Hosts

Panicum miliaceum (millet), *Setaria italica* (foxtail millet), *Sorghum halepense* (aleppo grass), *Sorghum sudanense* (Sudan grass) and *Sorghum bicolor* (common sorghum).

Geographic distribution

Worldwide

Biology and transmission

Soil borne and infected plant debris transmit the bacteria. Seed transmission of the pathogen is not known so far.

Detection/indexing methods used in CGIAR

At ICRISAT: Pre-export field inspection

Treatment

No seed treatment

Procedures in CGIAR in case of positive test

At ICRISAT: So far not detected

EPPO protocols

Not available.

General references

Williams RJ, Frederiksen RA and Girard JC. 1978. Sorghum and Pearl Millet Disease Identification Handbook. Information Bulletin No. 2. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 51 pp.

CGIAR-published references on seed health

Nil

Xanthomonas campestris (Pammel) Dowson pv. *pennamericanum*

Synonyms

Xanthomonas pennisiti, *Xanthomonas annamalaiensis*, *Xanthomonas rubrisorghii*

Disease name

Bacterial leaf streak

Importance to CGIAR Centers

High

Significance

Bacterial leaf streak is of minor importance.

Symptoms

Initial symptoms are narrow, water-soaked, transparent leaf streaks; 2-3 mm wide by 2-15 mm long generally appearing from second leaf stage of the seedlings. Lesions soon turn red, become opaque, and at intervals may broaden into somewhat irregularly shaped oval spots with tan centers and narrow red margins. In severe attacks, these coalesce to form long irregular streaks extending across the leaf blade. Abundant bacterial exudates are produced as light-yellow droplets, which dry to thin white or cream scales (Williams et al. 1978). [Symptom similar to that in S Fig 2 (pg 60)].

Hosts

Pearl millet and proso millet (*Panicum miliaceum*)

Geographic distribution

It is reported from Nigeria and Senegal.

Biology and transmission

Bacterial colonies are yellow and mucoid on the nutrient agar medium. Bacterial cells are aerobic, motile, gram-negative and rod-shaped. They differ pathologically, serologically and by membrane protein patterns from other pathovars of *X. campestris*. Cells measure 0.45×2.25 μm and have one polar flagellum. Optimal growth occurs between 26 and 30°C (Rangaswami et al. 1961).

Detection/indexing methods used in CGIAR

At ICRISAT: Pre-export field inspection and agar plate method are used.

Treatment

No seed treatment is available

Procedures in CGIAR in case of positive test

At ICRISAT: So far not detected

EPPO protocols

Not available.

General references

Rangaswami G, Prasad NN and Eswaran KSS. 1961. Two new bacterial diseases of sorghum. *Andhra Agricultural Journal* 8:269-272.

Williams RJ, Frederiksen RA and Girard JC. 1978. Sorghum and Pearl Millet Disease Identification Handbook. Information Bulletin No. 2. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 88 pp.

CGIAR-published references on seed health

Nil

Fungi

Cochliobolus lunatus RR Nelson & Haasis.

Synonym

Acrothecium lunatum, *Curvularia lunata*, *Curvularia lunata* var. *lunata*, *Pseudocochliobolus lunatus*

Disease name

Leaf spot or black kernel

Importance to CGIAR Centers

High

Significance

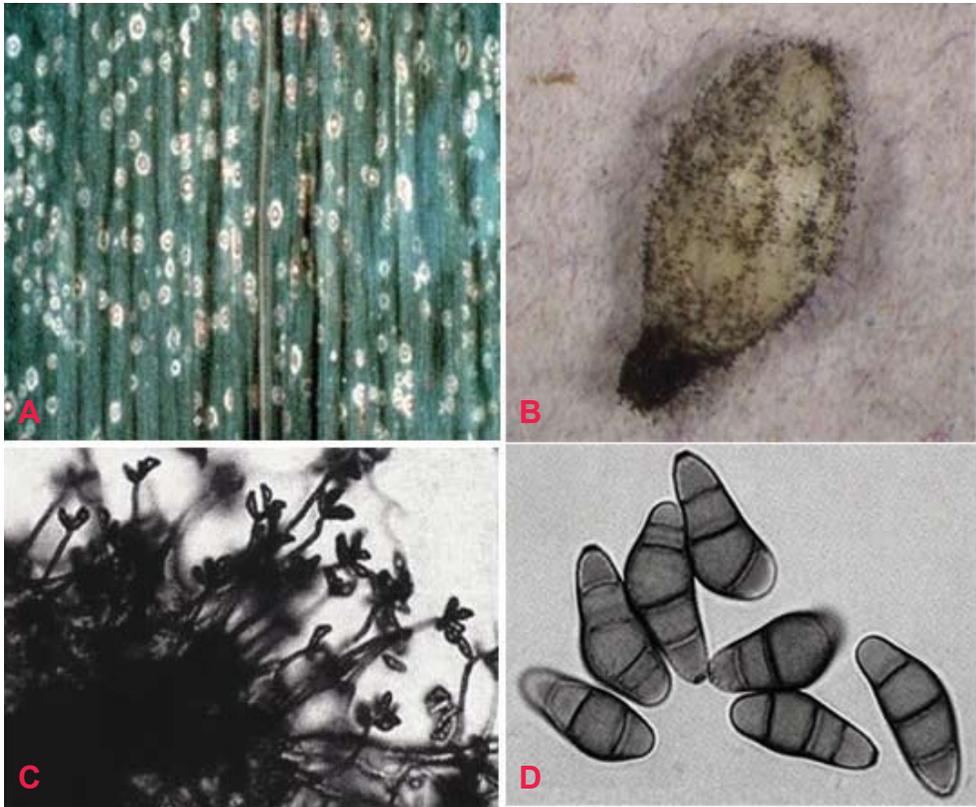
Less important in finger millet compared to sorghum

Symptoms

Leaf spots occur on leaves as small, diffuse and reddish with grayish centers (Shaw 1921).

Hosts

Poaceae (cereals), *Oryza sativa* (rice), *Pennisetum glaucum* (pearl millet), *Sorghum bicolor* (common sorghum), *Zea mays* (maize), *Eleusine coracana* (finger millet), *Setaria italica* (foxtail millet) and several leguminaceous crops.



FM Fig. 1. Leaf spot (*Cochliobolus lunatus*) of finger millet: A. leaf spots; B. mycelial growth on seed; C. conidiophores with conidia and D. conidia (Source: ICRISAT IB Nos. 2 and 34).

Geographic distribution

The pathogen is widely distributed in Europe, Asia and Africa.

Biology and transmission

Colonies are effuse, brown, blackish brown or black, hairy or velvety. Conidiophores are solitary or in small groups, simple or branched, straight or flexuous, sometimes geniculate, pale to dark brown, septate, up to 650 μm long, 5-9 μm wide, often swollen at the base to 10-15 μm . Conidia are acropleurogenous, 3-septate, almost always curved at the third cell from the base, which is usually longer and often darker than the others. Cells at each end are sub hyaline or pale brown while intermediate cells are light to dark brown, smooth, 20-32 \times 9-15 μm (Anil Kumar et al. 2003).

Detection/indexing methods used in CGIAR

At ICRISAT: Pre-export field inspection and blotter test

Treatment

Not known

Procedures in CGIAR in case of positive test

At ICRISAT: Incineration of the infected plants/seed samples and rejection of the seed samples.

EPPO protocols

Not available.

General references

Anil Kumar TB, Mantur SG and Madhukeshwara SS. 2003. Diseases of finger millet. All India Coordinated Small Millets Improvement Project, Indian Council of Agricultural Research, University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India. Bangalore, Karnataka, India: University of Agricultural Sciences. 126 pp.

Shaw FJF. 1921. Report of the Imperial Mycologist. Pages 34-40 *in* Scient. Reports Agric. Res. Inst, Pusa, 1920-21.

CGIAR-published references on seed health

Nil

Insects

Plodia interpunctella Hubner.

Synonyms

Not known

Common name

Indian Meal Moth

Importance to CGIAR Centers

Medium

Significance

Indian Meal Moth is a common grain-feeding pest. It can infest a variety of products and is perhaps the most economically important insect pest of processed food. (www.elsevier.com/retrieve/pii). Infestations of *P. interpunctella* can cause direct product loss and indirect economic costs through pest control costs, quality losses and consumer complaints (Phillips et al. 2000).

Symptoms

Plodia interpunctella is an external feeder. The larvae continuously spin a silken web both inside and on top of the grain surface, and feed within the web. The webbing contains larval excreta (frass) and exuvia (cast skins), and gives an unpleasant odor to the infested commodity. The infested commodity is sometimes covered on the surface with a thick mat of silken webbing (Mohandass et al. 2007).

Biology and transmission

Female moths lay between 60 and 400 eggs (Lyon 1991) on a grain surface. The eggs are ordinarily smaller than 0.5 mm and not sticky. They hatch in 2 to 14 days. The moth larvae are off-white with brown heads. When these larvae mature, they are usually about 12 mm long. The larval stage lasts from 2 to 41 weeks, depending on the temperature. Adult moths are 8-10 mm long with 16-20 mm wingspans. The outer half of their forewings is bronze, copper, or dark gray in color, while the upper half is yellowish-gray, with a dark band at the intersection between the two. The entire life cycle may range from 30 to 300 days (Mohandass et al. 2007).

Hosts

Arachis hypogaea (groundnut), *Oryza sativa* (rice), *Prunus* (stone fruit), stored products (dried stored products), *Triticum aestivum* (wheat), *Zea mays*



FM Fig. 2. Indian Meal Moth (*Plodia interpunctella*) of finger millet. (Source: ICRISAT IB No. 12).

(maize), *Avena sativa* (oats), *Corylus*, *Helianthus annuus* (sunflower), *Hordeum vulgare* (barley), *Juglans regia* (Carpathian walnut), *Pistacia vera* (pistachio), *Prunus dulcis* (almond) and *Theobroma cacao* (cocoa).

Geographic distribution

Plodia interpunctella is cosmopolitan in distribution especially in warm climates. In cool temperate countries, it can survive in heated buildings.

Detection/indexing methods used in CGIAR

The primary detection method is through pheromone-based trapping of males (Phillips et al. 2000). The pheromone commonly referred to as 'ZETA' was one of the first commercial pheromones for stored-product insects, and the response of males to this pheromone has been well documented.

Treatment at ICRISAT

Fumigation with methyl bromide @ 32 g m⁻³ for 4 h followed by seed treatment with chlorpyrifos at 3 g kg⁻¹ seed (Ghanekar et al. 1996, Toews et al. 2006).

Procedures in CGIAR in case of positive test

At ICRISAT: Infested samples are rejected in case of positive test.

EPPO protocols

Not available.

General references

Lyon WF. 2006. "Fact Sheet: Indianmeal Moth". Ohio State University. <http://ohioline.osu.edu/hyg-fact/2000/2089.html>.

Ghanekar AM, Ranga Rao GV, Murthy KS, Surender A and Shaik Babu Saheb. 1996. Seed protectants for healthy exports. Indian Journal of Plant Protection 24:37-43.

Mohandass S, Arthur FH, Zhu KY and Throne JE. 2007. Biology and management of *Plodia interpunctella* (Lepidoptera: Pyralidae) in stored products. Journal of Stored Products Research 43:302-311.

Toews MD, Campbell JF and Arthur FH. 2006. Temporal dynamics and response to fogging or fumigation of stored-product Coleoptera in a grain processing facility. Journal of Stored Products Research 42:480-498.

Phillips TW, Berbert RC and Cuperus GW. 2000. Post-harvest integrated pest management. Pages 2690–2701 in Encyclopedia of Food Science and Technology. 2nd edition (Francis FJ, ed.). New York: Wiley Inc.

CGIAR-published references on seed health

Chakrabarty SK, Anitha K, Girish AG, Sarath Babu B, Prasada Rao RDVJ, Varaprasad KS, Khetarpal RK and Thakur RP. 2005. Germplasm exchange and quarantine of ICRISAT mandate crops. Information Bulletin No. 69. Rajendranagar 500 030, Andhra Pradesh, India: National Bureau of Plant Genetic Resources; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 80 pp.

Prostephanus truncatus Horn.

Synonyms

Dinoderus truncatus

Common name

Larger grain borer

Importance to CGIAR Centers

High

Significance

The borer damages grains leading to significant weight loss (5-20%). The quantity of grain dust produced can be from 6 to 29 g kg⁻¹ grain (*Mailafiya* 2008).

Symptoms

Adults frequently attack stored seed with intact sheaths by boring into the base of seed. Adults bore into the grains, making neat round holes, and as they tunnel from grain to grain they generate large quantities of grain dust. Adult females lay eggs in chambers bored at right angles to the main tunnels.



FM Fig. 3. Larger Grain Borer (*Prostephanus truncatus*) of finger millet (Source: www.agrsci.dk/plb/bembi/africa.com).

Hosts

Manihot esculenta (cassava), stored products (dried stored products), *Zea mays* (maize), *Dioscorea* (yam) and *Triticum aestivum* (wheat).

Geographic distribution

Prostephanus truncatus is indigenous in Central America, tropical South America and the extreme south of the USA as a major pest. It is also distributed in Africa and Europe, but has restricted distribution in India.

Biology

The adult has the typical cylindrical bostrichid shape with body length of 3-4.5 mm. The declivity is flattened and steep and has many small tubercles over its surface. The limits of the declivity, apically and laterally, are marked by a carina. The antennae are 10-segmented and have a loose three-segmented club; the 'stem' of the antenna is slender and clothed with long hairs and the apical club segment is as wide as, or wider than, the preceding segments. The larvae are white, fleshy and sparsely covered with hairs. They are parallel-sided, ie, they do not taper. The legs are short and the head capsule is small relative to the size of the body.

Detection/indexing methods used in CGIAR

At ICRISAT: Pre-export field inspection and dry seed examination using magnifying lens

Treatment

Not known due to non-detection of the pest

Procedures in CGIAR in case of positive test

At ICRISAT: Incineration of the infested seed samples

EPPO protocols

Not available.

General references

Mailafiya DM, Ayertey JN and Cudjoe AR. 2008. Damage and weight loss potential of *Prostephanus truncatus* (Horn) Coleoptera: Bostrichidae) on sorghum grain: implication to cereal grain storage in sub-Saharan Africa. International Journal of pure and applied sciences 2:28-35.

CGIAR-published references on seed health

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Tribolium castaneum Herbst.

Synonyms

Not available

Common name

Red Flour Beetle

Importance to CGIAR Centers

Medium

Significance

Important in stored finger millet grain in several countries.

Symptoms

Infestation by adult beetles can be readily observed by the tunnels they leave when they move through flour and other granular food products. Damage is particularly serious in grains such as rice and wheat, which have either been dehusked or processed into other products. When infestation is severe, these products turn grayish-yellow and become moldy, and have a pungent odor. Infestation may also be apparent by the appearance of adults on the surface of the grains (Teetes et al. 1983).



FM Fig. 4. Red flour beetle (*Tribolium castaneum*) of finger millet (Source: ICRISAT IB No. 12).

Hosts

Arachis hypogaea (groundnut), *Avena sativa* (oats), *Bertholletia excelsa* (Brazil nut), *Hordeum vulgare* (barley), *Juglans* (walnuts), *Culinaris* (lentil), *Oryza sativa* (rice), *Phaseolus* (beans), *Phaseolus lunatus* (lima bean), *Pisum sativum* (pea), *Prunus dulcis* (almond), *Secale cereale* (rye), *Triticum* (wheat), *Triticum spelta* (spelt) and *Zea mays* (maize).

Geographic distribution

Tribolium castaneum is cosmopolitan in distribution. It is found in stored grain, seeds, flour, dried fruits and nuts worldwide (Teetes et al. 1983).

Biology and transmission

The adult is 2.3-4.4 mm long, rather flat, oblong and chestnut-brown (reddish-brown). It lays about 450 eggs in stored produce. The eggs are minute, cylindrical and white. The incubation period lasts for 5-12 days. The yellowish-white cylindrical grub is covered with fine hairs. The pupa is naked (without a cocoon), yellowish-white, becoming brown later, and adults emerge in 3-7 days (Teetes et al. 1983).

Detection/indexing methods used in CGIAR

At ICRISAT: X-ray radiography is used for suspected samples because it offers non-destruction of the seed. Dry seed examination with a magnifying lens is used to separate the infested seed.

Treatment

Fumigation of the samples with methyl bromide @ 32 g m⁻³ for 4 h followed by treatment with chlorpyrifos 3g kg⁻¹ seed (Ghanekar et al. 1996).

Procedures in CGIAR in case of positive test

At ICRISAT: Infested samples are rejected

EPPO protocols

Not available.

General references

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About ICRISAT



The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a non-profit, non-political organization that does innovative agricultural research and capacity building for sustainable development with a wide array of partners across the globe. ICRISAT's mission is to help empower 600 million poor people to overcome hunger, poverty and a degraded environment in the dry tropics through better agriculture. ICRISAT belongs to the Alliance of Centers of the Consultative Group on International Agricultural Research (CGIAR).

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