



Department
for Environment
Food & Rural Affairs

Pest specific plant health response plan: Outbreaks of *Tilletia indica* (Karnal bunt) in cereal crops

Oct 2021



Figure 1. Bunted grains of wheat that have been infected by *Tilletia indica* (Karnal bunt). Image courtesy of: Ruben Durán, Washington State University, Bugwood.org



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1. Introduction and scope

- 1.1. This pest specific contingency plan has been prepared by the Defra Risk and Horizon Scanning Team. It sets out the standard statutory approach for controlling and eradicating outbreaks of *Tilletia indica* Mitra. (Karnal bunt) in England.
- 1.2. This document will be used in conjunction with Defra's *Generic Contingency Plan for Plant and Bee Health in England* (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/593508/generic-contingency-plan-plant-bee-health-england.pdf), which gives details of the teams and organisations involved in pest response in England, and their responsibilities and governance. It also describes how these teams and organisations work together in the event of an outbreak of a plant health pest.
- 1.3. The plant health authorities in Northern Ireland, Scotland and Wales have been consulted on this plan and will use it as the basis for the action they will take in the event that *Tilletia indica* (Karnal bunt) is detected in their territories.
- 1.4. The purpose of the plan is to ensure a rapid and effective response to an outbreak of Karnal bunt and to make stakeholders aware of the planned action.
- 1.5. A datasheet containing background information on Karnal bunt is included in appendix 1.

2. Summary of the Threat

- 2.1. *Tilletia indica* (Karnal bunt) is a fungal pest of wheat (*Triticum* spp.) and occasionally triticale (x *Triticosecale*). It was first described from Karnal, India and is widespread in the North-east of the country. It is also found in Afghanistan, Iran, Iraq, Nepal and Pakistan. *T. indica* has been introduced to the USA, Mexico, Brazil and South Africa. *T. indica* causes both yield and quality losses by partially converting kernels of wheat (*Triticum*) into sori, a structure that contains a mass of fungal spores. Generally impacts are minor but can be large on a local scale (Carris *et al.*, 2006); if more than 3% of grains are bunted then the milled product will give off a fishy smell caused by the production of trimethylamine, which would cause flour to be rejected. Bunted kernels present no animal or human health risks.
- 2.2. There have been no outbreaks of *T. indica* in the UK or Europe, though in the UK it has been intercepted on imported grain from India in 2003, 2005, 2006, 2018 and 2019. The only interception records for continental Europe are from Italy, where *T. indica* was intercepted on imported durum wheat from Mexico in 1998 and 2006.
- 2.3. The most likely pathway of entry is via international trade of seed and grain of wheat or triticale that has been infected with or contaminated with *T. indica*. Wheat seed is grain which will be used to sow wheat crops and is thus of the highest risk of resulting in an outbreak of *T. indica*. Grain is used to refer to grain which will go for milling to produce flour and thus has a lower risk of resulting in an outbreak.

- 2.4. For more information on the Biology of *T. indica* please refer to the pest factsheet in appendix 1.

3. Risk assessments

- 3.1. *Tilletia indica* has been subject to pest risk analysis at both the UK (Sansford, 2004) and EU level (Sansford *et al.*, 2006) , which concluded that the pest fits the criteria for a quarantine organism and should continue to be regulated.
- 3.2. *T. indica* currently has a mitigated UK Plant Health Risk Register score of 40, which is reviewed as and when new information becomes available (<https://secure.fera.defra.gov.uk/phiw/riskRegister/viewPestRisks.cfm?csref=1138>).

4. Actions to prevent outbreaks

- 4.1. *Tilletia indica* is listed in Schedule 1 of The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020 and therefore the introduction into, and spread within Great Britain, is prohibited.

Seed of *Triticum*, *Secale* or *x Triticosecale*

- 4.2. Schedule 7 of The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020 requires that seeds of the genera *Triticum*, *Secale* and *x Triticosecale* from Afghanistan, India, Iran, Iraq, Mexico, Nepal, Pakistan, South Africa and the USA where *Tilletia indica* is known to occur be accompanied by a phytosanitary certificate with an official statement that they originate in an area where *Tilletia indica* is known not to occur.

Grain of *Triticum*, *Secale* or *x Triticosecale*

- 4.3. Schedule 7 of The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020 requires that grain of the genera *Triticum*, *Secale* and *x Triticosecale* from Afghanistan, India, Iran, Iraq, Mexico, Nepal, Pakistan, South Africa and the USA where *Tilletia indica* is known to occur must be accompanied by a phytosanitary certificate with an official statement that either: a) it originates in an area where *Tilletia indica* is not known to occur or b) no symptoms of *Tilletia indica* have been observed on the plants at the place of production during their last complete cycle of vegetation and representative samples of grain have been taken both at the time of harvest and before shipment and have been tested and found free of *Tilletia indica*.

Soil

- 4.4. Any soil from infected fields could also contain viable spores, but soil and growing medium is prohibited in Schedule 6 of The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020 from any Third country other than EU Member States, Leichtenstein and Switzerland.

- 4.5. Soil from contaminated fields could be transported on agricultural machinery however Schedule 7 of The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020 requires that machinery and vehicles which have been operated for agricultural or forestry purposes from third countries other than EU Member States, Leichtenstein and Switzerland must be accompanied by a phytosanitary certificate with an official statement that the machinery or vehicles are cleaned and free from soil and plant debris.

5. Response activities

Official action to be taken following the suspicion or confirmation of *T. indica* on imported seeds

- 5.1. The Plant Health and Seeds Inspectorate (PHSI) of the Animal and Plant Health Agency (APHA) conduct risk based targeted sampling of seed consignments that originate from countries where *T. indica* is known to occur. The inspection rate is reviewed yearly and can be increased based on interceptions on seed or grain from a particular country.
- 5.2. Sampling will also occur if seed lots have been re-exported from within the EU to the UK but are known to have originated from a country where *T. indica* is known to occur. Seed lots are sampled according to ISTA (International Seed Testing Association) seed sampling rules. Samples are sent to Fera Science Ltd. for *T. indica* testing. After sampling the seed, the lot is released to the importer.
- 5.3. If *T. indica* is suspected by laboratory testing, the seed should immediately be traced and held until the diagnosis has been confirmed and any other known recipients of the consignments within the EU notified.
- 5.4. If diagnosis is confirmed, the seed and its packaging should be destroyed by deep burial or closed incineration. Only closed incineration will be acceptable as spores can be spread in smoke. The exporting country should be notified through the Europhyt system.
- 5.5. If the seed has already been planted, the field(s) should be placed under statutory notice to prevent the movement of plant material and soil from the field. The emerging crop should be destroyed before heading (Ideally before GS41 Flag leaf sheath extending) and the land tilled. Fungicide application prior to destruction would be recommended to decrease spore loads. Fungicides containing the active ingredients azoxystrobin, epoxiconazole (only licensed until 31 October 2021), and tebuconazole have all been shown to be effective against *T. indica* spores. The Risk and Horizon Scanning Team in Defra will recommend an approved fungicide in the event of a finding in the field. Plant material should then either be treated with herbicide or physically cut followed by ploughing into the field. A broad-spectrum herbicide such as glyphosate may be recommended however specific recommendations will be given by the Risk and Horizon Scanning Team in Defra. Plant material should not be removed from the field to avoid the risk of spread of spores. Machinery used in the field should be cleaned as detailed in 5.38. Actions for confirmed findings in a field should then be carried out (see 5.29 to 5.45).

Official action to be taken following the suspicion or confirmation of *T. indica* on imported grain

- 5.6. The PHSI conduct risk based targeted sampling of grain consignments that originate from countries where *T. indica* is known to occur. The inspection rate is reviewed yearly and can be increased based on interceptions on seed or grain from a particular country. Representative samples (2 kg as grain consignments are often too large to follow ISTA rules as set out elsewhere) are taken and sent to Fera Science Ltd. for testing. Grain consignments are held until initial results are received from Fera Science Ltd, usually within 24 hours.
- 5.7. If *T. indica* is suspected during laboratory testing, grain should continue to be held until confirmation is received.
- 5.8. If *T. indica* is confirmed by laboratory testing, the importer should be given a choice between re-export or destruction by closed incineration or deep burial.
- 5.9. Any containers or packaging that has held the grain should be traced if possible and disinfected or destroyed as appropriate (See section 5.38).
- 5.10. Transportation should be in closed containers, and any conveyances or packaging that is not exported with the commodity should be appropriately cleaned after use (See section 5.38).
- 5.11. A Europhyt notification should be made upon official confirmation of an interception of *T. indica*.

Official action to be taken following suspicion of *T. indica* in the field

- 5.12. If *T. indica* is suspected in a growing crop, any bunted ears should be sent to the Seeds Export Laboratory at Fera Science Ltd. for testing.
- 5.13. The field should be placed under notice until the diagnosis is confirmed, and the crop should not be harvested. Fungicide application (as recommended by Defra's Risk and Horizon Scanning team) may be advised if the crop has not reached the stage after which fungicide use is not approved (either GS69/71 depending on active). Fungicide application prior to destruction may be recommended to decrease spore loads. Fungicides containing the active ingredients azoxystrobin, epoxiconazole (only licensed until 31 October 2021), and tebuconazole have all been shown to be effective against *T. indica* spores. If the suspected infection was most likely a result of infected seed, then tracing of the seed will commence. This decision will be taken on a case by case basis.

Official action to be taken following findings of *T. indica* in a sample of UK grown wheat at grain or seed processors

- 5.14. It is most likely that any detection of an outbreak would be through samples collected at grain or seed processors as the infection level in a growing crop can be very low and difficult to detect during visual inspections.
- 5.15. The UK conducts surveys as part of a multi-annual survey programme for the presence of *T. indica* by sampling grain or seed from UK wheat crops. This survey aims to collect samples from as many geographic locations as possible, with more samples being collected from those regions with the greatest cereal production.
- 5.16. Samples of seed and untreated and unprocessed grain are sampled according to ISTA (International Seed Testing Association) sampling rules (ISTA, 2019) and are submitted to the Seeds Export Lab at Fera Science Ltd. Where possible such samples are traceable to the field of origin and are as representative of the harvest as is practical.
- 5.17. If *T. indica* is confirmed in a sample of UK wheat or seed at a grain or seed processor then action as detailed in 5.7 to 5.10 should be followed.
- 5.18. In the case of a positive at a seed processors seed which has already left the seed processors must be traced and placed under notice to prevent sowing.
- 5.19. The grain or seed should be traced back to the field of origin (where possible) which should be placed under notice to prevent sowing of any host crops or movement of soil by any means until the source of *T. indica* can be confirmed. If the field of origin cannot be traced and the grain is known to come from a single farm, then the whole farm should be placed under notice and further evidence sought to narrow down the field of origin. If the tested grain contains grain from more than one farm, then each farm should be placed under notice and investigations carried out to try to establish the farm and field of origin. If straw is still in the field, then this should be held in the field. It should not be allowed to be moved on for processing as it could be contaminated with spores. If straw has been moved it will be traced and action taken in accordance with the risk posed by the specific situation.
- 5.20. A positive result in a UK grain or seed may be due to contamination, for example if the grain was being stored in a bin previously used to store grain from a country where *T. indica* is known to occur. Data on all grain or seed that has been processed in the last three months should be examined.
- 5.21. If no processing of grain or seed from countries affected by *T. indica* has taken place in the past 3 months, then it should be assumed that the spores originated from the UK sample. In this case official outbreak actions should commence as detailed in 5.29 to 5.45.
- 5.22. If grain or seed from a *T. indica* affected country has been processed in the past 3 months, the possibility of contamination should be investigated.

Confirming a new outbreak

- 5.23. The confirmation of *T. indica* in a growing UK crop will lead to the declaration of an outbreak. A Europhyt outbreak notification must be made once confirmed.
- 5.24. If there is a reasonable possibility that a finding in UK grain or seed at a processor is due to contamination, the guidelines as outlined in section 5.25 to 5.27 should be followed to confirm an outbreak.

How to survey to determine whether there is an outbreak

- 5.25. If a finding occurs at a grain or seed processors action should be taken as detailed in section 5.14 to 5.22.
- 5.26. The seed used to plant the contaminated crop in the previous season should be traced. If the seed originated from a *T. indica* affected country, it should be assumed that the spores originated on the UK crop and an outbreak declared.
- 5.27. If seed did not originate from a *T. indica* affected country other possible routes of contamination should be investigated. It is possible that an outbreak could have been present for a number of years so the origin of seeds planted for the past 5 years should be traced if possible. The locations of nearby mills which could have processed contaminated grains from which spores have been released should also be investigated.

Diagnostic procedures

- 5.28. There are two protocols for identification of *T. indica* in the laboratory: the EPPO diagnostic protocol (EPPO, 2007, EPPO, 2018) and an International Standards for Phytosanitary Measures 27 protocol (IPPC, 2014). Either of these should be followed for laboratory identification of *T. indica*. The EPPO protocol is generally used by Fera Science Ltd.

Criteria for determining an outbreak

- 5.29. The Core Contingency Group (CCG) will declare an outbreak if a) spores of *T. indica* are found in a sample of UK grain and there are no grounds for reasonable suspicion of contamination or b) *T. indica* is found in a growing crop, or in grain sampled from a crop at harvest.

Official Action to be taken following the confirmation of an outbreak

Communication

- 5.30. The Incident Management Team will assess the risks and communicate details to the IPPC, EU (via a Europhyt notification) and EPPO, in accordance with ISPM 17: pest reporting (<https://www.ippc.int/en/publications/606/>), as well as within Government to Ministers, senior officials, other government departments and agencies and devolved authorities (e.g., the

Environment Agency) on a regular basis as appropriate; and to stakeholders. The scale of the outbreak will determine the size and nature of the management team and action.

Surveillance

- 5.31. Information to be gathered on the suspicion of *T. indica* by the PHSI, in accordance with ISPM 6; guidelines for surveillance (http://www.acfs.go.th/sps/downloads/13717_ISPM_6_E.pdf):
- The origin of the wheat/triticale seed.
 - Details of other premises or destinations where the same batch of wheat or triticale seed may have been sent. Other crops sown from the same seed lot should be inspected or grain tested for the presence of *T. indica*.
 - The layout of the premises and surrounding area, including a map of the cultivations/buildings, at risk growers and any other growers and any public footpaths that may run through the area.
 - Details of the host plant: the species, variety, growth stage and any other relevant information.
 - Description of the surrounding habitat.
 - Level of infection, including a description of symptoms (photos should be taken where possible).
 - The date and time the sample was taken, how it was identified and by whom.
 - Current controls in place e.g. chemical treatments such as seed treatments that may have been used, or fungicide applications that may have been applied.
 - Details on the movement of people, equipment, machinery etc. to and from the infected area. Also inter relationship with other host crops in locality and if agricultural operations are contracted out.
 - Cultural and working practices.
- 5.32. In the event of an outbreak being confirmed, it is likely that immediate sanctions will be placed on the UK by other countries for the movement of all wheat or triticale seed or grain. As a consequence, a more intensive national survey will be required so that areas where the pathogen is known not to occur can be identified, allowing for exports to resume from these regions. The UK produced over 13 million tonnes of wheat in 2018, and exports both wheat seed and grain to the EU and beyond.
- 5.33. A national survey to identify Pest Free Areas (PFA) will be conducted. Wheat will be sampled over Triticale as it is much more widely grown and much more likely to be a host. Samples should be submitted to Fera Science Ltd. for testing via the EPPO diagnostic protocol.
- 5.34. Regions that test negative for *T. indica* can become officially recognised Pest Free Areas.
- 5.35. If the outbreak is likely to have occurred prior to the planting of the crop in which *T. indica* has been diagnosed, then the possibility of spread from this previous outbreak must be investigated. In particular if this is a seed crop then seed derived from previous crops in the affected field should be traced.

Demarcated Zones

5.36. Once an outbreak has been confirmed then a statutory demarcated zone will be established. This will include two zones outlined below:

- The **infected zone** will be at least 1 km around the infected field(s). In this zone, no host crops can be planted for 3 years, which is the time for which *T. indica* spores have been demonstrated to survive in European soils, and other procedures as outlined later in the plan must be carried out.
- There will be an additional **buffer zone** of at least 1 km beyond the demarcated area. Extensive surveys will be carried out in this area. Any hosts grown will be visually inspected for bunted ears at least once between heading and harvest, and grain and seeds produced from host material within this buffer zone should be held in a secure location, tested by field where possible and found to be free of *T. indica* before it is moved out of the buffer zone.

5.37. Further general surveys will be carried out on hosts grown beyond the buffer zone, which may include visual inspection and/or sampling. Any general surveys are likely to focus on wheat rather than triticale and in areas where spread is most likely to occur i.e. land where machinery has been used that has also been used in the infected fields.

Decontamination procedures

5.38. The following articles that have come into contact with contaminated grain or are used in contaminated fields will need to be decontaminated. Decontamination procedures are based on USDA (2007) unless otherwise referenced. Full disinfection may also be required this will be at the discretion of the PHSI.

- Conveyances (trucks, trailers etc.) used to transport or store any contaminated grain should be washed down with a high-pressure wash. In some cases, disinfection may also be required as detailed below.
- Sowing, tilling/ploughing/spraying and harvesting equipment used in the outbreak fields should be cleaned thoroughly to remove any soil or plant debris before it is moved to uninfected fields. This can be achieved by first removing excess soil and debris from all parts of the machine and then washing down using a high-pressure wash.
- Appropriate disinfection options are cleaning with a 1.5% sodium hypochlorite solution, a drench with hot water (at least 80°C) and detergent or cleaning with steam (of at least 100°C) (Smilanick *et al.*, 1997, USDA, 2007).
- Footwear worn in contaminated fields should be scrubbed to remove soil, preferably at the exit to the field followed by disinfection with 1.5% sodium hypochlorite solution.
- Any storage containers which have held contaminated grain should be traced and cleaned, including any silos that were used to hold the grain. If there is contaminated grain currently in a silo it should be destroyed by closed incineration or deep burial.

- Decontamination of mills will be required if contaminated grain has been processed ahead of detection. Any flour produced can be released as this does not pose a risk to either plant health or human health. Additionally, any bran produced can also be released as this does not pose a health risk as animal feed or for human consumption. However, any machines used for pelleting will also require disinfection. All waste (dust, screening etc.) must be bagged and disposed of at a PHSI approved landfill site or destroyed by closed incineration. The following methods can be used for cleaning of any equipment used during the processing of the *T. indica* infected grain:
 - applying steam at the critical temperature of 77°C to all surfaces to the point of runoff
 - cleaning with a solution of hot water and detergent (82°C minimum) applied under pressure of at least 1.4 bar (20 psi).
 - wetting all surfaces to the point of run off with a 1.5% sodium hypochlorite solution and letting it stand for 15 minutes, followed by a thorough wash down

Pest Management procedures

- 5.39. The following procedures should be carried out in infected fields.
- 5.40. If *T. indica* is confirmed, the growing crop will need to be destroyed. Burning *in situ* is not an option as smoke is reported to cause the long-distance spread of viable *T. indica* spores. It would be advised that the crop should be treated with fungicide to minimise spore load as much as possible, and thus minimise inoculum load in the field. Following this the crop should either be cut or left in the field and ultimately ploughed into the soil. Plant material should not be removed from the field to minimise the risk of spread of spores. Harvesting of the crop will not be allowed as this process results in a lot of dust generation and is likely to lead to airborne spread of spores to neighbouring fields. All equipment used to cut the contaminated crop or plough it into the soil of the field, as well as any machinery and conveyances must be cleaned appropriately after leaving the infected field. More details of decontamination procedures can be found in sections 5.38.
- 5.41. No host crops can be planted in the infected field and all agricultural fields which fall within the infected zone for 3 years.
- 5.42. In order to limit the movement of soil from the field(s), which could contain viable spores, no root vegetables or bulbs can be grown within the known infected field(s). The recommended crops to be grown would be combinable non-host crops such as oilseed rape, barley, oats and some fodder crops. Alternatively, the field can be left fallow for some or all of the 3 years. Herbicide treatments should be applied to prevent emergence of volunteer hosts if left fallow or non-host crops grown.
- 5.43. All equipment and shoes used in the infested field must be properly cleaned and disinfected as described in section 5.38 before it is used in any other fields.
- 5.44. The soil must be tilled at least once a year for the full 3 years. This action will expose *T. indica* spores that may have become buried and encourage 'suicidal germination'. This

should ideally be done during warm weather between 15-25°C and not during a dry period, as relative soil moisture >15% is required for spore germination.

- 5.45. Public footpaths that run through the infected field should be closed or re-routed to avoid movement of soil out of the infected area until eradication can be declared.

Review measures in the case of prolonged official action

- 5.46. The EPPO protocol states that if continuing official action is required within the demarcated area over a prolonged period, a review of eradication and containment measures should be undertaken regularly to determine the success and cost-effectiveness of measures in the longer term. This review will involve consultation with stakeholders and should include:

- Evaluation of the effectiveness of current measures
- Evaluation of the economic impact and cost-effectiveness of continuing existing measures
- Consideration of further measures to strengthen containment and eradication actions
- Consideration of statutory obligations and impact on import and export procedures
- Consideration of alternative approaches, including pursuing measures to contain the pest rather than eradication or even the cessation of statutory action.

In circumstances where it is considered that the pest cannot be eradicated or contained and official action is no longer considered appropriate, stakeholders should be consulted and a timetable and mechanism for the removal of official measures, and for the dissemination of pest management information, should be agreed with the EU commission.

6. Criteria for declaring eradication / change of policy

- 6.1. After three years of growing non-host crops then the growing of hosts will be allowed and these will be tested for the presence of *T. indica*. As the spores can lie dormant for a period of several years and infection is only seen in years with favourable conditions (on average once every 4 years in areas where *T. indica* is established) then testing of host crops should occur over four years, following the initial three years with no hosts grown. Ideally the host crop grown should be wheat, rather than triticale, as infection on triticale is rare and thus a negative result may not be indicative of the eradication of the pathogen. As infection can be localised within a field the entire field should be planted with wheat.
- 6.2. In order to determine if eradication has been achieved field inspections should occur at least once between heading and harvest. No symptoms of *T. indica* should be seen. Symptoms of bunt which are subsequently demonstrated to be common bunt can be discounted. No *T. indica* spores should be detected in harvested grain when a

representative sample is taken at harvest and tested according to the EPPO diagnostic protocol.

- 6.3. *Tilletia indica* will be declared eradicated from an outbreak site after at least three years of growing non-hosts followed by four years of growing host crops (*Triticum*) where *T. indica* is not detected.
- 6.4. If during the four years of testing crops for the presence of *T. indica*, *T. indica* is detected then the field will remain under notice and no host crops should be planted for a further three years, and the process repeated along with consideration of if the period of not growing host crops should be extended.

7. Evaluation and review of the contingency plan

- 7.1. The Defra Contingency Plan for Plant Health in England requires that the pest specific plan is reviewed following an outbreak. This pest specific contingency plan should also be reviewed annually to take into account of changes in legislation, control procedures, sampling and diagnosis methods, and any other relevant amendments.
- 7.2. Lessons should be identified during and after any *T. indica* or non-*T. indica* outbreak, including what went well and what did not. These should be included in any review of the contingency plan leading to continuous improvement of the plan and response to outbreaks.

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Appendix 1



Plant Pest Factsheet

Karnal Bunt

Tilletia indica



Figure 1. Harvested grain with Karnal bunt © Fera Science Ltd

Background

Karnal bunt (also known as partial bunt) is a quarantine disease that infects wheat, durum wheat and triticale. It is caused by the fungal pathogen *Tilletia indica* Mitra. The disease was first formally reported on wheat in the Karnal district of northern India in 1930. Karnal bunt has the potential to reduce grain quality and marketability. Introduction of this pathogen to the UK could cause economic damage by limiting potential export markets. Official eradication measures would be required in the event of an outbreak occurring.

Geographical Distribution

Tilletia indica was first described in India and is widespread in the North-east of the country. It is endemic in Afghanistan, Iran, Iraq, Nepal and Pakistan, and has been introduced to Brazil, Mexico, South Africa and the USA. The pathogen is not present in the UK or Europe, but interceptions of contaminated grain have occurred in the UK and in Italy.

Host Plants

Wheat (*Triticum aestivum*), durum wheat (*T. durum*) and triticale (*x Triticosecale*), although the latter is only rarely infected.



Figure 2. Bunted ear (*Tilletia indica*) of wheat exhibiting stunted grains with streaks and some blackened areas containing spores (left). Uninfected ear of wheat (right) © Ruben Durán, Washington State University & Mary Burrows, Montana State University, Bugwood.org.

Symptoms

The pathogen is sometimes referred to as a member of the smut fungi group because affected grains have a black, sooty appearance. Infection begins at the germ end of the seed, then spreads within the periderm layer, reducing the seed to a mass of black spores (teliospores) known as sori. The infection may be limited to just the germinal end of the seed (point infection) or may spread along, and outwards from, the groove. During harvest and handling, the seed and sori ruptures, disseminating the teliospores and leaving behind a seed which is broken or hollow at the germ end, or eroded along the groove.

The disease is not readily detected in the field as typically only a few seeds in an ear become infected and infected grains are usually concealed within the glumes. Karnal bunt is more easily found when inspecting grain after harvest, either by visual inspection of a seed sample or, more reliably, by conducting a seed wash test for teliospores, in a laboratory (Fig 3).

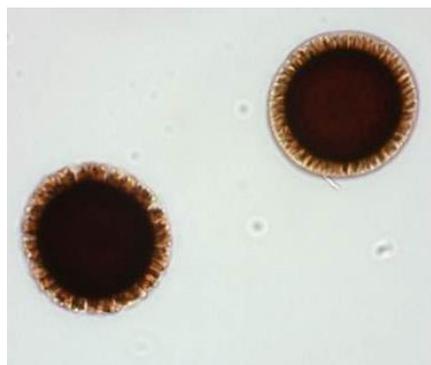


Figure 3. Magnified teliospores of *Tilletia indica* © Fera Science Ltd

Symptoms of Karnal bunt on wheat can be confused with other seed diseases including common bunt (*Tilletia caries*), which is present in the UK. It can also be very difficult to differentiate *Tilletia indica* morphologically from other *Tilletia*'s including *T. walkeri* and *T. horrida* (Fig 4). To confirm a diagnosis of *Tilletia indica* characteristic features of at least 10 teliospores are recorded. This can take several seed washings, and consequently laboratory tests to differentiate these species take some time.

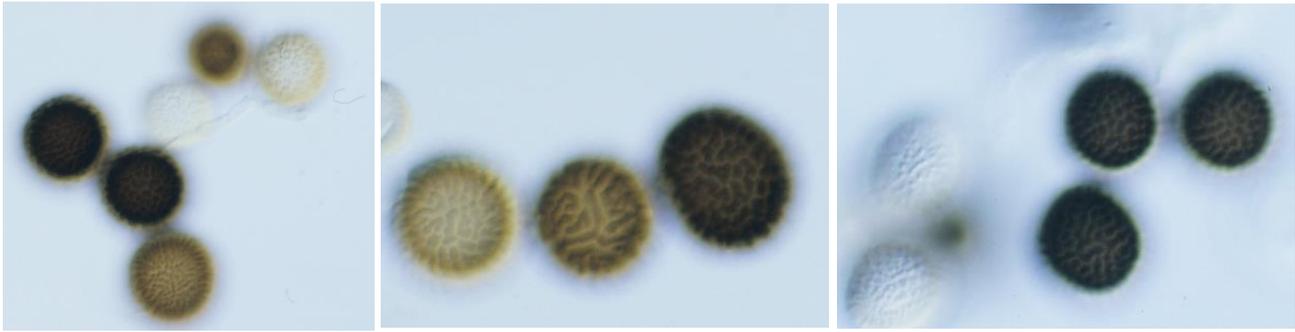


Figure 4. *Tilletia indica* (left), *Tilletia walkeri* (middle) and *Tilletia horrida* (right) spores. © Fera Science Ltd

How does it develop and spread?

The primary route of introduction of Karnal bunt to new regions is on contaminated seed for planting. Grain for animal feed or human consumption also poses a potential risk, as it is imported in large volumes and, depending on transport conditions, teliospores could escape the consignment and enter wheat production areas. Spread could be facilitated by secondary contamination from conveyances such as rail freight carriages, trucks or trailers which have carried contaminated grain or contaminated field equipment. Air borne spread has also been considered, especially at a local level.

The cycle of disease starts when infected seed is harvested. The mechanical action of harvesting causes infected seeds and sori to rupture, liberating the teliospores. The teliospores fall to the ground, together with infected or contaminated seed and plant debris, where they remain viable until conditions are appropriate for their germination.

Under warm (15-25°C) and moist conditions, teliospores on or near the soil surface germinate to produce sporidia which are spread by wind or rain onto new seedlings. During flowering these sporidia invade the floret tissues and then enter the developing seed to produce a mass of black teliospores within the seed's pericarp. When these teliospores are liberated during harvest onto the soil surface, or dispersed on or in the seed, the cycle begins again. These very specific conditions required for germination and infection are believed to occur around once in 4 years in *Tilletia indica*'s native range. Teliospores can survive in the soil for at least 3 years or on stored seed for longer periods.

Economic Impact

Karnal bunt can reduce both yield and grain quality. Bunted kernels smell of fish due to the trimethylamine that is produced. If more than 3% of the grains used to make flour are 'bunted' then, the flour can have a distinct fishy odour. However, such infection levels are rare and have never been recorded in the field in the USA. Bunted kernels present no risk to animal or human health.

Many countries will not accept imports of grain unless they originate from areas designated free from Karnal bunt. Outbreaks can, therefore, lead to significant export losses, and the main economic impact is due to export sanctions. After the introduction of Karnal bunt to the USA, phytosanitary measures implemented in Texas between 2001 and 2002 were estimated to cause

economic losses of \$25 million. The USA implemented a National survey for Karnal bunt at a county level so that wheat growing areas could be declared free of Karnal bunt thus allowing export from these areas. This National survey for Karnal bunt is estimated to prevent an average annual loss of 15.1% of the export market.

Potential economic impacts of the introduction of Karnal bunt to the EU have previously been assessed and concluded that the pest could have moderate impacts on yield but a massive impact on quality, especially given the potential lack of resistance to the pathogen in European cultivars of wheat.

Advisory Information

Suspected outbreaks of *Tilletia indica* or any other non-native plant pest should be reported to the relevant authority:

For **England and Wales**, contact your local **APHA Plant Health and Seeds Inspector** or the **PHSI Headquarters**, York.

Tel: 0300 1000 313 (please select option 3 when calling)

Email: planthealth.info@apha.gov.uk

For **Scotland**, contact the **Scottish Government's Horticulture and Marketing Unit**:

Email: hort.marketing@gov.scot

For **Northern Ireland**, contact the **DAERA Plant Health Inspection Branch**:

Tel: 0300 200 7847 Email: planthealth@daera-ni.gov.uk

For additional information on UK Plant Health please see:

<https://secure.fera.defra.gov.uk/phiw/riskRegister/>

<https://www.gov.uk/plant-health-controls>

<http://www.gov.scot/Topics/farmingrural/Agriculture/plant/PlantHealth/PlantDiseases>

<https://www.daera-ni.gov.uk>

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