APPROVED: 17 May 2019
Doi: 10.5281/zenodo.2789903

Tilletia indica
Pest Report to support ranking of EU candidate priority pests

EFSA (European Food Safety Authority),
Baker R, Gilioli G, Behring C, Candiani D, Gogin A, Kaluski T, Kinkar M, Mosbach-Schulz O, Neri FM, Preti S, Rosace MC, Siligato R, Stancanelli G and Tramontini S

Requestor: European Commission
Question number: EFSA-Q-2018-00405
Output number: EN-1658
Correspondence: alpha@efsa.europa.eu

Acknowledgements: EFSA wishes to acknowledge the contribution of Trond Rafoss to the EKE and the review conducted by Anna Maria Vettraino.

Table of Contents

1. Introduction to the report

This document is one of the 28 Pest Reports produced by the EFSA Working Group on EU Priority Pests under task 3 of the mandate M-2017-0136. It supports the corresponding Pest Datasheet published together on Zenodo[1] and applies the methodology described in the Methodology Report published on the EFSA Journal (EFSA, 2019).

This Pest Report has five sections. In addition to this introduction, a conclusion and references, there are two key sections, sections 2 and 3.

Section 2 first summarises the relevant information on the pest related to its biology and taxonomy. The second part of Section 2 provides a review of the host range and the hosts present in the EU in order to select the hosts that will be evaluated in the expert elicitations on yield and quality losses. The third part of Section 2 identifies the area of potential distribution in the EU based on the pest's current distribution and assessments of the area where hosts are present, the climate is suitable for establishment and transient populations may be present. The fourth part of Section 2 assesses the extent to which the presence of the pest in the EU is likely to result in increased treatments of plant protection products. The fifth part of section 2 reviews additional potential effects due to increases in mycotoxin contamination or the transmission of pathogens.

In Section 3, the expert elicitations that assess potential yield losses, quality losses, the spread rate and the time to detection are described in detail. For each elicitation, the general and specific assumptions are outlined, the parameters to be estimated are selected, the question is defined, the evidence is reviewed and uncertainties are identified. The elicited values for the five quantiles are then given and compared to a fitted distribution both in a table and with graphs to show more clearly, for example, the magnitude and distribution of uncertainty. A short conclusion is then provided.

The report has two appendices. Appendix A contains a host list created by amalgamating the host lists in the EPPO Global Database (EPPO, online) and the CABI Crop Protection Compendium (CABI, 2019). Appendix B provides a summary of the evidence used in the expert elicitations.

It should be noted that this report is based on information available up to the last day of the meeting[2] that the Priority Pests WG dedicated to the assessment of this specific pest. Therefore, more recent information has not been taken into account.

For *Tilletia indica* the following documents were used as key references: PRA produced by the EC Fifth Framework Project QLK5-1999-01554: Pest Risk Analysis for *Tilletia indica* (Sansford et al., 2008).

[1] Open-access repository developed under the European OpenAIRE program and operated by CERN, https://about.zenodo.org/

[2] The minutes of the Working Group on EU Priority Pests are available at http://www.efsa.europa.eu/sites/default/files/wgs/plant-health/wg-plh-EU_Priority_pests.pdf

2. The biology, ecology and distribution of the pest

2.1. Summary of the biology and taxonomy

Tilletia indica is a single taxonomic entity, in the Tilletiaceae family. *Tilletia indica* is a floret-infecting smut fungus and the causal agent of Karnal bunt in wheat (*Triticum* spp.) and triticale (× Triticosecale), created by crossing wheat (Triticum) (as the female parent) with Cereal Rye (Secale cereale) (as the male parent).

There is limited knowledge of its long distance spread capacity: this pathogen can survive long periods as teliospores before germinating and infecting the wheat crop to produce detectable levels of disease, making it difficult to define where it has spread to within the US (Sansford et al., 2008).

2.2. Host plants

2.2.1. List of hosts

The main host species identified from the literature are *Triticum aestivum* (bread wheat), *Triticum durum* (durum wheat) and *Triticosecale* (triticale). Aujla et al. (1985) also showed that the wild wheat species *Aegilops geniculata, A. sharonensis, A. peregrina* var. *peregrina* and "*Triticum scerrit*" are potential hosts of *T. indica*, without specifying whether the infections were observed under natural conditions (Carris et al., 2006). Royer and Rytter (1988) also listed the following species developing infection via artificial inoculation: *Oryzopsis miliacea* (synonym of *Piptatherum miliaceum*), *Bromus ciliatus, B. tectorum, Lolium canariense, L. multiflorum, L. perenne, T. monoccocum, T. tauschii, T. timopheevi, Aegilops bicornis, A. caudata* (currently *A. markgrafii* according to Kilian et al., 2011), *A. columnaris, A. comosa, A. cylindrica, A. mutica, A. searsii, A. sharonensis, A. tauschii, A. triaristata* (currently *A. neglecta* according to Kilian et al., 2011) and *A. triuncialis* (Royer and Rytter 1988). Among these, *A. columnaris, A. comosa, A. cylindrica, A. geniculata, A. markgrafii, A. neglecta, A. peregrina, A. triuncialis* (Kilian et al., 2011), *Bromus tectorum, L. multiflorum*, *L. perenne* (CABI, 2018), *Oloptum miliaceum* (Acta Plantarum, online) and *T. monococcum* (as a relict crop in Italy and Spain, Laghetti et al., 2009, Zapata et al., 2004) are found in Europe.

Despite currently being regulated, *Secale cereale* is no longer considered to be a natural host of *T. indica* (Sansford et al., 2008).

European wheat cultivars are susceptible to infection and disease development under EU climatic conditions (Riccioni et al., 2008). Sansford et al. (2008) stated that: "European winter, spring and durum wheat cultivars have not been bred for resistance to *T. indica* and […] have been shown to exhibit a range of susceptibility to infection by the pathogen similar to that which occurs in countries where it is established".

Appendix A provides the full list of hosts.

2.2.2. Selection of hosts for the evaluation

Triticum aestivum (bread wheat) and *Triticum durum* (durum wheat) were assessed for impact since they are both susceptible to *T. indica* with the potential for yield and quality losses. Although *Triticosecale* (triticale) is also susceptible, it has not been included in the impact assessment because it is not only more resistant than durum and bread wheat but also because its primary use is for animal feed and the effects of Karnal bunt, such as dark colour and a fishy smell from infected kernels, do not result in the losses that can occur in cereals for human consumption.

2.2.3. Conclusions on the hosts selected for the evaluation

Triticum aestivum (bread wheat) and *Triticum durum* (durum wheat) were assessed for impact since they are both susceptible to *T. indica* with the potential for yield and quality losses. Although *Triticosecale* (triticale) is also susceptible, it has not been included in the impact assessment because it is not only more resistant than durum and bread wheat but also its primary use is for animal feed and the effects of Karnal bunt, such as dark colour and a fishy smell from infected kernels, do not result in the losses that can occur in cereals for human consumption.

2.3. Area of potential distribution

2.3.1. Area of current distribution

Figure 1 provides an overview of the current area of distribution of the pest. In the EU no outbreaks have yet been reported.

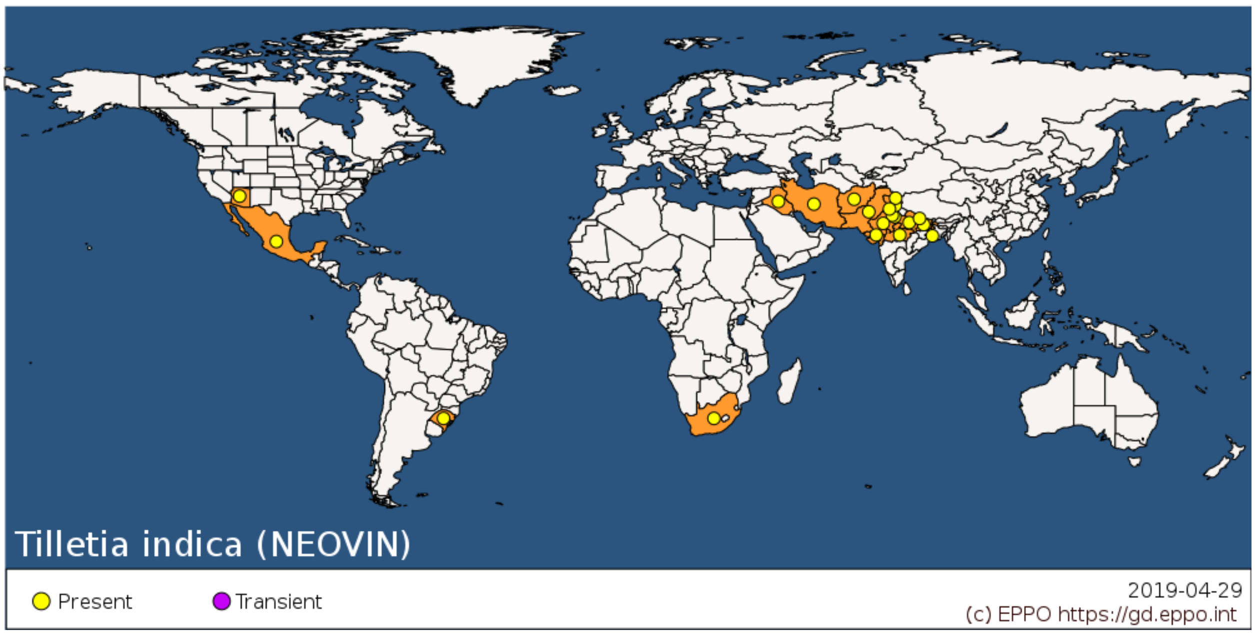


Figure 1 Distribution map of *Tilletia indica* from the EPPO Global Database accessed 29/04/2019.

2.3.2. Area of potential establishment

The likelihood of infection by *T. indica* teliospores has been modelled with the humid thermal index (HTI) based on Jhorar et al. (1992). When the HTI (the ratio of the mean afternoon relative humidity to the mean daily maximum temperature) lies between 2.2 and 3.3 during key growth stages, conditions are suitable for infection; Johrar et al. (1992) also showed a correlation between HTI and disease severity. In the EU Karnal Bunt Project, Baker et al. (2005) combined the HTI model and two wheat phenology models with 1995-2002 climatic data interpolated to a 1 km grid in order to map the potential risk of *T. indica* infection in Europe. Baker et al. (2005) calculated the Humid-Thermal Index on a 1 x 1 km grid for 3 specific sowing dates per host in 8 years from 1995 to 2002. The average proportion for all grid cells with arable land within a NUTS2 region was calculated.

Maps for bread and durum wheat were generated with a risk score out of 24 (based on the number of years with HTI within range during the critical growth stages) for each 1 km where the PELCOM land cover map (Mücher et al., 2000) predicted arable cultivation. EFSA has generated maps showing the data for NUTS2 (see figure 2 and 3).

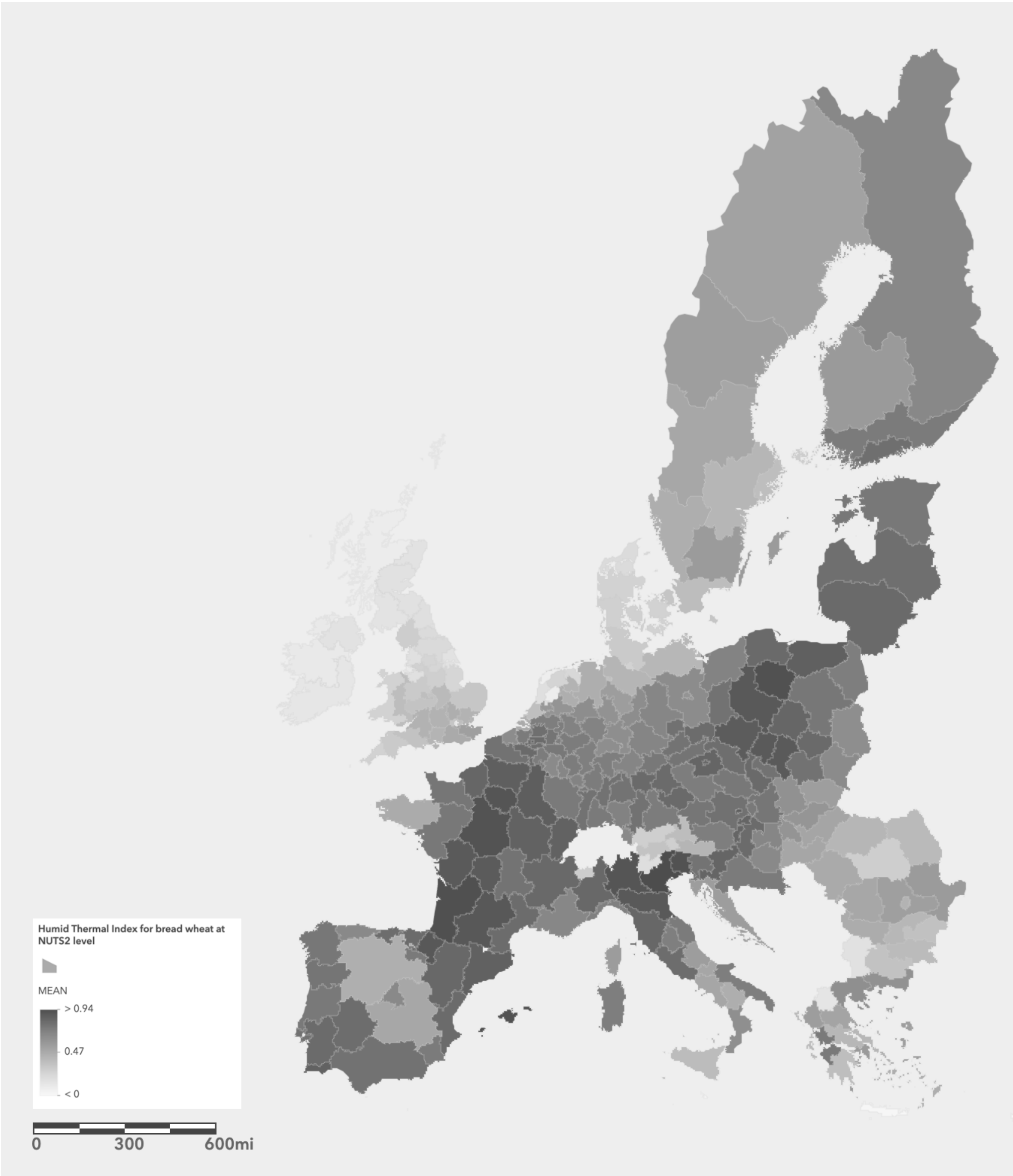


Figure 2 Thermal Index for bread wheat in the EU NUTS2 regions. This link provides an online interactive version of the map that can be used to explore the data further: https://arcg.is/0X9nOb

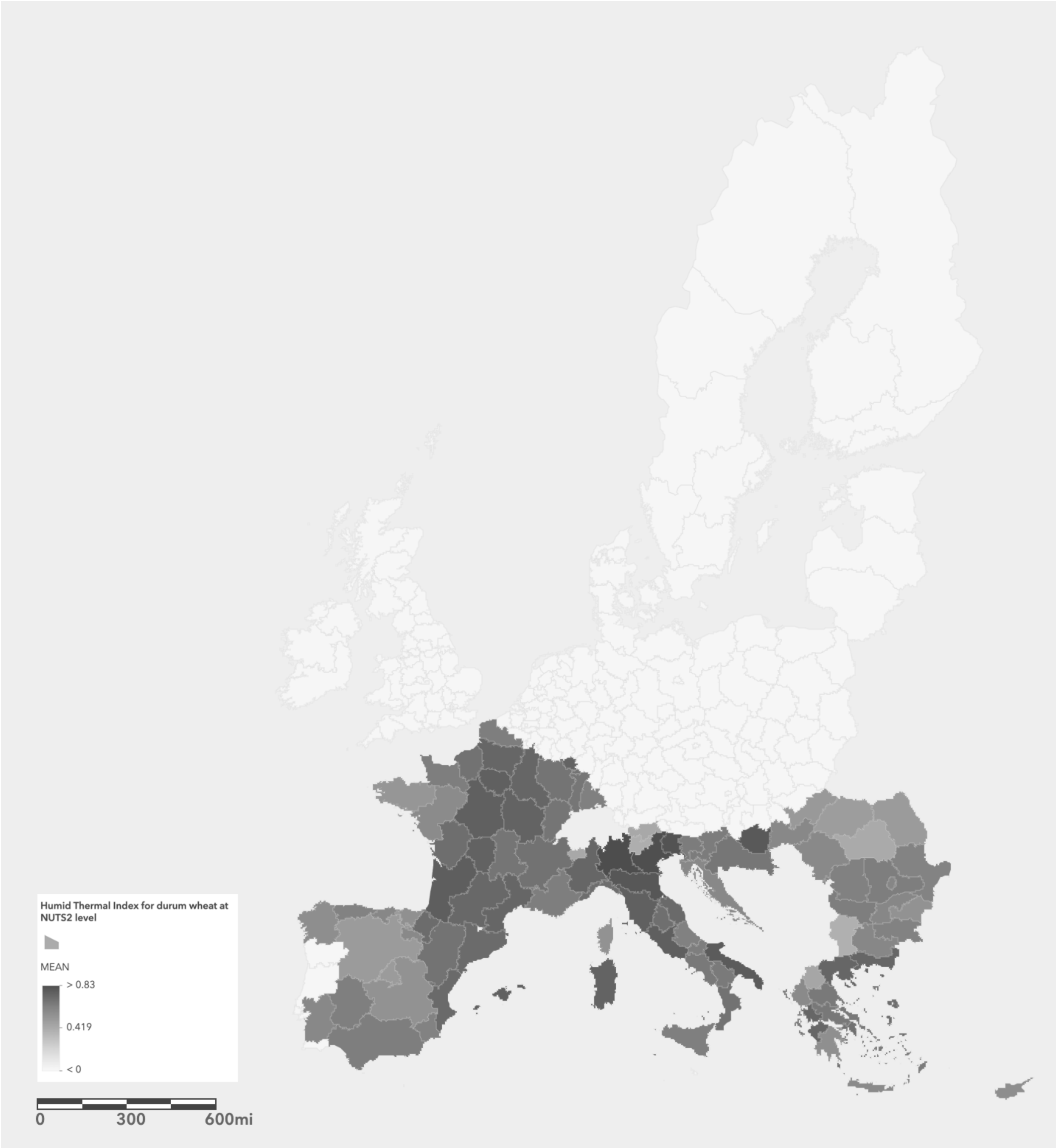


Figure 3 Thermal Index for durum wheat in the EU NUTS2 regions. This link provides an online interactive version of the map that can be used to explore the data further: https://arcg.is/0X9nOb

2.3.3. Transient populations

Tilletia indica is not expected to form transient populations in the EU (for "transient" see the definition in EFSA, 2019).

2.3.4. Conclusions on the area of potential distribution

All the area of production of *Triticum aestivum* (bread wheat) and *Triticum durum* (durum wheat) in the EU is considered to be suitable for *T. indica* and was therefore used as the area of potential distribution in this assessment. This covers all EU NUTS2 zones. Triticale is grown in an area comparable to that planted with bread and durum wheat.

2.4. Expected change in the use of plant protection products

For the control of *T. indica* a series of fungicides are available (examples provided in Table 1). In EU areas of host production, fungicides applications on bread and durum wheat are currently used against other pathogens. Most of them are considered to be effective, for a.i. and for treatment time, against *T. indica*. The proportion of wheat growing area treated with foliar fungicides and the extent to which some of the currently applied PPPs are ineffective against *T. indica* are the main identified uncertainties.

Table 1: Plant protection products applied against *Tilletia indica*

Control strategy	Number of treatments	Additional information (conditions, crop, location, etc)	Reference
mancozeb, carbendazim, fentin hydroxide, bitertanol and propiconazole	A range of fungicides give effective control of sporidia on wheat foliage if applied at the 'early heading' stage.	Sporidia released from germinating teliospores land on leaf surfaces and can germinate to produce epiphytic colonies which go on to produce further airborne sporidia capable of infecting florets	Agarwal et al., (1993)
propiconazole, epoxiconazole, tebuconazole and azoxystrobin	good in vitro efficacy against mycelial growth and sporidial germination		Sansford et al., 2006
azoxystrobin	single spray treatment at GS (growth stage) 39 (flag leaf ligule just visible), GS49 (first awns visible), GS65 (mid-anthesis) or GS71 (caryopsis watery ripe).	effective both pre and post-infection	Sansford et al., 2008
propiconazole	single spray treatment at GS39, GS49, GS65 or GS71	effective both pre and post-infection	Sansford et al., 2008
Propioconazole, Agrozim and carbendazim and triadimefon	application of foliar fungicides between late boot and flowering		Sharma et al., 2017

Due to the fact that effective treatments with plant protection products (PPPs) are currently available, the most suitable PPP indicator is Case "B" and the category is "0" based on Table 2.

Table 2: Expected changes in the use of Plant Protection Products (PPPs) following *Tilletia indica* establishment in the EU in relation to four cases (A-D) and three level score (0-2) for the expected change in the use of PPPs

Expected change in the use of PPPs	Case	PPPs indicator
PPPs effective against the pest are not available/feasible in the EU	A	0
PPPs applied against other pests in the risk assessment area are also effective against the pest, without increasing the amount/number of treatments	**B**	**0**
PPPs applied against other pests in the risk assessment area are also effective against the pest but only if the amount/number of treatments is increased	C	1
A significant increase in the use of PPPs is not sufficient to control the pest: only new integrated strategies combining different tactics are likely to be effective	D	2

2.5. Additional potential effects

2.5.1. Mycotoxins

The species is not known to be related to problems caused by mycotoxins.

2.5.2. Capacity to transmit pathogens

The species is not known to vector any plant pathogens.

3. Expert Knowledge Elicitation report

3.1. Yield and quality losses

3.1.1. Structured expert judgement

3.1.1.1. Generic scenario assumptions

All the generic scenario assumptions common to the assessments of all the priority pests are listed in the section 2.4.1.1 of the Methodology Report (EFSA, 2019).

3.1.1.2. Specific scenario assumptions

- The potential proportion of loss in yield ($r_{loss,n}$) per host and NUTS2 region is estimated as product of three components:

  $r_{loss,n,h} = r_{loss|D} \bullet r_{D|I} \bullet r_{I,n,h}$

  with n = Index per NUTS2 region, h = Index per host
- **Average proportion of suitable area** for infection during a long-term time frame: $\mathbf{r_{I,n,h}}$
  - Estimated per NUTS 2 region (n) and host (h)
  - Suitable area is defined as arable land with a favourable Humid-Thermal-Index (HTI): 2.2 ≤ HTI ≤ 3.3 for host specific sowing dates:
    - Sowing dates for bread wheat: Julian dates 274, 305 and 335
    - Sowing dates for durum wheat: Julian dates 294, 314 and 335
  - Sufficient long term time frame is the average of at least 5 years.
  - It is assumed that the fungus with ungerminated viable teliospores is present and causes infection when conditions are suitable
  - It is assumed that the HTI is equal for all hosts
  - It is assumed that all hosts can be grown on all arable land within a NUTS2 region
  - Data were taken from Baker et al. (2005)
- **Average proportion of diseased fields** after infection: $\mathbf{r_{D|I}}$
  - A field is diseased, when at least one plant develops bunted grains
  - For the maximum extent it is assumed that this proportion is 100%
- **Average proportion of yield loss** in diseased fields: $\mathbf{r_{loss|D}}$
  - A field is diseased, when at least one plant develops bunted grains
  - Parameter was elicited using expert judgement
- **Average proportion of suitable area**

  Baker et al. (2005) calculated the Humid-Thermal Index on a 1x1km grid for 3 specific sowing dates per host in 8 years from 1995 to 2002. The average proportion for all grid cells with arable land within a NUTS2 region was calculated.
- **Average proportion of diseased fields**

  This parameter is set to 100%.
- **Average proportion of yield loss in diseased fields**

As explained in more detail below, the EFSA Working Group (WG) took into account evidence from Mexico (Brennan and Warham, 1990) to assume that the weight of an infected grain is reduced by 25% due to the infection. To obtain the average proportion of yield loss in diseased fields the WG re-calculated the values only for samples with detected infections (over 0%). The relative yield loss in diseased fields was 0.15% in Southern Sonora and 0.38% in Sinaloa.

- When the grain contains more than 1.5% of Karnal bunt infected grains, the wheat cannot be sold for human consumption and it therefore needs to be downgraded to grain for animal feed or further processed (washed and/or diluted with clean grain).

3.1.1.3. Selection of the parameter(s) estimated

Slight contamination of wheat with bunted kernels may lower the price of the cereal but could be handled by simple processing such as washing the grain or diluting contaminated lots with uncontaminated wheat. This may influence the price and change processing procedures.

A clear decrease in quality is reached when the level of infection is so high that the wheat can no longer be used for human consumption and is downgraded to animal feed. This is due to changes in odour and taste caused by the disease. It is established that the threshold for the level of infection causing a downgrading of the product is 1.5% bunted kernels.

3.1.1.4. Defined question(s)

What is the percentage yield loss for bread wheat and durum wheat under the scenario assumptions in the area of the EU under assessment for *Tilletia indica*, as defined in the Pest Report?

What is the percentage of the harvested bread wheat and durum wheat damaged by *Tilletia indica*, that would lead to downgrading the final product because of quality issues under the scenario assumptions in the area of the EU under assessment as defined in the Pest Report?

3.1.1.5. Evidence selected

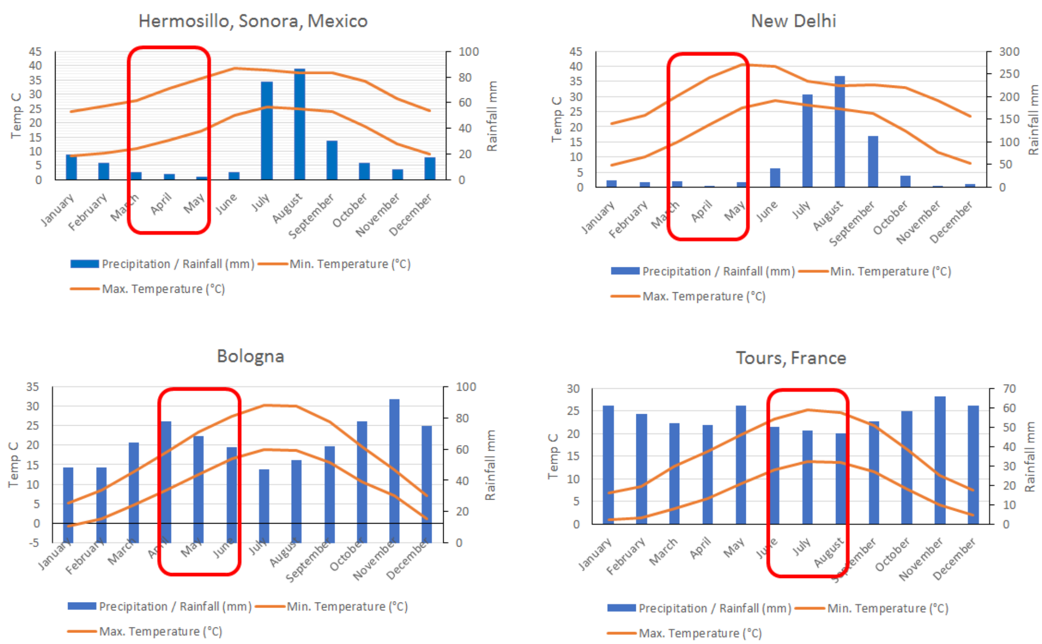
The experts reviewed the evidence obtained from the literature (see Table B.1 in Appendix B) selecting the data and references used as the key evidence for the EKE on impact.

As set out below, additional evaluations were made by:

- re-calculating some statistics in Brennan and Warham (1990)
- comparing the time of harvest in Mexico, India and Europe
- studying fungicide use in Europe and its potential efficacy against *Tilletia indica*

Based on Brennan and Warham (1990), the WG assumed that the sample is representative for the whole yield in two regions of Mexico (Southern Sonora and Northern Sinaloa), and that the weight of an infected grain is reduced by 25% due to the infection. With these assumptions the WG calculated an average relative yield loss of 0.07% in Southern Sonora and 0.27% in Northern Sinaloa (see Table 2). To obtain the average proportion of yield loss in diseased fields the WG re-calculated the values only for samples with detected infections (over 0%). The relative yield loss in diseased fields was 0.15% in Southern Sonora and 0.38% in Northern Sinaloa.

The WG also compared the climatic conditions of Sonora (North-East Mexico), New Dehli (Northern India), and two main wheat production areas in Europe, namely Bologna (Northern Italy) and Tours (Central France) to facilitate extrapolation from the Indian and Mexican studies to the European situation.



Red boxes indicate the local harvest period of wheat
Source: en.climate-data.org

Figure 4 Climatic comparison of wheat production areas in Mexico, India, and two main locations in Europe

The higher temperatures in India and Mexico will be more favourable for the disease, while the lower precipitation is less influential for the later development of the fungus.

The final discussion compared agricultural practices in regions with Karnal bunt disease and the current practice of wheat production in Europe. The group concluded that:

- fungicides are widely used in European wheat production
- Many fungicides used are also effective against *T. indica*
- a treatment in the heading phase is particularly effective against *T. indica*, while seed treatment is regarded as not effective.

Table 3: Level of infected grain and relative loss in yield in Northern Sinaloa, Mexico (Re-calculation of table 2.6 in Brennan and Warham (1990))

	Level of infected grain											
Percent of infested grain [%]	**0**	**0.1-0.5**	**0.5-1**	**1-2**	**2-3**	**>3**		**Average level, If infected**		**Relative yield loss, if infected**		
Midpoint [%]	**0**	**0.3**	**0.75**	**1.5**	**2.5**	**12.2[1]**	**Average level**		**Relative loss in yield**		**Part >2% infected**	**Part >1% infected**
Year	**Percentage of samples, Sinaloa, Mexico [%]**						**[%]**	**[%]**	[%]	[%]	[%]	[%]
1983/84	92.9	7.1	0	0	0	0	0.021	0.300	0.005	0.075	0.0	0.0
1984/85	49.1	36.2	3.6	4.9	1.8	4.4	0.791	1.554	0.198	0.388	6.2	11.1
1985/86	15.9	34.1	9.5	9.5	5.1	25.9	3.603	4.285	0.901	1.071	31.0	40.5
1986/87	71.2	24.9	1.6	0.9	0.9	0.5	0.184	0.638	0.046	0.159	1.4	2.3
1987/88	85.6	14.4	0	0	0	0	0.043	0.300	0.011	0.075	0.0	0.0
1988/89	14.4	49.9	9.8	7.5	9.2	9.3	1.700	1.986	0.425	0.497	18.5	26.0
Long term average							**1.0571**	**1.5104**	**0.2643**	**0.3776**	**9.52**	**13.32**

Grey cells as given in Table 2.6 in in Brennan and Warham (1990)

(1): Average of individual measurements as given in Brennan and Warham (1990) is between 5% (1986/87) and 12.2% (1985/86), total average by back-calculation

3.1.1.6. Uncertainties identified

- Only Indian and Mexican studies included the average proportion of yield loss in diseased fields in the references reviewed
- All published studies report the total average yield loss per region, but not the average yield loss in infected fields. The reported values therefore underestimate the parameter of interest.
- The climatic conditions in Mexico and India during the harvest period are hotter and drier than in Europe and are therefore more favourable for the development of Karnal bunt disease.
- The current wheat production practices in Europe, e.g. the use of fungicides, are partly effective against *T. indica*. Detailed information was not available.
- Differences may exist between bread and durum wheat, but varietal differences are estimated as assumed to be more important. Variety specific studies and a comparison of varieties grown in Mexico/India and Europe have not been published.

3.1.2. Elicited values for yield losses on bread and durum wheat

What is the percentage yield loss for bread wheat and durum wheat under the scenario assumptions in the area of the EU under assessment for *T. indica*, as defined in the Pest Report?

The five elicited values on yield loss on bread wheat and durum wheat on which the group agreed are reported in the table below.

Table 4: The 5 elicited values on yield loss (%) on bread wheat and durum wheat

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	0%	0.025%	0.050%	0.1%	0.5%

3.1.2.1. Justification for the elicited values for yield loss on wheat and durum wheat

Reasoning for a scenario which would lead to high yield loss (99th percentile / upper limit)

The high yield loss scenario relates to situations where fungicides are relatively ineffective due to poor timing and/or too few treatments and high temperatures following infection are favourable for development of the fungus in the ear. These high temperatures would be similar to those that occur in the areas of Mexico and India where the disease is prevalent.

Reasoning for a scenario which would lead to low yield loss (1st percentile / lower limit)

The low yield loss scenario relates to situations where (i) fungicides are highly ineffective due to good timing and sufficient numbers of treatments and (ii) relatively low temperatures following infection are unfavourable for development of the fungus in the ear.

Reasoning for a central scenario equally likely to over- or underestimate the yield loss (50th percentile / median)

The experts chose a lower median yield loss than the 0.15% calculated for Southern Sonora and 0.38% for Northern Sinaloa in Mexico due to the greater overall usage of fungicides in the EU and the cooler temperatures in European bread and durum wheat production.

Reasoning for the precision of the judgement describing the remaining uncertainties (1st and 3rd quartile / interquartile range)

The values elicited by the experts show they have greater confidence in the low values but that these have high uncertainty.

3.1.2.2. Estimation of the uncertainty distribution for yield loss on bread wheat and durum wheat.

The comparison between the fitted values of the uncertainty distribution and the values agreed by the group of experts is reported in the table below.

Table 5: Fitted values of the uncertainty distribution on the yield loss (%) on bread and durum wheat.

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	0%					0.025%		0.050%		0.100%					0.500%
Fitted distribution	0.005%	0.007%	0.009%	0.013%	0.019%	0.025%	0.032%	0.050%	0.078%	0.100%	0.135%	0.186%	0.270%	0.373%	0.544%

Fitted distribution: Lognorm(0.00084595,0.0011549), @RISK7.5

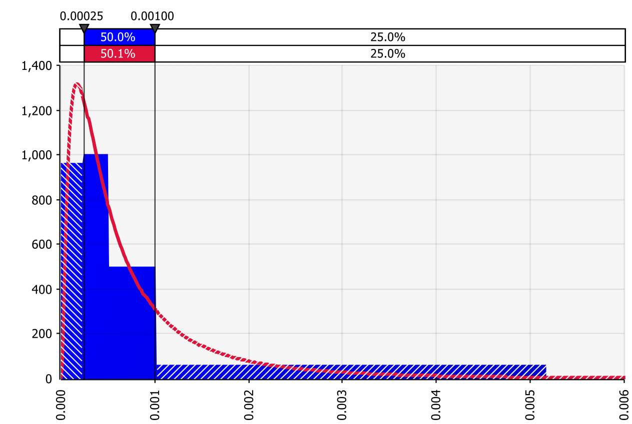


Figure 5 Comparison of judged values (histogram in blue) and fitted distribution (red line) for yield loss on bread and durum wheat.

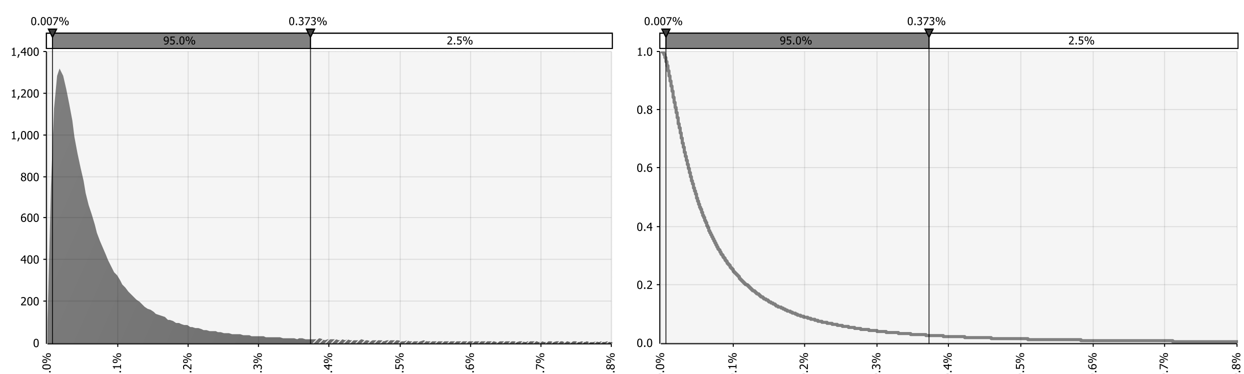


Figure 6 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for yield loss on bread and durum wheat.

3.1.3. Elicited values for quality losses on bread and durum wheat

What is the percentage of the harvested bread wheat and durum wheat damaged by *T. indica*, that would lead to downgrading the final product because of quality issues under the scenario assumptions in the area of the EU under assessment as defined in the Pest Report?

The five elicited values on quality loss on bread wheat and durum wheat on which the group agreed are reported in the table below.

Table 6: The 5 elicited values on quality loss (%) on bread wheat and durum wheat

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	0%	1%	2%	4%	10%

3.1.3.1. Justification for the elicited values for quality loss on wheat and durum wheat

Reasoning for a scenario which would lead to high yield loss (99th percentile / upper limit)

The high value of 10% assumes a similar situation in the EU as in Mexico, considering that in the EU fungicide treatment is reduced and crop rotation is limited.

Reasoning for a scenario which would lead to low yield loss (1st percentile / lower limit)

The low value of 0% is based on the assumption that the infestation level in Europe would not reach 1% of infested grain and not result in any quality loss.

Reasoning for a central scenario equally likely to over- or underestimate the yield loss (50th percentile / median)

The median value is set to 2% reflecting the higher likelihood of low infestation levels.

Reasoning for the precision of the judgement describing the remaining uncertainties (1st and 3rd quartile / interquartile range)

The precision reflects the fact that the experts are more certain that higher values are less likely. However, the experts are uncertain on the likelihood of lower values.

3.1.3.2. Estimation of the uncertainty distribution for quality loss on bread wheat and durum wheat.

The comparison between the fitted values of the uncertainty distribution and the values agreed by the group of experts is reported in the table below.

Table 7: Fitted values of the uncertainty distribution on the yield loss (%) on *Betula* sp.

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	0.0%					1.0%		2.0%		4.0%					10.0%
Fitted distribution	0.1%	0.1%	0.2%	0.4%	0.7%	1.0%	1.3%	2.1%	3.1%	3.9%	4.9%	6.2%	7.9%	9.5%	11.7%

Fitted distribution: Gamma(1.2133,0.023111), @RISK7.5

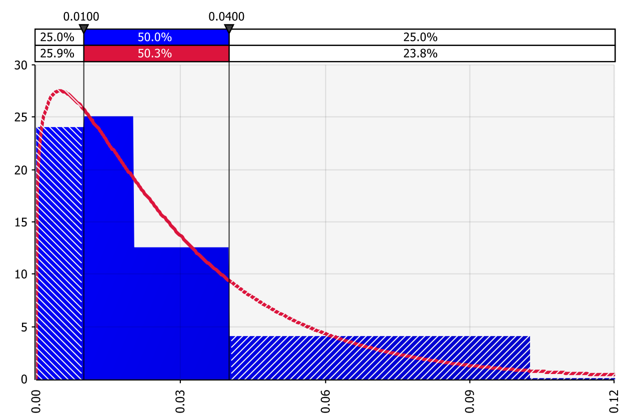


Figure 7 Comparison of judged values (histogram in blue) and fitted distribution (red line) for quality loss on bread and durum wheat.

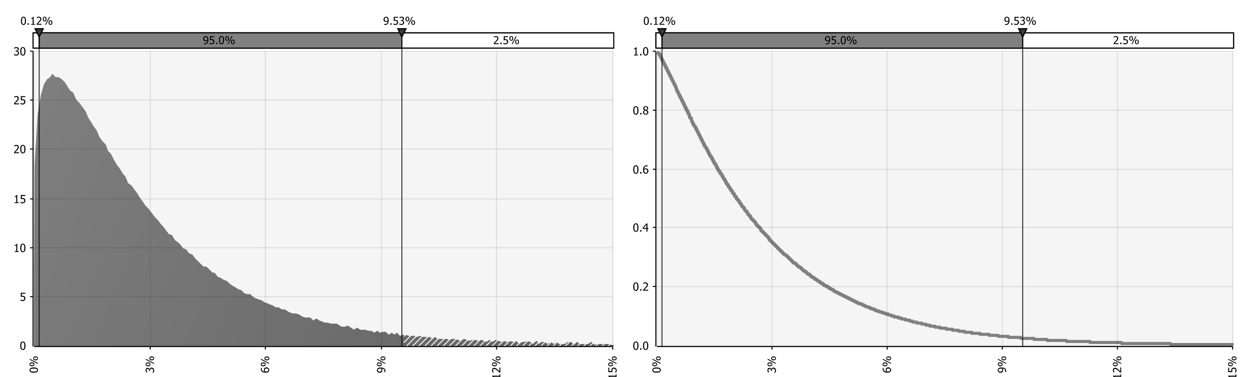


Figure 8 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for yield loss on bread and durum wheat.

3.1.4. Conclusions on yield and quality losses

Based on the general and specific scenarios considered in this assessment, the percentage yield loss for bread wheat and durum wheat is estimated to be 0.05% (with a 95% uncertainty range of 0.007 – 0.37%).

The percentage quality losses for bread and durum wheat is estimated to be 2% (with a 95% uncertainty range of 0.1 – 9.5%).

3.2. Spread rate

3.2.1. Structured expert judgement

3.2.1.1. Generic scenario assumptions

All the generic scenario assumptions common to the assessments of all the priority pests are listed in the section 2.4.2.1 of the Methodology Report (EFSA, 2019).

3.2.1.2. Specific scenario assumptions

The principal method of spread is by teliospores with soil, e.g. by agricultural machinery within a farm and by wind erosion. Movement with animal manure is also possible.

3.2.1.3. Selection of the parameter(s) estimated

The spread rate has been assessed as the number of metres per year.

3.2.1.4. Defined question(s)

What is the spread rate in 1 year for an isolated focus within this scenario based on average European conditions? (units: m/year)

3.2.1.5. Evidence selected

The experts reviewed the evidence obtained from the literature (see Table B.2 in Appendix B) selecting the data and references used as the key evidence for the EKE on spread rate.

3.2.1.6. Uncertainties identified

Current application of stubble burning in the EU: since 2016 it is not an acceptable practice according to Directive (EU) 2016/2284[3] therefore the WG assumed that this method of spread is no longer relevant to the EU.

---

[3] Directive (Eu) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC. OJ L 344, 17.12.2016, p. 31.

3.2.2. Elicited values for the spread rate

What is the spread rate in 1 year for an isolated focus within this scenario based on average European conditions? (units: m/year)

The five elicited values on spread rate on which the group agreed are reported in the table below.

Table 8: The 5 elicited values on spread rate (m/y)

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	100	500	1000	3000	10000

3.2.2.1. Justification for the elicited values of the spread rate

Reasoning for a scenario which would lead to wide spread (99th percentile / upper limit)

Overall, the experts based their estimates on the availability of spores and wind. The spread associated with fire was not considered, due to the general prohibition on burning crop residues in the EU.

The upper value of 10000 is based on the extreme situation of strong winds leading to soil movement (wind erosion), and movement by contractors with their machinery from farm to farm.

Reasoning for a scenario, which would lead to limited spread (1st percentile / lower limit)

The lower value of 100 is based on transmission from one plant to another plus other factors, such as wind and movement by agricultural machinery within one field.

Reasoning for a central scenario, equally likely to over- or underestimate the spread (50th percentile / median)

The median value of 1000 is based on field to field spread without extreme winds.

Reasoning for the precision of the judgement describing the remaining uncertainties (1st and 3rd quartile / interquartile range)

The precision is based on the expert views that lower distances were more likely.

3.2.2.2. Estimation of the uncertainty distribution for the spread rate

The comparison between the fitted values of the uncertainty distribution and the values agreed by the group of experts is reported in the table below.

Table 9: Fitted values of the uncertainty distribution on the spread rate (m/y)

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	100					500		1000		3000					10000
Fitted distribution	10	29	66	150	280	467	685	1238	2046	2631	3467	4531	5989	7459	9412

Fitted distribution: Gamma (0.86624,2193.1), @RISK7.5

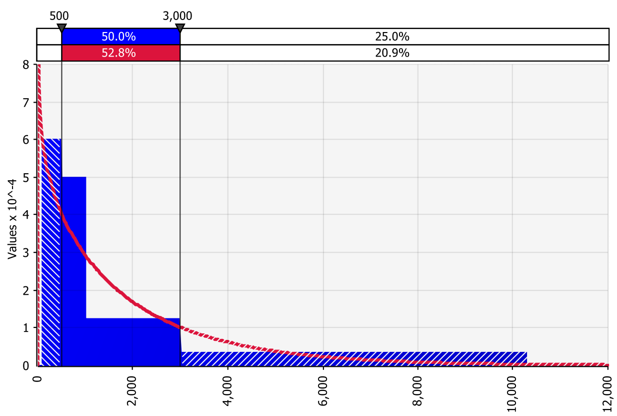


Figure 9 Comparison of judged values (histogram in blue) and fitted distribution (red line) for spread rate.

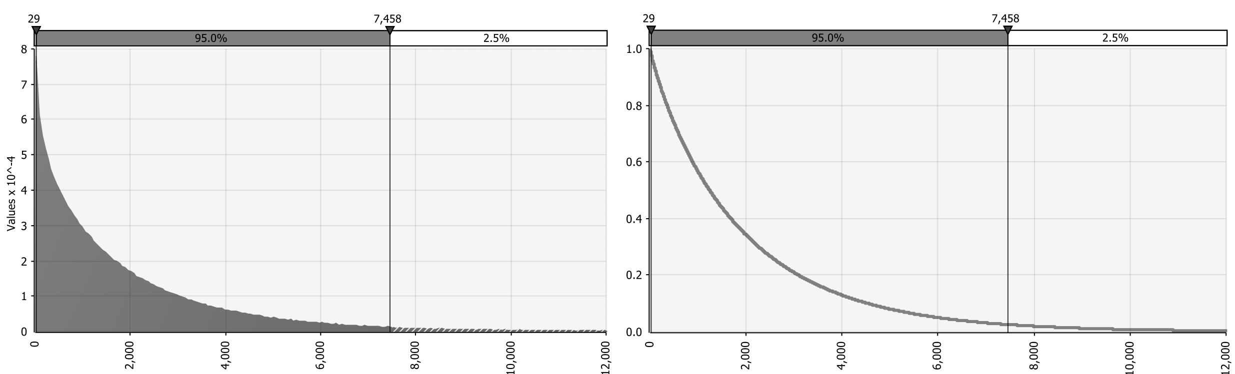


Figure 10 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for spread rate.

3.2.3. Conclusions on the spread rate

Based on the general and specific scenarios considered in this assessment, the maximum distance expected to be covered in one year by *T. indica* is 1200 m (with a 95% uncertainty range of 29 - 7,500 m).

3.3. Time to detection

3.3.1. Structured expert judgement

3.3.1.1. Generic scenario assumptions

All the generic scenario assumptions common to the assessments of all the priority pests are listed in the section 2.4.2.1 of the Methodology Report (EFSA, 2019).

3.3.1.2. Specific scenario assumptions

No specific assumptions are introduced for the assessment of the time to detection.

3.3.1.3. Selection of the parameter(s) estimated

The time for detection has been assessed as the number of years between the first event of pest transfer to a suitable host and its detection.

3.3.1.4. Defined question(s)

What is the time between the event of pest transfer to a suitable host and its first detection within this scenario based on average European conditions? (unit: years)

3.3.1.5. Evidence selected

The experts reviewed the evidence obtained from the literature (see Table B.3 in Appendix B) selecting the data and references used as the key evidence for the EKE on spread rate.

3.3.1.6. Uncertainties identified

- Time needed to express symptoms on a single plant
- Number of cropping cycles to have detectable expression of symptoms
- Detection by the farmer is not likely
- Detection likely to occur first in seed production
- Detection also expected after harvest
- Visual inspection of the field is not sufficient

3.3.2. Elicited values for the time to detection

What is the time between the event of pest transfer to a suitable host and its first detection within this scenario based on average European conditions? (unit: years)

The five elicited values on time to detection on which the group agreed are reported in the table below.

Table 10: The 5 elicited values on time to detection (years)

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	2	9	12	16	20

3.3.2.1. Justification for the elicited values of the time to detection

Reasoning for a scenario which would lead to a long time for detection (99th percentile / upper limit)

The upper value of 20 is based on the difficulty of detection and situations where infection levels are low.

Reasoning for a scenario which would lead to a short time for detection (1st percentile / lower limit)

The experts set the lower value to 2 because the spread rate is low, it may take quite some time before the pathogen is detected and that, in order to grow and infect at a detectable level, a time period of 2 years might be needed, based on the information found in the papers from Mexico.

Reasoning for a central scenario, equally likely to over- or underestimate the time for detection (50th percentile / median)

The median value of 12 is based on consideration of both the difficulty of detection and the likelihood of infection based on maps modelled with the Humid Thermal Index during the key phenological stages when wheat is susceptible.

Reasoning for the precision of the judgement describing the remaining uncertainties (1st and 3rd quartile / interquartile range)

The precision based greater uncertainty towards the lower limit.

3.3.2.2. Estimation of the uncertainty distribution for the time to detection

The comparison between the fitted values of the uncertainty distribution and the values agreed by the group of experts is reported in the table below.

Table 11: Fitted values of the uncertainty distribution on the time to detection (years)

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	2					9		12		16					20
Fitted distribution	3	4	5	6	8	9	10	12	14	15	17	18	20	22	23

Fitted distribution: Weibull (2.9137,13.805), @RISK7.5

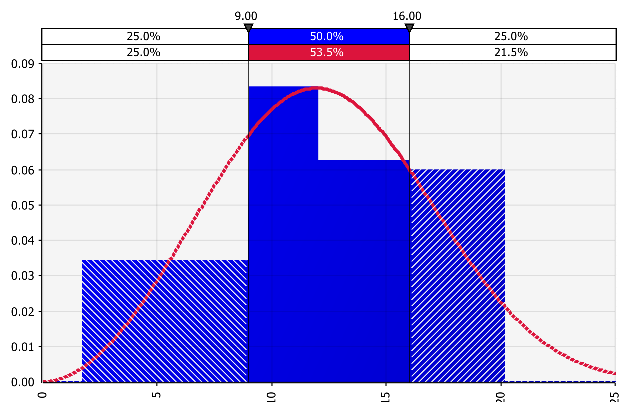


Figure 11 Comparison of judged values (histogram in blue) and fitted distribution (red line) for time to detection.

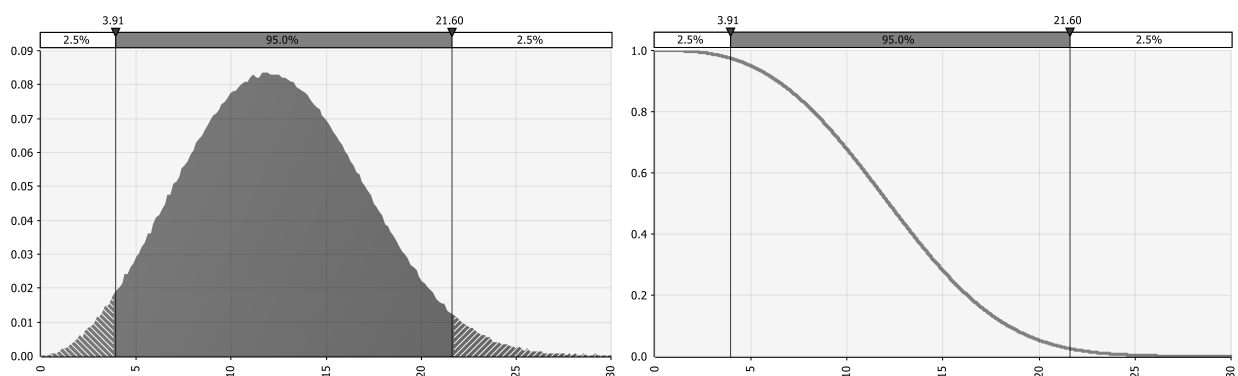


Figure 12 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for time to detection.

3.3.3. Conclusions on the time to detection

Based on the general and specific scenarios considered in this assessment, the time between the event of pest transfer to a suitable host and its detection is estimated to be 12 years (with a 95% uncertainty range of 4 - 22 years).

4. Conclusions

Hosts selection

Triticum aestivum (bread wheat) and *Triticum durum* (durum wheat) were assessed for impact since they are both susceptible to *T. indica* with the potential for yield and quality losses. Although *Triticosecale* (triticale) is also susceptible, it has not been included in the impact assessment because it is not only more resistant than durum and bread wheat but also because its primary use is for animal feed and the effects of Karnal bunt, such as dark colour and a fishy smell from infected kernels, do not result in the losses that can occur in cereals for human consumption.

Area of potential distribution

All the area of production of *Triticum aestivum* (bread wheat) and *Triticum durum* (durum wheat) in the EU is considered to be suitable for *T. indica* and was therefore used as the area of potential distribution in this assessment. This covers all EU NUTS2 zones. Triticale is grown in an area comparable to that planted with bread and durum wheat.

Expected change in the use of plant protection products

Due to the fact that effective treatments with plant protection products (PPPs) are currently available, the most suitable PPP indicator is Case “B” and the category is “0”.

Yield and quality losses

Based on the general and specific scenarios considered in this assessment, the percentage yield loss for bread wheat and durum wheat is estimated to be 0.05% (with a 95% uncertainty range of 0.007 – 0.37%).

The percentage quality losses for bread and durum wheat is estimated to be 2% (with a 95% uncertainty range of 0.1 – 9.5%).

Spread rate

Based on the general and specific scenarios considered in this assessment, the maximum distance expected to be covered in one year by *T. indica* is 1200 m (with a 95% uncertainty range of 29 - 7,500 m).

Time for detection after entry

Based on the general and specific scenarios considered in this assessment, the time between the event of pest transfer to a suitable host and its detection is estimated to be 12 years (with a 95% uncertainty range of 4 - 22 years).

5. References

Acta Plantarum, online. *Oloptum miliaceum* (L.) Röser and H.R. Hamasha - IPFI, Acta Plantarum. Available online: http://www.actaplantarum.org/flora/flora_info.php?id=5906 [Accessed on 2 June 2019]

Agarwal VK, Singh DV, Mathur S (1993). Seed-borne diseases and seed health testing of wheat, 3, 31-43.

Amaya CA, 1982. Efecto de diferentes niveles del hongo causante del carbón parcial sobre las características organolépticas del pan. Boletín Técnico. Laboratorio de Calidad Industrial. Mexico, DF, CIM-MYT.

Aujla SS, Sharma I, Gill KS and Kour V, 1985. *Neovossia indica* on wild species of wheat. Indian Phytopath. 38:191.

Babadoost M, 2000. Comments on the zero-tolerance quarantine of Karnal bunt of wheat. Plant disease 84, 711-712.

Baker RHA, Sansford CE, Gioli B, Miglietta F, Porter JR and Ewert F, 2005. Combining a disease model with a crop phenology model to assess and map pest risk: Karnal bunt disease (*Tilletia indica*) of wheat in Europe. In: Alford DV, Backhaus GF, eds. Introduction and Spread of Invasive Species. BCPC Symposium Proceedings 81, 89–94.

Beniwal MS; Pankaj Chawla; Rajender Singh; Chawla P; Singh R, 2000. Effect of soaking of bunted seeds in water on teliospore germination of *Neovossia indica*. Indian-Phytopathology 53: 2, 219-220.

Bonde MR, Peterson GL, Schaad NW and Smilanick JL, 1997. Karnal bunt of wheat. Plant Disease 81, 1370–1377.

Brennan JP and Warham EJ, 1990. Economic Losses from Karnal Bunt of Wheat in Mexico. CIMMYT: International Maize and Wheat Improvement Center

Brennan JP, Warham EJ, Byerlee D and Hernandez-Estrada J, 1992. Evaluating the economic impact of quality-reducing, seed-borne diseases: lessons from karnal bunt of wheat. Agricultural Economics 6, 345-352.

CABI (Centre for Agriculture and Bioscience International), 2019. Datasheet report for *Tilletia indica* (Karnal bunt of wheat). Crop Protection Compendium. Last modified 30 January 2019.

Carris LM, Castlebury LA and Goates BJ, 2006. Nonsystemic bunt fungi - *Tilletia indica* and *T. horrida*: a review of history, systematics, and biology. Annual Review of Phytopathology, 44, 113–133.

EFSA (European Food Safety Authority), 2010. Scientific opinion on a quantitative pathway analysis of the likelihood of *Tilletia indica* M. introduction into EU with importation of US wheat. EFSA Journal 2010; 8(6):1621. [88 pp.]. doi:10.2903/j.efsa.2010.1621. Available online: www.efsa.europa.eu

EFSA (European Food Safety Authority), Baker R, Gilioli G, Behring C, Candiani D, Gogin A, Kaluski T, Kinkar M, Mosbach-Schulz O, Neri FM, Siligato R, Stancanelli G and Tramontini S, 2019. Scientific report on the methodology applied by EFSA to provide a quantitative assessment of pest-related criteria required to rank candidate priority pests as defined by Regulation (EU) 2016/2031. EFSA Journal 2019;17(5):5731, 64 pp. https://doi.org/10.2903/j.efsa.2019.5731

Forster RL and Goates BJ, 1997. Karnal bunt. University of Idaho. CIS 1067, 6 pp. Available at http://www.cals.uidaho.edu/edComm/pdf/CIS/CIS1067.pdf

Fuentes-Dávila G, 1996. Karnal bunt. In Bunt and Smut Diseases of Wheat: Concepts and Methods of Disease Management (eds. Wilcoxson RD and Saari EE), pp. 26–32. International Maize and Wheat Improvement Center (CIMMYT), Mexico (US). 74 pp.

Fuentes-Dávila G, 1997. Carbón parcial del trigo: situación actual y perspectivas. Memorias del primer Simposio Internacional de Trigo, 7 al 9 de Abril de 1997, Cd. Obregón, Sonora, México, 105-118.

Fuentes-Dávila G, B.J. Goates, P. Thomas, J. Nielsen, B. Ballantyne, 2002. Smut diseases. In: Bread Wheat, Improvement and production. Ed. Curtis BC, Rajaram S and Gómez Macpherson H. FAO, Rome, 2002. Available at http://www.fao.org/docrep/006/y4011e/y4011e0h.htm

Garrett KA and Bowden RL, 2002. An Allee effect reduces the invasive potential of *Tilletia indica*. Phytopathology, 92, 1152-1159.

Goates BJ and Jackson EW, 2006. Susceptibility of wheat to *Tilletia indica* during stages of spike development. Phytopathology, 96, 962-966.

Gopal S and Sekhon KS, 1988. Effect of karnal bunt disease on the milling, rheological and nutritional properties of wheat: effect on the quality and rheological properties of wheat. Food Science, 53, 1558-1559.

Hussain M, Sharif M, Ullah M and Sarwar M, 1988. Studies on the feasible use of Karnal bunt infected wheat for bread and "chapati" making. In Proc. 1st Nat. Food Workshop, Lahore, India, June 1988.

Jhorar OP, Mavi HS, Sharma I, Mahi GS, Mathauda SS and Gurmeet Singh, 1992. A biometeorological model for forecasting Karnal bunt disease of wheat. Plant Disease Research, 7, 204-209.

Joshi LM, Singh DV, Srivastava KD and Wilcoxson RD, 1983. Karnal bunt: a minor disease that is now a threat to wheat. The Botanical Review, 49, 309-330

Kilian B, Mammen K, Millet E, Sharma R, Graner A, Salamini F, Hammer K and Ozkan H, 2011. *Aegilops*. Chapter 1 of C. Kole (ed.), Wild Crop Relatives: Genomic and Breeding Resources, Cereals, DOI 10.1007/978-3-642-14228-4_1, # Springer-Verlag Berlin Heidelberg 2011

Laghetti G, Fiorentino G, Hammer K and Pignone D, 2009. On the trail of the last autochthonous Italian einkorn (*Triticum monococcum* L.) and emmer (*Triticum dicoccon* Schrank) populations: a mission impossible? Genetic resources and crop evolution 56 (8), 1163-1170.

Medina CL, 1985. Efecto de diferentes niveles de infección con carbón parcial en la calidad de trigo y las características organolépticas del pan. Thesis. Ciudad Obregón, Sonora, México, Departamento de Química e Ingeniería Química, Instituto Tecnológico de Sonora. 63 pp.

Mehdi V, Joshi LM and Abrol YP, 1973. Studies on chapati quality. vi. Effect of wheat grains with bunts on the quality of chapattis. Bulletin of Grain Technology 11, 195-197.

Mücher CA, Steinnocher KT, Kressler FP and Heunks C, 2000. Land cover characterization and change detection for environmental monitoring of pan-Europe. International Journal of Remote Sensing 21, 1159-1181.

Murray MG and Brennan JP, 1998. The risk to Australia from *Tilletia indica* Mitra, the cause of karnal bunt of wheat. Australasian Plant Pathology 27, 212-225.

Ottman M, 2015. Cultural practices for Karnal bunt control. The University of Arizona, College of Agriculture and Life Sciences, Tucson, Arizona. AZ 1287.

Peña RJ, Amaya A and del Toro E, 1992. Effect of grain washing and storage of wheat samples (Cultivar Seri M82) with different infection levels of Karnal bunt (*Tilletia indica*) on quality parameters. In: Update on Karnal bunt research in Mexico. Eds Fuentes-Davila G and Hettel GP, Wheat Special Report No. 7. Mexico, DF, CIMMYT, 21-28

Rattan GS and Aujla SS, 1991. Distribution of infection in Karnal bunt infected wheat spike. Annals of Biology, 6, 179-180.

Riccioni L, Inman A, Magnus HA, Valvassori M, Porta-Puglia A, Conca G, Di Giambattista G, Hugues K, Coates M, Bowier R, Barnes A, Sansford C, Razzaghian J, Prince A and Peterson G, 2008. Susceptibility of European bread and durum wheat cultivars to *Tilletia indica*. Plant Pathology, 57, 612-622.

Royer MH and Rytter J, 1988. Comparison of host ranges of *Tilletia indica* and *T. barclayana*. Plant Dis. 72:133-136.

Rush C, Stein JM, Bowden RL, Riemenschneider R, Boratynski T and Royer MH, 2005. Status of Karnal bunt in the United States 1996 to 2004. Plant Disease 89, 212–23.

Sansford C, Baker R, Brennan J, Ewert F, Gioli B, Inman A, Kelly P, Kinsella A, Leth V, Magnus H, Miglietta F, Murray G, Peterson G, Porta-Puglia A, Porter J, Rafoss T, Riccioni L, Thorne F and Valvassori M, 2006. Risks associated with *Tilletia indica*, the newly-listed EU quarantine pathogen, the cause of Karnal bunt of wheat. EC Fifth Framework Project QLK-19990-01554, 136 pp.

Sansford C, Baker R, Brennan J, Ewert F, Gioli B, Inman A, Kinsella A, Magnus H, Miglietta F, Murray G, Porta-Puglia A, Porter J, Rafoss T, Riccioni L and Thorne F, 2008. The new Pest Risk Analysis for *Tilletia indica* , the cause of Karnal bunt of wheat, continues to support the quarantine status of the pathogen in Europe. Plant Pathology, 57, 603–611.

SARH (Secretaría de Agricultura y Recursos Hidráulicos), 1987. Cuarentena Interior número 16 contra el Carbón Parcial del Trigo. Diario Oficial 33-42. Secretaría de Agricultura y Recursos Hidráulicos, Mexico.

Sekhon KS, Saxena AK, Randhawa SK and Jill KS, 1980. Effect of Karnal bunt disease on quality characteristics of wheat. Bulletin of Grain Technology 18, 208-212.

Sekhon KS, Randhawa SK, Saxena AK and Jill KS, 1981. Effect of washing/steeping on the acceptability of Karnal bunt infected wheat for bread, cookie and chapati making. Journal of Food Science and Technology, 18, 1-2.

Sharma A, Sharma P, Dixit A and Tyagi R, 2017. Karnal bunt of wheat in India and its management: a review. Plant Pathology and Quarantine, 7, 165–173.

Singh A, 1994. Epidemology and management of kamal bunt disease of wheat, Research Bulletin No. 127, Directorate of Experiment Station, GB Pant University of Agriculture and Technology, Pantnagar. p 167.

Warham EJ, 1986. Karnal bunt disease of wheat: a literature review. Tropical Pest Management, 32, 229–242.

Zapata L, Peña-Chocarro L, Pérez-Jordá and Stika HP, 2004. Early Neolithic agriculture in the Iberian Peninsula. Journal of World Prehistory, Vol. 18, No. 4, 283-325. DOI: 10.1007/s10963-004-5621-4

Zhu F, 2018. Triticale: Nutritional composition and food uses. Food Chemistry, 241, 468–479.

Appendix A – CABI/EPPO host list

The following list, defined in the Methodology Report (EFSA, 2019) as the full list of host plants, is compiled merging the information from the most recent PRAs, the CABI Crop Protection Compendium and the EPPO Global Database. Hosts from the CABI list classified as 'Unknown', as well as hosts from the EPPO list classified as 'Alternate', 'Artificial', or 'Incidental' have been excluded from the list.

Genus	**Species epithet**
Secale	*cereale*
Triticale	
Triticosecale	
Triticum	
Triticum	*aestivum*
Triticum	*durum*

Appendix B – Evidence tables

B.1a Summary on the evidence supporting the elicitation of yield losses

Yield loss estimates		Summary		Source/Reference
Country	Value	Evidence (Cited from Sansford et al. 2006)	Limitations	
		"At a field level, yield losses are normally low overall, but in situations where conditions favour the disease individual crops may be severely affected".		Sansford et al., 2006
Karnal, India	20%	"The earliest reported yield loss was 20% in experimental wheat plots at Karnal, India"	This historical value is from experimental plots in India, frequently cited in other papers. No information on the experimental conditions is given.	McRae, 1933, in Joshi et al. 1983, Warham, 1986 and Beniwal et al., 2000).
Northern India	0.2%	"Munjal (1975, in Warham, 1986) quoted an overall incidence of 0.6% for ca. one-third of the wheat production area of northern India in 1969–70 and a loss in grain yield of 0.2% which equated to a loss of 40,000 metric tonnes per year. Munjal suggested that because infected grains are blown away during winnowing and cleaning, the overall yield losses may be higher."	The interpretation of the cited figure on yield loss is not clear. The author suggests that the figure underestimates the yield loss.	Munjal (1975, in Warham 1986)
India	0.3-0.5%	"Karnal bunt occurs sporadically becoming epidemic only in certain years but may cause substantial losses; on average the total loss in India may be ca. 0.3 to 0.5% of total production but in some fields infection may be as high as 89% leading to substantially greater effects."	If the value refers to total loss in India, it is underestimating the loss for the infested area.	Joshi et al., 1983
India	0.3-0.5%	"in epidemic years in Uttar Pradesh yield and quality losses in wheat amounted to at least 1% of the total value of the crop, with a mean loss in production in epidemic years in India of 0.3–0.5%".	Unclear if the mean yield losses in epidemic years of 0.3-0.5 refers to the whole of India, this would be an underestimation of what could happen only in the infected areas	Singh (1994)
Mexico	0.12%	"Brennan and Warham (1990) and Brennan et al. (1992) evaluated the economic impact of Karnal bunt of wheat in Mexico and stated that economic losses rose sharply in the 1980s as a result of increased levels of disease. Based on the 'quantities of grain delivered with different levels of infected grain and by assuming a 25% loss of weight in infected grains',	The original reference was available and checked in detail. In Sonora the average yield loss was 0.07%, whereas the average yield loss in Northern Sinaloa was calculated as 0.27%. However, these values seem to include the samples without any spores (zero % of infected	Brennan and Warham (1990), Brennan et al. (1992), Fuentes-Davila (1996)

		the average yield loss in north-western Mexico (southern Sonora, Sinaloa and Baja California Sur) was estimated at 0.12% per year; this was later cited by Fuentes-Dávila (1996)"	grains) so it may not reflect the average yield loss of the affected areas. The results were re-calculated by the WG (see below).	
EU	0.1%	"The yield loss in affected crops assumed for the Project's analysis of potential impacts in the EU was 0.1% and this was derived from Brennan and Warham (1990). This figure was itself a derived figure for affected areas of north-western Mexico (southern Sonora, Sinaloa and Baja California Sur) and was estimated from data on the 'quantities of grain delivered with different levels of infected grain and by assuming a 25% loss of weight in infected grains'. It is not a definite prediction of the likely impacts of T. indica on yield in the PRA area". "T. indica is likely to cause similar effects on crop yield and quality in the PRA area as it does in its existing area of distribution. In other words, the effects will vary from crop to crop and year to year. European winter, spring and durum wheat cultivars have not been bred for resistance to T. indica and, in this Project, have been shown to exhibit a range of susceptibility to infection by the pathogen similar to that which occurs in countries where it is established. The environmental conditions in the PRA have been shown to be favourable for infection and disease development. The effect on yield will be relatively small in percentage terms except possibly in localised 'hotspots' of disease where conditions are highly favourable to infection and disease development".	The EU project assumed an overall average low impact of ca 0.1% yield losses in affected crops in the EU, however this was not considered to be a definite prediction of the likely impacts of T. indica on yield in the PRA area.	Brennan and Warham (1990), Sansford et al (2006)

B.1b Summary on the evidence supporting the elicitation of quality losses

Threshold	Summary	Source/Reference

Country	Value	Evidence (Cited from Sansford et al. 2006)	
		Sansford et al (2006) noted that: "Direct quality losses are a substantial direct cost associated with a Karnal bunt outbreak. These occur when infected milling wheat is considered unsuitable for human food uses and as a result is downgraded to feed wheat. There can be a considerable economic cost associated with the loss of value of milling wheat down-graded to feed wheat and it is therefore essential that this component is captured in the analysis (Murray and Brennan, 1998)".	Murray and Brennan (1998), Sansford et al (2006)
	3%	Sansford et al (2006) noted that: "The overriding feature of this pathogen is the effect it has on the quality of infected grain, since, according to Warham (1986), when more than 3% of grains are affected the grain is no longer accepted for processing and is declared unfit for human consumption".	Warham (1986), Sansford et al (2006)
India	1%-10%	Sansford et al (2006) noted that: "Flour milled from 10% infected grain was reported to be in dark in colour; chapattis made from contaminated flour were inedible. One per cent infection of grain led to chapattis deemed 'slightly affected' with respect to palatability; 3% infection of grain resulted in chapattis that had a disagreeable odour and were unpalatable Joshi et al (1983).	Joshi et al (1983), Sansford et al (2006)
UK	>0%	Sansford et al (2006) stated that: "The National Association of British and Irish Millers (NABIM) would most likely reject any grain found to be affected by Karnal bunt irrespective of the percentage affected, since flour made from infected grain is discoloured, baking quality is impaired and palatability is reduced due to the fishy odour of trimethylamine which the fungus produces"	Sansford et al (2006)
India	1-3%	EFSA (2010) noted that: "*Tilletia indica* reduces flour quality in terms of colour, odour and palatability. There appears to be some controversy on the level of infection that affects flour quality. According to Mehdi et al. (1973), 1-3 % infected kernels may be sufficient to render wheat grain unacceptable for human consumption.	EFSA (2010) , Mehdi et al. (1973)
	>3%	EFSA (2010) noted that: "Other researchers, however, tend to agree that with 3 % or less infected kernels the quality characteristics such as appearance and palatability for bread are unaffected (Sekhon et al., 1980).	EFSA (2010), Sekhon et al. (1980)
	<5% and <10%	EFSA (2010) noted that: "Grain with 5 % infected kernels can be used to produce satisfactory products if they are first washed, whereas if they are washed and steeped, samples with 10 % infected grains can be used to produce acceptable products (Sekhon et al., 1981).	EFSA (2010), Sekhon et al. (1981)
	<9%	EFSA (2010) noted that: "According to Peña et al. (1992), in general, levels of infection of up to 9 % do not influence negatively the milling and baking quality characteristics of wheat.	EFSA (2010), Peña et al. (1992)
	<3%	EFSA (2010) noted that: "In addition, flour and bread samples are organoleptically acceptable at 1-3 % infection level, respectively."	EFSA (2010), Peña et al. (1992)
	<6%	EFSA (2010) noted that: The same authors concluded that washing prior to milling make it possible to produce flour and bread having acceptable organoleptic characteristics from wheat lots with up to 6 % infection"	EFSA (2010), Peña et al. (1992)
	>3%	Rush et al. (2005) stated that: "Unfortunately, the worldwide concern about Karnal bunt as an important plant pathogen is largely unjustified in terms of the actual damage it causes to wheat yield and quality. When wheat is infected by *T. indica*, diseased seed may have reduced viability and vigor (4,62,71), and flour from grain with over 3% bunted kernels imparts an off color and unpleasant odor (58,59). However, there are no toxicological issues of concern (7), and the incidence of disease in most fields is typically so low (usually <0.1% in the United States) that impact on yield and quality is non-existent (63). Quality issues can be dealt with by the method of grain processing, and bunted grain can be diluted with clean grain to a point that any negative impact is completely eliminated. Nevertheless, as long as major wheat	Rush et al. {2005)

		importing countries maintain restrictive import quarantine laws, the disease will continue to be an economic issue for countries trying to export grain from Kb-infested regions (12)".	
	<1%	Fuentes-Davila (1997) stated that: "KB may also reduce flour quality. In view of the importance of color, odor, and palatability of whole meal and chapaties, 1-4% infected kernels may be sufficient to render wheat grain unacceptable for human consumption (Mehdi et al. 1973, Sekhon et al. 1980, Amaya 1982, Medina 1985, Hussain et al. 1988).	Amaya (1982), Fuentes-Davila (1997), Mehdi et al. (1973), Sekhon et al. (1980), Medina (1985), Hussain et al. (1988)
	<5%	At 5% infection, quality distinctly deteriorates (Sekhon et al. 1980). There is also a loss in flour recovery and chemical changes in composition of flour and gluten content cause poor dough strength (Gopal and Sekhon 1988)"	Sekhon et al. (1980); Gopal and Sekhon (1988)
	<10%	Fuentes-Dávila et al. (2002) stated that: "If grains are washed and steeped, wheat lots with 7-10% infected grains are acceptable for consumption (Sekhon et al. 1981, Medina 1985, Hussain et al. 1988)".	Fuentes-Dávila et al. (2002), Sekhon et al. (1981), Medina (1985), Hussain et al. (1988)
Mexico	3%	Fuentes-Davila (1997) stated that: "In northwestern Mexico, lots of grain with more than 3% infected kernels are rejected by the milling industry. However, they can be used for animal feed (Anon. 1989b)".	Fuentes-Davila (1997)
Mexico	2%; 0%	Fuentes-Davila (1996) stated that: "Further, a federal quarantine prohibits growing bread wheat in fields that have more than 2% KB infection. The movement of wheat grain from affected counties to other parts of Mexico is prohibited unless fumigated with methyl bromide. Seed grown for certification has a 0% infection tolerance and must be treated with a fungicide. Trucks, combines, and agricultural machinery cannot leave the quarantined areas unless cleaned and treated as determined by the Department of Agriculture. Movement of germplasm, however, is allowed under certain, but strict quarantine rules (SARH 1987)".	SARH (1987)

B.2 Summary on the evidence supporting the elicitation of the spread rate

Spread	Additional information	Reference
dispersal gradients for T. indica: over 1,000 m it would be at least 3 orders of magnitude.	Assumption: authors use datasets from other pathogens	Garrett and Bowden, 2002
probability of a single ovary of a spike (mean of 5 ovaries per spike) being infected by a single sporidium: 0.02 probability of simultaneous infection of 2 and 3 closely lying ovaries in a spikelet: 4×10^{-3} and 8×10^{-3} respectively		Bedi PS, Dhiman JS (1984) cited by Sansford et al., 2006
it spreads to adjacent florets and spikelets, infecting as many as 31 grains around the infection site.		Dhaliwal and Singh (1988) cited by Sansford et al., 2006
	Sporidia are spread by wind and water/rain splash. Teliospores can be spread by wind to adjacent fields (Warham, 1986) during harvest or soil movement, including wind blow of dry soils	Sansford et al., 2006
	Teliospores can be spread longer distances by wind or air currents if liberated into the upper atmosphere by activities such as stubble burning (human assisted) or in soil blown by wind in dry conditions.	Sansford et al., 2006
a spore the size and mass of a T. indica teliospore could move in excess of 500km under appropriate wind conditions.	3000 m elevation	Nelson (1996) cited by Sansford et al., 2006
	Faeces or manure derived from animals which have fed on *T. indica* teliospores are two natural means of spread	Sansford et al., 2006

B.3 Summary on the evidence supporting the elicitation of the time to detection

Reference	Criteria	Evidence	Additional information
	Biology of the pest – life cycle		
Joshi et al., 1983 Forster and Goates, 1997	Effects on symptoms expression	aggregation of infected plants in a wheat field, the irregular distribution of symptomatic kernels in a spike	
	Effects on detectability	symptomatic kernels are difficult to detect unless the grain is threshed and examined.	
Rattan and Aujla, 1991; Bonde et al., 1997; Babadoost, 2000.	Effects on symptoms expression	Not all the spikes on a plant show symptoms of the disease, and within a spike only a few kernels may be bunted	
Joshi et al., 1983	Effects on symptoms expression	The disease severity on individual kernels varies from small points of infection (infected kernels) to completely bunted kernels with most of the infected kernels being partially bunted (partial bunt).	
Babadoost, 2000; Murray and Brennan, 1998; Rush et al., 2005	Effects on incidence	the disease incidence is usually very low	
	Effects on detectability	symptoms are unlikely to be detected in the field	
Forster and Goates, 1997	Effects on symptoms expression	Symptoms similar to black point (Alternaria alternata), common bunt (Tilletia tritici, Tilletia laevis) and dwarf bunt (T controversa)	
	Effects on detectability	Possible confusion with other fungal diseases	
Goates and Jackson, 2006	Effects on incidence	When naturally deposited inoculum is present only prior to emergence of the spike, infection did not occur even under very high disease pressure. For an individual spike, the highest risk of infection occurs over a period of approximately 12 days during which the spike emerges and progresses to the completion of anthesis. Different results compared to other papers	
	Host conditions during the period of potential detection – crop before maturity		
Bonde et al., 1997; Ottman, 2015	Effects on detectability	the symptoms of the disease are unlikely to be detected	in the field