Plant Biosecurity Report
2019-2020

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Ministry of Agriculture and Forests (MoAF)
Thimphu

Introduction

The plant biosecurity is gaining significance with expansion of global trade of agricultural commodities and transboundary movement of plant genetic resources. The catastrophic impact through intrusion of pest and disease like historical Irish famine caused by potato late blight introduced from Central America and Golden nematode of potato introduced to India in 1960s from the UK furnished vivid evident that introduction and establishment of quarantine pest affects the crop production and economy of the country (Khetarpal, R.K. and Gupta, K. 2007). Currently, International Plant Protection Convention (IPPC) requires all contracting parties to establish National Plant Protection Organization (NPPO) and develop international cooperation in prevention of introduction and spread of regulated pest.

In Australia, several area of major biosecurity concerns are new race of wheat stem rust, loss of pollination European honey bee services from parasite Varroa mite and disease, incursion of exotic fruit fly. Wheat stem rust epidemic in 1973 in Australia caused about $200-300 million and expected yield loss of more than 70 percent. Wheat stem rust, Ug99 is now only found in African countries and Middle East, although Ug99 is under control in Australia for more than 30 years, there is a potential threat to wheat industry as eradication and containment become difficult due to high mobility of the disease. The disease spread to larger distance by wind, movement of goods and people. Loss of European honey bees will severely impact fruits and vegetables as loss of pollination services can impact economy of the country which has annual contribution of $4-6 billion. Australia has already recorded more than 280 species of fruit fly which seven of them have severe economic impact. To support in keeping horticulture sector well protected from threat of fruit flies, substantial investment has been made and preparedness efforts are relatively high as horticulture industry worth more than $5 billion worth crops susceptible to fruit flies. Countries across the globe with strong biosecurity capabilities are also facing challenges from exotic pest and disease.

Bhutan Agriculture and Food Regulatory Authority (BAFRA) as the NPPO has the mandate to protect health of plant, animal and human including the biodiversity and environment from exotic pest and disease. Currently, BAFRA is grappling with biosecurity issues with invasive species and pest such as outbreak of Giant African Land Snails (GALS) at Gyelposhing and widespread concern of Citrus greening disease in the country. Biosecurity catastrophic is yet to unveil should there be any complacency in phytosanitary measures taken and sound and improved biosecurity approach are adopted for risk management.

A. Plant Biosecurity measures for prevention of exotic plant pests, diseases and invasive alien species

Over the years, Bhutan has been experiencing increased import agricultural commodities exposing to increased risk of pest and disease introduction. Agricultural germplasm and plant products such as seed and seedlings, cereals, oilseeds, flowers, fresh fruits and vegetables are including timbers and woods which has serious quarantine risk. Due to inadequate and unavailability of quality planting materials for distribution to the growers, import has been only the option although there are 139 different type of plant nurseries registered in the country. The only National Seed Centre (NSC) government authority mandated for distribution of quality inputs is not able to fulfill in meeting the requirements. Apparently quarantine risks are higher with increase in trade. In general, there is gradual increase in import of seeds, seedlings, fruits and vegetables from 2016 to 2018, in contrary there was a decline in import of bamboo, wood and wood products, however it is uncertain that import may or may not take place as per the records available (BAFRA).

At arrival at entry points, all the plant and plant products consignments are inspected and verified for plant health status freedom from exotic pest and diseases. It is abided by plant quarantine and quarantine rules to prevent from introduction and spread of pest and disease of quarantine importance to safeguard farming system and biodiversity of the kingdom. Although, legislation and regulations are in place but does not sufficiently provide clear and strong legality in implementing biosecurity measures. All entry points have biosecurity offices established with basic quarantine facilities which need to be upgraded with latest treatment and diagnostic technologies.

Plant consignments are physically inspected and documents verified for release relying on the full trust and faith from the authority of exporting country. Lack professional quarantine officials, well equipped facilities including laboratory and harmonized guidelines are some of critical issues to address standard inspection and import assessment at border. Quarantine Inspectors work as team at entry points with limited knowledge in the field of plant biosecurity from various disciplinary like food and livestock compromising plant biosecurity thus requiring intense trainings. All biosecurity related legislations and regulations, activities are implemented in a compartmentalized manner. Need to strengthen interlinkages and coordination among different agencies at the border and pre-border to protect biosecurity breach and post-entry monitoring for managing pest status and biosecurity risk.

In 2019, FAO has notified outbreaks on some of the transboundary pests and diseases. The situation of these pests and diseases as reported by FAO are mentioned below:

1. Desert Locust

Desert Locust are always present somewhere in the deserts between Mauritania and India. If good rains fall and green vegetation develop, Desert Locust can rapidly increase in number and within a month or two, start to concentrate, gregarize which, unless checked, can lead to the formation of small groups or bands of wingless hoppers and small groups or swarms winged adults. This is called an OUTBREAK and usually occurs with an area of about 5,000 sq. km (100 km by 50 km) in one part of a country. If an outbreak or contemporaneous outbreaks are not controlled and if widespread or unusually heavy rains fall in adjacent areas, several successive seasons of breeding can occur that causes further hopper band and adult swarm formation. This is called an UPSURGE and generally affects an entire region. If an upsurge is not controlled and ecological conditions remain favourable for breeding, locust populations continue to increase in number and size, and the majority of the infestations occur as bands and swarms, then a PLAGUE can develop. A major plague exists when two or more regions are affected simultaneously. Outbreaks commonly occur and only a few lead to upsurges. Similarly, few upsurges lead to plagues. The last major plague was in 1987-89 and the last major upsurge was in 2003-05. Upsurges and plagues do not occur over night; instead they take many months to develop.

The unprecedented Desert Locust threat to food security and livelihoods persists in the Horn of Africa and is increasing in southwest Asia. In the Horn of Africa, second-generation spring swarms are present in northwest Kenya, eastern Ethiopia, and parts of Somalia. Breeding continues in eastern and northern Ethiopia and in central and northern Somalia where hopper bands are present. Most of the swarms in northwest Kenya will migrate northwards and cross South Sudan to Sudan while other swarms will migrate to Ethiopia. A few swarms could transit northeast Uganda. Swarms that concentrate in northern Somalia are likely to move east to the Indo-Pakistan summer breeding areas. Breeding may commence in areas of recent rains on the Red Sea coast in Yemen and Saudi Arabia while breeding will continue in the interior of Yemen. Some swarms could migrate from Yemen to northern Somalia and northeast Ethiopia in July. While the northward swarm migration from Kenya is imminent, the later it starts, the more likely swarms will find good breeding conditions once they arrive in Sudan and this will reduce the risk of further migration to West Africa. In southwest Asia, many of the spring-bred swarms migrated to the Indo-Pakistan border before the monsoon rains so some swarms continued east to northern states and a few groups reached Nepal. These swarms will return to Rajasthan with the start of the monsoon in the coming days to join other swarms still arriving from Iran and Pakistan, which is expected to be supplemented by swarms from the Horn of Africa in about mid-July. Early breeding has already occurred along the Indo-Pakistan border where substantial hatching and band formation will take place in July that will cause the first-generation summer swarms to form in mid-August. Sudan, Ethiopia, South Sudan, Somalia, Pakistan, and India should remain on high alert during the next four weeks. West Africa should continue to take anticipatory measures and preparatory steps.

2. Fall Armyworm

On 4th December 2019, Rome, FAO launched today a three-year Global Action for Fall Armyworm Control to scale up efforts to curb the growing spread of the invasive pest which is causing serious damage to food production and affecting millions of farmers across the world. Fall Armyworm (FAW), a crop pest native to the Americas, has rapidly spread through Africa, and to the Near East and Asia in the past four years. It threatens food security of hundreds of millions of people and the livelihoods of smallholder farmers. This is a global threat that requires a global perspective and need to greatly scale up the existing efforts to prevent the further spread of this harmful pest to new regions.

FAO is seeking to mobilize $500 million over the next three years to control Fall Armyworm. It is expected to mobilize global resources and expertise to enhance national capacities to tackle FAW, reinforce efforts to discourage widespread use of highly hazardous pesticides, and provide resources for scientific research and innovation to develop efficient solutions to tackle the pest, such as FAO's Fall Armyworm Monitoring and Early Warning System mobile app. Doing so will help to bring the pest under control in the affected areas and reduce the risk of its further introduction and spread to new regions, including Europe and South Pacific. Deadly pest. The Fall Armyworm (FAW) is an insect pest, which causes considerable yield losses in cultivated maize, rice, sorghum, millet, and other crops as it is capable of attacking over 80 species of crops, if not under good management and control. Based on 2018 estimates, every year up to 17.7 million tonnes of maize are lost to this pest in Africa alone. This amount of maize could feed tens of millions of people; and represents an economic loss of up to $4.6 billion. Article available at http://www.fao.org/news/story/en/item/1253916/icode/

3. Cassava mosaic disease (CMD) and Cassava brown streak disease (CBSD)

Cassava (Manihot esculenta Crantz) is the fifth most produced staple food crop in the world, being a basic source of staple food for an estimated 800 million people worldwide. Cassava is an increasingly popular crop. Currently, approximately 291 million tonnes are produced around the world, over a territory of 26.3 million hectares, with increases, respectively, of 55 percent and 66 percent since 2000. Cassava is grown by smallholder farmers in more than 100 tropical and subtropical countries of Africa, Asia and Latin America. Thanks to its efficient use of water and soil nutrients. and tolerance to drought, cassava can produce reasonable yields using limited or no inputs, even in areas with poor soils and unpredictable rainfall. Like other crops, cassava is vulnerable to pests and diseases that can cause heavy yield losses. Insect pests such as white flies and mealybugs, and diseases caused by viruses and phytoplasma, affect the production of cassava worldwide. Of the viral diseases, Cassava mosaic disease (CMD) and Cassava brown streak disease (CBSD) are the most widespread, severely affecting at least 50 percent of cassava crops in Africa.

The food security of 135 million people in Central and East Africa alone. At least half of all plantings in Africa are affected by one of these diseases. Scientists estimate that annually, 15–24 percent (equivalent to approximately 12–23 million tonnes) of the crop is lost due only to CMD in Africa. The negative impact is more severe when the cassava plants are also infected with CBSD. Without adequate response mechanisms, CBSD may cause losses of up to 100 percent, as experienced in many cases in the African Great Lakes region.

Despite the alert call made by FAO and other related organizations on the above-mentioned pests and disease, there has been no incidences of these pests' occurrence in Bhutan, and hence no official notification on introduction and outbreak of exotic plant pests and diseases in the country were issued. It indicates that the phytosanitary measures implemented has been very successful in preventing the introduction of exotic plant pests and diseases from the foreign countries. Similarly, no record of invasive alien species has been reported.

Some of the activities carried out by BAFRA for safeguarding the plant biosecurity are:

Image 1 and 2: Illegal import of plant products intercepted at Phuentsholing Entry Point

Image 3 and 4: Disposal of illegally imported plant products at PAQS, Phuentsholing

B. Developed Bhutan Phytosanitary Treatment Manual 2020

The Bhutan Agriculture and Food Regulatory Authority (BAFRA), Ministry of Agriculture and Forests, as the competent authority for biosecurity and food safety systems to promote the quality and safety of food and agricultural related products. The standards set in the manual by BAFRA covers following areas:

1.To render guidelines for assessment, audit, accreditation of Treatment agencies / Treatment operators.

2. Treatment manual for Chemical and Non chemical method.

Objectives:

❖ Protecting sustainable agriculture and enhancing global food security through the prevention of pest spread

❖ Protecting the environment, forests and biodiversity from plant pests

❖ Facilitating economic and trade development through the promotion of harmonized scientifically based phytosanitary measures, and

❖ Developing phytosanitary capacity for members to accomplish the preceding three objectives.

By focusing on these objectives, the BAFRA on Phytosanitary Measures of the NPPO intends to:

❖ Protect farmers from economically devastating pest and disease outbreaks.

❖ Protect the environment from the loss of species diversity.

❖ Protect ecosystems from the loss of viability and function as a result of pest invasions.

❖ Protect industries and consumers from the costs of pest control or eradication.

❖ Facilitate trade through International Standards that regulate the safe movements of plants and plant products.

❖ Protect livelihoods and food security by preventing the entry and spread of new pests of plants into a country. To manage the high biosecurity risk posed by ineffective chemical and non-chemical treatments performed offshore.

BAFRA has developed Bhutan Phytosanitary Treatment Manual (BPTM) 2020 to guide the quarantine inspectors for mitigating the phytosanitary risks through different treatment protocols (both chemical and non-chemical treatments). BAFRA has also imparted training to the officials on BPTM 2020.

C. Pest Risk Analysis for import of agricultural commodities

This PRA report is prepared in response to the PRA proposal submitted by the Department Agriculture, Cooperation and Farmers Welfare (DACFW) India for export of fresh okra, onion and tomato to Bhutan.

A total of 127 pests are identified to be associated with the specified commodity types. Of these, onlyten pests are identified to be of quarantine concern as a result of importation of these three commodities to Bhutan. Among these, only six pests have been identified requiring pest risk management measures.

Quarantine pests that require risk management includes *Liriomyza sativae*on okra and tomato. *Clavibacter michiganensis* subsp. *michiganensis*is associated with importation of tomato and requires risk management. *Frankliniella occidentalis* and *Urocystis cepulae* pose moderate pest risk associated with of importation of onion from India, and thus require risk management.

The proposed risk management measures include requirement for field and consignment inspection before export and inclusion of phytosanitary certificates stating that consignments have been inspected during the season and are collected from crop/field free of the specified pests of concern. Inspections are also required at the port of entry by the importing country and appropriate remedial actions to be employed in case of interception of pests.

Background

In November 2019, the Ministry of Agriculture and Forests issued an Office Order (Ref.: BAFRA/MoAF/1-25/2019/605, dated 6 November 2019) appointing a four-member technical working group (TWG) for the Pest Risk Analysis. The team is headed byDr Dorjee (National Plant Protection Centre, Department of Agriculture). The other team members comprised of Mr. Sonam Dorji N from Bhutan Agriculture and Food Regulatory Authority (BAFRA), Mr. Karma Choephyel (Agriculture Research and Development Centre-Yusipang, Department of Agriculture), and Mr/ Jigmi Tenzin (Agriculture Production Division, Department of Agriculture). During the first meeting of TWG, convened on 26 November 2019, it was decided that the members of the team from the research and the Department be replaced by unit heads of the National Plant Protection Centre (NPPC) and a key person from Bhutan Agriculture and Food Regulatory Authority (BAFRA). Hence, the new members: Dr Kiran Mahat (Head, Entomology Unit) and Dr Namgay Om (Head, Pathology Unit). Dr Dorjee and Sonam Dorji N were retained as before.

The PRAs to be conducted were on importation of fresh okra [*Abelmoschus esculentus* (L.) Mönch], onion [*Allium cepa* L.]and tomato [*Solanum lycopersicum* L.] for consumption in Bhutan. The Department of Agriculture, Cooperation and Farmers Welfare (DACFW) of India had requested BAFRA to conduct PRA for gaining market access to Bhutan in April 2017 (Appendix 1). The PRA request from India included technical information on the pests associated with okra, onion and tomato. Information on production practices for these commodities were also provided. As per the request by BAFRA, the PRA core team conducted PRA on the import of fresh okra, onion bulb and tomato fruit for consumption in Bhutan even though import of these commodities are in existence at the time of the PRA.

Scope

This PRA is related to the assessment of risk that may be associated with the importation of fresh okra, onion bulbs, and tomato fruits for consumption in Bhutan from India. The pest list provided by India, quarantine pests of Bhutan, National Plant Pest Database of Bhutan (NPPDB) and pest list from CABI database are considered for this assessment. The assessment considers all production areas of okra, onion and tomato in India. Due to time constraint and limited resources, in terms of relevant data and information, and access to literatures; a detailed and comprehensive PRA is not considered.

Note: *Information in this document are as per the existing data and/or information available at the time of preparation of the PRA document. The information is subject to review and examination, corrections and deletions*.

PRA Methods

At the start of this PRA, a standard guideline for Bhutan for conducting PRA was lacking. Thus, the decision process for this PRA was conducted following thestandardsfor the European and

Mediterranean Plant Protection Organisation (EPPO)on quarantine pests as provided in the Pest Risk Analysis Training – ParticipantManual (IPPC 2007) and Biosecurity Import Risk Analysis Guidelines for Australia (Department of Agriculture and Water Resources 2016). These standardsare based on ISPM 2: Framework for pest risk analysis (FAO 2019a) and ISPM 11: PRA for quarantine pest (FAO 2019b).

The PRA consists of three stages:

Stage 1 – Initiation

Stage 2 – Pestcategorisation and assessment

Stage 3 – Risk management

Pest risk analysis was conducted separately for each commodity. Pest risk is assessed each for the likelihood of pest entry; establishment and spread in Bhutan as a result of import of okra, onion and tomato from India; and the economic and social consequence should these happen. To assess each of these stages, a series of criteria are considered for assessing the likelihood of pest risk. Overall risk of each pest for that particular commodity is estimated based on the combined likelihood of the likelihood of entry, establishment and spread, and consequences.

Risk management measures for each pest with overall risk of unacceptable levels are presented.

PRA Method – Stage 1 Initiation

PRA area is defined as '**area** in relation to which a **pest risk analysis** is conducted (ISPM 2, 1995)' [FAO 2019c). For this PRA, all regions of Bhutan are identified as the PRA area.

This stage is to identify pests associated with the commodity pathway while importing okra, onion and tomato fruit from India to Bhutan for human consumption; and gather information on those pests. For this PRA, CABI database (CABI 2020) was used to generate pest lists for each commodity type. Only those pests known to be associated with the specific commodity type were listed, e.g., on okra pods, onion bulbs, and tomato fruit.Pest list provided by DACFW India in the PRA proposal was also considered.

PRA Pest Categorisation and Risk Assessment

Due to time constraint and limited literature resources, and the existence of long-term unregulated trade of these commodities between India and Bhutan, comprehensive pest categorisation into potential quarantine pests and quarantine pests is not followed.

Instead, pest lists obtained in Stage 1 (Section 5.1) and the lists submitted by DAFCW, India in the PRA proposal were examined and compared with the information in the National Plant Pest Database for Bhutan (NPPDB) (NPPC Version 1.0 2017). Pests recorded in India and Bhutan (i.e. NPPDB)were not included in the assessment. Pests of cosmopolitan nature were not included in the assessment even if they are not listed in the NPPDB.

Pests in the quarantine pest list of Bhutan (Schedule IV: Plant Quarantine Rules and Regulations of Bhutan 2018) for the specific commodity were included for assessment. Pests which are known quarantine pests for the commodity in other countries if not recorded in Bhutan but present in India as per CABI and EPPO databaseswerealso included in the assessment.

Assessment of entry, establishment and spread

The following definition from ISPM 5 – Glossary of phytosanitary terms (FAO 2019c) is adopted:

- Pest entry is the 'movement of a **pest** into an **area** where it is not yet present, or present but not widely distributed and being **officially controlled** [ISPM 2, 1995]'
- Establishment of pest is 'perpetuation, for the foreseeable future, of a pest within an area after entry [FAO, 1990; revised ISPM 2, 1995; IPPC, 1997; formerly "established"]'
- Spread of a pest is 'expansion of the geographical distribution of a **pest** within an **area** [ISPM 2, 1995]'

Assessment of entry, establishment and spread was conducted for each pest identified for okra, onion, and tomato following EPPO standard. The standard involves a series of questions constructed based on commodity pathway; its volume, and frequency of import; transport & storage, and its end use; the biology and ecology of the pest; pest management; economic and social impact. Each question is responded using qualitative descriptorsof likelihood of 'high', 'medium', 'low', or 'negligible' (adapted from Biosecurity Australia - Department of Agriculture and Water Resources 2016). Each descriptor is assigned a numeric score (Table 2) which is adopted from the scoring model for potential quarantine invertebrate species (IPPC 2005).

To estimate the likelihood for entry, establishment and spread,each question under each category is rated as a likelihood of 'high', 'medium', 'low', or 'negligible'.

Then, the combined score for entry is estimated by multiplying the total number of responses rated either 'high' or 'medium' or 'low' or 'negligible' with the corresponding numeric score for that likelihood. The products of each likelihood are then added.The resulting sum gives the 'combined

Table 1. Description of likelihoods and corresponding numeric score (adapted from IPPC 2005; Department of Agriculture and Water Resources 2016)

Likelihood	Description	Numeric score
High	The event is very likely to occur	6
Moderate	The event would occur with even likelihood	3

Low	The event is unlikely to occur	1
Negligible	The event would almost certainly not occur	0

score' for entry. This 'combined score' is assigned a 'likelihood' of 'high', 'medium', 'low' or 'negligible' according to the score range for that likelihood (Table 3).Combined scores for establishment and spread are estimated in the same manner. For example, for likelihood of the entry, if there are a total of 11 questions (qualitative assessments) and the following assessments are achieved:

- 5 questions received 'low' likelihood responses then 5 times the numeric score for 'low' which is '1' gives:
  5 x 1 = 5;
- 4 questions received 'moderate' likelihood, then 4 times the numeric score for 'moderate' which is '3' gives: 4 x 3 = 12;
- 2 questions received 'high' likelihood, then 2 times the numeric score for 'high' which '6' gives:
  2 x 6 = 12

Likelihood estimate for entry will be: 5 + 12 + 12 = 29, which falls in the range of 12 - 33 (Table 3) and corresponds to 'moderate'**.**

If any question is not responded due to lack of information or limited expertise or is not relevant then that question is excluded from the assessment by reducing the total number of responses used for obtaining the score ranges. For example, if the likelihood of entry originally has 11 questions but one question does not have any response then the total responses for entry will be 10. Hence, the score range will be: 0 for negligible; 1–10 for low (instead of 1–11 in the original version) and so on.

After estimating the likelihood for each of entry, establishment and spread is completed, the combined likelihood of entry (E) and establishment (E) is estimated using the matrix rule in Table 4. Same matrix is used to estimate the combined likelihood of entry and establishment (EE) with that of spread (S), e.g.,

1) Likelihood 1= likelihood of entry (E); Likelihood 2 = likelihood of establishment (E)
   Likelihood 1 x Likelihood 2 = EE

2) Likelihood 1 = combined likelihood of entry & establishment (EE); Likelihood 2 = likelihood of spread (S)

Likelihood 1 x Likelihood 2 = EES

Table 2. Estimating the likelihood for entry, establishment, spread and consequence (adapted from IPPC 2005;Department of Agriculture and Water Resources 2016).

Likelihood & scoring		**Likelihood of Entry (e.g., 11 questions)**	**Likelihood of establishment (e.g., 17 questions)**	**Likelihood of spread (e.g., 3 questions)**	**Consequence (e.g., 15 questions)**
Negligible	0	0	0	0	0
Low	1	1– 11	1 – 17	1 – 3	1 – 15
Moderate	3	12 – 33	18 – 51	4 – 9	16 – 45
High	6	34 – 66	52 – 102	10 – 18	46 – 90
Total score (number of responses x corresponding scores)		e.g., if combined score is 29 then entry likelihood is Moderate since it falls in the range of 12 -33.	e.g., 56, establishment is High		

Table 3. Matrix for combining likelihood (adapted from Department of Agriculture and Water Resources 2016)

		Likelihood 2			
		High	**Moderate**	**Low**	**Negligible**
Likelihood 1	**High**	High	Moderate	Low	Negligible
	Moderate		Low	Low	Negligible
	Low			Negligble	Negigible
	Negligible				Negligible

1.1.1 Assessment of consequences

The potential consequences are estimated if the pestfor the particular commodity is to enter, establish and spread in Bhutan. This assessment helps to establish a structured analysis of consequences of the pest on the economy, environment and society.

The consequence risk is assessed in the same manner as for the likelihood of entry, establishment and spread by adding up the scores for the responses and assigning the ‘likelihood criterion’ based on the score range for the resulting score.

1.1.2 Estimation of overall risk

Overall risk is estimated using the matrix in Table 5. For this, the combined likelihood of entry, establishment and spread is combined with the likelihood of consequences.

For example:

Example 1: if EES is 'low' and the consequences is 'moderate' then overall risk will be:

Risk = EES x Consequences	**Low x High = Moderate**
Overall risk	**Moderate**

Example 2: if EES is 'high' and the consequences is 'low', then the overall risk will be:

Risk = EES x Consequences	**High x Low = Low**
Overall risk	**Low**

Overall risk of low means the risk level is acceptable and no risk management is required whereas an overall risk of moderate or high would require risk management.

Table 4. Overall risk matrix (adapted from Department of Agriculture and Water Resources 2016)

Likelihood of entry, establishment and spread (EES)		**Consequences**			
		Negligible	**Low**	**Moderate**	**High**
	High	Negligible	Low	Moderate	High
	Moderate	Negiligble	Low	Moderate	High
	Low	Negligible	Negligible	Low	Moderate
	Negligible	Negligible	Negligible	Negligible	Low

1.2 Risk Management Methods

This stage identifies the phytosanitary measures required to bring the risk level to an acceptable level while ensuring that negative impacts on trade are minimized. Phytosanitary measures are proposed for both exporting and importing countries in accordance with the guidelines in ISPM 2 and11. Measures are proposed as pre-entry for exporting country, and entry requirement for the importing country where necessary.

2. Result: PRA initiation

Pests of okra, onionand tomatopresent in India and are known to be associated with the specific commodity types (CABI 2020) are given in Appendices 2 – 4. The lists also include pests in the PRA proposal submitted by DACFW, India. The lists do not contain all pests submitted by DACFW, but only those known to be associated with the specific pathway.

A total of 127 pests are identified to be associated with the three commodities. Highest number of pests associated with commodity pathway is recorded for tomato with 55 pests. Onion has 37 pests associated with the commodity pathway while only 33 pests are recorded for okra (Appendices 2 – 4).

3. Results of Pest Risk Assessment for Quarantine Pests

A quarantine pest list (Table 6) for each commodity was obtained based on the information provided in Appendices 2 – 4, the NPDB and expert judgment. The quarantine pests of concern to be associated with the specific commodity pathway for fresh okra, onion, and tomato fruits and their associated risks were identified and assessed. The following were assessed for each commodity.

3.1 Okra

<u>*Summary*</u>

The quarantine pests of okra comprise of two insect pests, *Liriomyza sativae* (vegetable leaf miner) and *Maconellicoccus hirsutus* (pink mealybug), and one bacterium, *Pseudomonas syringae*pv. *syringae* (Table 6). No viruses, mites, phytoplasmas or nematodes of concern are identified with potential imports of okra from India. No weed species are associated with the import of fresh fruits for consumption as there is a minimal chance of weeds coming as contaminants along with fresh fruits for human consumption.The overall risk of *M. hirsutus* and *P. syringae*pv. *syringae* is assessed as negligible and low respectively. On the other hand, the overall risk for *L. sativae* was assessed as moderate requiring pest management measures.

Table 5. Quarantine pests of okra, onion and tomato for Bhutan.

	Host & pest scientific name	Common name	Present in India?	Associated with the commodity type?
	<u>Okra</u>			
1.	*Liriomyza sativae* Blanchard	vegetable leaf miner	Yes (CABI 2020)	Yes (CABI 2020)
2.	*Maconellicoccus hirsutus* (Green)	pink hibiscus mealybug	Yes (CABI 2020)	Yes (CABI 2020)

3.	*Pseudomonas syringae* pv. *syringae* van Hall	bacterial canker or blast (stone and pome fruits)	Yes (CABI 2020)	Yes (CABI 2020)
	<u>Onion</u>		Yes (CABI 2020)	Yes (CABI 2020)
1.	*Frankliniella occidentalis* (Pergande)	western flower thrips,	Yes (CABI 2020)	Yes (CABI 2020)
2.	*Stromatinia cepivora* (Berk.)Whetzel	white rot	Yes (CABI 2020)	Yes (CABI 2020)
3.	*Urocystis cepulae* Frost	onion smut	Yes (CABI 2020)	Yes (CABI 2020)
	<u>Tomato</u>		Yes (CABI 2020)	Yes (CABI 2020)
1.	*Clavibacter michiganensis* subsp. *michiganensis* (Smith)Davis et al.	bacterial canker	Yes (CABI 2020)	Yes (CABI 2020)
2.	*Pseudomonas syringae* pv. *syringae* van Hall	bacterial canker or blast (stone and pome fruits)	Yes (CABI 2020)	Yes (CABI 2020)
3.	*Liriomyza sativae* Blanchard	vegetable leaf miner	Yes (CABI 2020)	Yes (CABI 2020)
4.	*Tuta absoluta*			

3.1.1 *Liriomyza sativae* Blanchard

The vegetable leaf miner, *Liriomyza sativae* Blanchard is an invasive species originally known to be found in America and now spread in many parts of Africa, Asia and the Pacific region (Lonsdale 2011; CABI 2020b). *Liriomyzasativae* is a polyphagous pest of many vegetable and flower crops and have been recorded from nine plant families, although its preferred hosts tend to be in the Cucurbitaceae, Fabaceae and Solanaceae family (CABI 2020a).

*Liriomyzasativae*is considered as one of the most devastating invasive New World pest species and is also known to be a vector of plant pathogens including plant viruses. *Liriomyzasativae*has spread in many regions of the world. It is an A1 quarantine pest in the EPPO (CABI 2020a). The insect has been reported from India, but not from Bhutan.

Liriomyzasativae is very small fly (1-1.3 mm body length, up to 1.7 mm in female with wings 1.3-1.7 mm.) The mesonotum is shiny black to the edge of a bright yellow scutellum; the face, frons and third antennal segment are bright yellow. Males and females are generally similar in appearance. *Liriomyza sativae* are not very active fliers, but in crops they show active mining and many of them may be seen walking rapidly over the leaves with only short jerky flights to adjacent leaves (CABI 2020a). The insect can be observed on leaves and fruits, but will not be observed on plant parts such as stems, roots, seeds, inflorescences, bark and bulbs. In tomatoes the damage is mostly caused by their mines on leaves which are white with dampened black and dried brown areas, typically serpentine, tightly coiled, or of irregular shape.

3.1.1.1 Likelihood of entry of *L. sativae*

The likelihood of entry of *L. sativae* with the importation of okra is assessed as **Moderate.**

- The pest is present in India. During 2016, *L. sativae* was observed for the first time infesting tomato (*Solanum lycopersicum* L.) leaves in experimental farms of an institute at Umiam (Meghalaya State) (Dnyaneshwar et al. 2018).
- The leaf miner can survive as eggs, larvae in tomato fruits, leaves and stem.
- Okra is imported into Bhutan from India, but not in large volume as other vegetables.
- The infestations with*L. sativae* are conspicuous, hence they can be detected visually.

3.1.1.2 Likelihood of establishment of *L. sativae*

The likelihood of establishment of *L.sativae*is assessed as **High.**

- *Liriomyzasativae* is a polyphagous pest of many vegetable crops and flower plants. It has been recorded from nine plant families with its most preferred hosts being Cucurbitaceae, Fabaceae and Solanaceae.
- Since the pest has a wide host range, it has a potential to establish in vegetable crops which are widely grown in Bhutan such as tomatoes, potatoes, beans and cucurbits.
- As this pest prefers areas with a warm temperature, and protected cultivation (CABI 2020a); there is potential for it to establish especially in warm-humid areas in Bhutan.

3.1.1.3 Likelihood of spread *L. sativae*

The likelihood of spread of *L.sativae*is assessed as **High**.

- Since it is a polyphagous pest, the likelihood of it spreading is high. The pest has been recorded feeding on nine plant families, although its preferred hosts tend to be Cucurbitaceae, Fabaceae, and Solanaceae.
- *Liriomyzasativae*is able to colonize a wide range of plants, thus ensuring success in establishing itself at any opportunity (CABI 2020a).

3.1.1.4 Consequences

The consequences resulting from the entry, establishment and spread of *L.sativae* due to importation of okra is assessed as **Moderate**.

- The pest has a potential to cause serious economic loss to the country. Losses of 80% have been reported for celery in Florida and high yield losses in tomato in many parts of its range due to this pest incidence (CABI 2020a).
- Young plants are particularly susceptible to damage and consequent reduced efficiency or death, whilst older plants may also be seriously damaged through leaf loss due to many mines occurring in each leaf (CABI 2020a).
- In term of the economic consequences;major crops grown in Bhutan like tomato, beans, cucurbits, maize will be highly susceptible if this pest establishes and crop losses will be huge. Social impact will also be high as growers will lose income from these crops.

3.1.1.5 Endangered area

- Major vegetables known to be the hosts of *L. sativae* are extensively grown in Bhutan. Hence, all these areas are at risk.

3.1.1.6 Combined estimate of likelihood of entry, establishment and spread

Combined estimate of likelihood of entry, establishment and spread is assessed using the matrix in Table 3. The combined likelihood is assessed as **Moderate.**

Likelihood of entry (E) x Likelihood of establishment (E) = EE
EE Moderate x High= **Moderate**
EE x Likelihood of Spread (EES) Moderate x High = **Moderate**

3.1.1.7 Overall risk of *L. sativae*

The overall risk of *L. sativae* is estimated using the matrix in Table 4.

Overall risk for *L. sativae*	
Descriptor	**Risk**
Likelihood of entry, establishment, and spread (EES)	Moderate
Consequence (C)	Moderate
Overall risk = EES x C = Moderate x Moderate	Moderate

The overall risk of **Moderate** does not achieve the acceptable level of import risk for this pest. Hence, pest risk management measures are required for importation of okra from India.

3.1.2 *Maconellicoccus hirsutus*(Green) (Pink mealybug,)

The pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green) (Hemiptera: Pseudococcidae), is an invasive pest of horticultural and agricultural crops worldwide. It has recently expanded its range in the Americas and the Caribbean (Chong et al. 2015). This pest, however, has not been recorded in Bhutan.

The pest can proliferate rapidly and hence can severely impact many horticultural crops, particularly ornamental plants. *Maconellicoccus hirsutus* is highly polyphagous and has been recorded feeding on hosts from 76 plant families and over 200 plant genera (Ben-Dov et al. 2003). The pest shows preference for hosts in the families: Malvaceae, Leguminosae and Moraceae (Ben-Dov et al. 2003).

Crawlers are pink. Immature females and newly matured females have greyish-pink bodies dusted with mealy white wax. The adult female is 2.5-4 mm long, soft-bodied, elongate oval and slightly flattened; on maturation, she begins to secrete sticky, elastic, white wax filaments from her abdomen to form a protective ovisac for her eggs. As her pinkish-grey body fills with salmon-pink eggs, it assumes a pink colour; but this is often not immediately visible because the entire colony tends to become covered by white, waxy ovisac material (CABI2020b). The feeding of *M. hirsutus* causes malformation of shoots and leaves caused by the injection of a toxic saliva (Kairo et al. 2000). In addition to lowering the aesthetic value of the plant, this deformation can also result in lowered crop yields. Like other sap sucking insects, *M. hirsutus* also excretes a sugary honeydew on which sooty mold develops, further deteriorating the quality of the agricultural or forest product (Gonzalez-Gaona et al. 2010). On plant, it also can introduce a growth regulator-type toxin during feeding, which results in severe stunting, decline, and deformation of growing terminals, leading to "bunchy top" (Chong et al. 2015).

3.1.2.1 Likelihood of entry for *Maconellicoccus hirsutus*

The likelihood of entry of *Maconellicoccus hirsutus* with the importation of okra is assessed as **Moderate.**

- This pest is native to South Asia and is present in India but not in Bhutan.
- The mealy bug can be present in fruits as adults, eggs, larvae, nymphs, pupae and above ground parts such as leaves, stems and calyx.
- Local movement of *M. hirsutus* occurs at the first instar (crawler) stage. Crawlers are very small (0.3 mm long), light and can survive more than a day without feeding.
- Accidental introductions to new countries can occur via fruits and infested plant material.

3.1.2.2 Likelihood of establishment for *Maconellicoccus hirsutus*

The likelihood of establishment for *M. hirsutus*is assessed as **Moderate.**

- Since okra is not grown widely in Bhutan and is not a very popular vegetable, the endangered area is considered to be minimum.
- If established in Bhutan, some of the potential plants it can infest are citrus, mangoes, plum, beans, and maize.

3.1.2.3 Likelihood of spread

The likelihood of spread of *M. hirsutus* is assessed as **Low.**

- The pest prefers plants within the family Malvaceae; okra is not widely grown in Bhutan and other members of Malvaceae present in Bhutan are known to be of less economic importance e.g., ornamental plants such as hibiscus, and hollyhock.
- Okra is imported mostly for house-hold consumption and is not imported as a planting material. The likelihood of spread through natural means and/or human assistance is therefore considered low.

3.1.2.4 Consequences

The impact of establishment of *M. hirsutus* is assessed as **Moderate**.

- As okra is not grown widely in Bhutan, the economic impact is considered as moderate. The pest therefore might have minimum impact on the crop yield and the quality of the crop.
- If established in Bhutan, there is a potential for it to infest other alternative host plants such as citrus, mangoes, plum, beans, and maize.

- However, the environmental consequences might be greater than the economic consequences due to its feeding damage and ability to damage or kill native plant species.

3.1.2.5 Endangered area

Maconellicoccus hirsutus might endanger areas where ornamental plants and vegetables are widely grown. Additionally, it has the potential to impact areas that grow crop such as citrus, mangoes, plum, beans, and maize.

3.1.2.6 Combined estimate of likelihood of entry, establishment and spread of *M. hirsutus*

Combined estimate of likelihood of entry, establishment and spread is assessed using the matrix in Table 3. The combined likelihood is assessed as **Negligible.**

Likelihood of entry (E) x Likelihood of establishment (E) = EE	
EE	Moderate x Moderate = **Low**
EE x Likelihood of Spread =	EES
EES	Low x Low = **Negligible**

3.1.2.7 Overall risk of the *M. hirsutus*

The overall risk is estimated using the matrix in Table 4 which combines the likelihood of entry, establishment and spread with the economic consequences.

Overall risk for *Maconellicoccus hirsutus*	
Descriptor	**Risk**
Likelihood of entry, establishment, and spread (EES)	Negligible
Consequences (C)	Moderate
Overall risk = EES xC = Negligible x Moderate	Negligible

The overall risk for *M. hirsutus* is assessed as **Negligible**. This level of risk is of acceptable level and further assessment of risk management is not required.

3.1.3 *Pseudomonas syringae*pv. *syringae* van Hall

*Pseudomonas syringae*pv. *syringae*van Hall is a gram negative, aerobic and rod-shaped bacterium belonging to alpha subclass of Proteoabacteria. The bacterium causes disease in many unrelated hosts including okra (CABI 2020c).

The bacterium has two phases of growth in/on plants- the epiphytic phase when the bacterium lives on the surface of the plants or plant parts e.g., leaves, stems, fruits, and the endophytic phase when the bacterium enter plant tissues (Xin et al. 2018).

The bacterium is present in India but not in Bhutan. It is reported on okra in Rajasthan (Sharma et al. 2014), peach in Kashmir (CABI 2020c), and peas in Himachal Pradesh (Jindal and Pathania 1997).

The bacterium flourishes during cool and frequent wet weather as shown by higher bacterial population during spring and autumn than in summer. Rain water favours growth of the bacterium but rapid growth results from leaf wetness due to dew (Hirano and Upper 1990).

The bacterium can be present on bark, flowers including calyx, fruits and pods, leaves, roots, stems, seedlings, and seeds including grains (CABI 2020c). On all these plants parts, symptoms may not be visible to the naked eye (CABI 2020c).

3.1.3.1 Likelihood of entry for *P. syringae*pv. *syringae*

The likelihood of entry of *P. syringae* pv. *syringae* with the importation of fresh okra is assessed as **Moderate.**

- *Pseudomonas syringae* pv. *syringae* is associated with fresh okra as a pathway and is present in India e.g., reported on in Rajasthan (Sharma et al. 2014). Reports from other okra growing areas are lacking but it cannot be ruled out based on biology of pathogen and suitable climatic condition of other areas in India.
- *Pseudomonas syringae*pv.*syringae* has a wide host range and presence of the bacterium on other hosts in India are evident (e.g., Peach in Kashmir)
- Okra importation to Bhutan is quite frequent and of high volume.
- *Pseudomonas syringae* pv.*syringae* can exist epiphytically without exhibiting any symptom, thus escaping visual inspection although the exporting country has a surveillance system for detection and immediate response in place.

3.1.3.2 Likelihood of establishment for *P. syringae*pv. s*yringae*

The likelihood of establishment for *P. syringae*pv. s*yringae* is assessed as **High.**

- The pathogen can infect a wide range of unrelated hosts (CABI 2020c) of which at least seven (apple, chilli, citrus, rice, maize, tomato) are important crops cultivated in most regions of Bhutan. Other hosts such as rhododendrons, hibiscus, willows, and clovers are also present in Bhutan.
- While beans, chilli, lettuce, rice, maize and tomato are grown almost all over Bhutan, pome and stones fruits such as apples, peaches and plums are restricted to cooler regions. Mango and citrus are grown in the semi-tropical regions of Bhutan. Hence, the presence of many host species in Bhutan will enable this bacterium to establish in Bhutan.
- The bacterium is capable of entering host plants through natural openings such as stomata and artificial wounds such as bruises on plant surfaces.
- Weather conditions favouring the bacterium growth and multiplication prevail in most regions of Bhutan where the host plants are present.

3.1.3.3 Likelihood of spread of *syringae*pv. s*yringae*

The likelihood of spread of *P. syringae*pv. *syringae* is assessed as**Moderate**.

- The bacterium is seed borne in addition to being epiphytic on plants. Therefore, movement of any plant parts from where the bacterium is present increases the likelihood of long- distance dispersal. Rain and wind can spread the bacterium. However, the bacterium needs to survive e.g., in debris and plants, and require suitable conditions such as high humidity and rain for spread to a suitable host. Waste of imported fresh okra in the urban areas are disposed as municipal waste and sale and consumption of okra is minimum in the rural areas.
- However, containment, if established, will be difficult due to lack of technical expertise and effective control measures.

3.1.3.4 Consequences

The impact of establishment of *P. syringae*pv. *syringae* is assessed as **Moderate**.

- There is no direct impact on okra production in Bhutan as okra is not a major crop in Bhutan. Production is limited to backyard cultivation.
- However, *P. syringae*pv. *syringae* has a wide host range and is known to cause serious diseases limiting crop production in many crops e.g.:
    - bacterial apical necrosis (BAN) in Mango in southern Spain and Portugal (Cazorla et al. 1998).
    - yield losses of 5 to 50% in wheat (Forster and Schaad 1988; Duveiller and Maraite 1993; Kietzell and Rudolph 1997 as cited in Valencia-Botín and Cisneros-L ópez 2012).
- If established on any of the major crops such as apple, rice, citrus or chilli in Bhutan;*P.syringae*pv. *syringae* would be expected to cause serious losses in production of these crops.
- It is expected that viable production of crops such as apple, citrus, mango, chili and rice would be impaired if *P. syringae*pv. *syringae* is established on these hosts due to lack of knowledge and expertise in disease containment and control in the country.
    - Control measures in other countries consist of copper based pesticides, antibiotics and resistant varieties, all of which are very challenging for Bhutan to adopt. Moreover, Bhutan strongly advocates organic agriculture.

- No environmental impacts are known other than that it can infect some species in the wild including rhododendrons.

3.1.3.5 Endangered area

*Pseudomonas syringae*pv. *syringae*has a wide host range which are present all over in Bhutan. Hence, all areas are considered as endangered area.

3.1.3.6 Combined estimate of likelihood of entry, establishment and spread

Combined estimate of likelihood of entry, establishment and spread of *P. syringae*pv. *syringae* is assessed using the matrix in Table 3. The combined likelihood is assessed as **Low.**

Likelihood of entry (E) x Likelihood of establishment (E) = EE
EE Moderate x High= **Moderate**

EE x Likelihood of Spread (S) = EES	EES Moderate x Moderate = **Low**

3.1.3.7 Overall risk of *P. syringae*pv. *syringae*

The overall risk is estimated using the matrix in **Table 4** which combines the likelihood of entry, establishment and spread with the economic consequences. The overall risk is assessed as **Low.**

Overall risk for *Pseudomonas syringae* pv. *syringae*	
Descriptor	**Risk**
Likelihood of entry, establishment, and spread (EES)	Low
Consequences (C)	Moderate
Overall risk = EES x C = Low x Moderate	**Low**

The overall risk for *P. syringae* pv.*syringae*is assessed as low, which is at an acceptable level. Therefore, specific risk management is not required.

3.2 Onion

<u>*Summary*</u>

The quarantine pests of onion comprise of one insect pest,*Frankliniella occidentalis*(Western flower thrips) and two fungal pathogens: *Stromatinia cepivora* (white rot) and *Urocystis cepulae* (onion smut) as shown in Table 6. No other pests were identified for further assessment. The overall risk of *F. occidentalis* wasassessed as **moderate**while the risks for *S. cepivora*, and *U. cepulae* were assessed as **low** and **moderate**respectively.

3.2.1 *Frankliniellaoccidentalis* (Pergnade)

The western flower thrips, *Frankliniella occidentalis* (Pergande) is highly polyphagous, breeding on many horticultural crops that are transported around the world. The western flower thrips, *Frankliniella occidentalis* is an invasive insect pest. This species of thrips is native to the Southwestern United States but has spread to other continents, including Europe, Australia, and South America. *Frankliniella occidentalis* is species no. 177 on the list of A2 pests regulated as quarantine pests in the European Plant Protection Organization (EPPO) region (version 2005-09). It has been recorded from India (Suganthy et al. 2016), but has not been recorded in Bhutan.

The pest can breed on a wide range of plant species in many different habitats, from lowland to alpine and from humid to arid and can reproduce successfully in a wide range of temperature and humidity under experimental conditions. However, the speculation is that they may not survive outdoor cold winters in northern Europe (CABI 2020d). It is a highly polyphagous species with at least 250 plant species from more than 65 families being listed as hosts. The pest can cause leaf deformation, fruit spotting and most importantly transmit at least five different tospoviruses.

3.2.1.1 Likelihood of entry for ***F.occidentalis***

The likelihood of entry of *F. occidentalis* with the importation of tomato is assessed as **High.**

- This pest is reported to have established in India in 2015.
- Individuals are very small and they reside in concealed places on plants, thus are easily hidden and hard to detect in transported plant material.
- Onion is imported frequently and in large volume into Bhutan from India therefore the likelihood for this pest to enter through import of onion is high.

3.2.1.2 Likelihood of establishment for ***F. occidentalis***

The likelihood of establishment for *F. occidentalis*as the result of importation of tomato is assessed as **High.**

- *Frankliniella occidentalis* has been reported from India.
- *Frankliniella occidentalis* is a quarantine pest for Bhutan and considered to have a moderate likelihood to establish in Bhutan due to its wide host range.
- The main host for *F. occidentalis* which are cultivated in Bhutanincludes carrot, lettuce, onion and garlic, cabbage, radish, cucumber, pea, peach, apple, apricot, tomato, potato.
- Therefore, the pest has a high likelihood for establishment in Bhutan.

3.2.1.3 Likelihood of spread

The likelihood of spread of *F. occidentalis*as a result of entry and establishment associated with the importation of tomato is assessed as**High.**

- *Frankliniella occidentalis* is naturally abundant in many wild flowers throughout western North America and has spread across the USA, Canada and reached the Netherlands in 1983; and then spread outwards across Europe (Kirk and Terry2003).
- Having become well established in Europe and Israel, it spread to the highlands of eastern Africa and subsequently entered New Zealand in 1992 and Australia in 1993.
- Internationally, *F. occidentalis* has been recorded to be carried on any plants for planting or on bulb, and nursery stocks, which are the main means of dispersal of this pest (EPPO 2020a).
- Therefore, the likelihood of spread for this pest is considered to be high through imports of large volume of onions into Bhutan from India.

3.2.1.4 Consequences

The economic impact of establishment of *F. occidentalis*is assessed as **Moderate**.

- *F. occidentalis* is of quarantine significance for Bhutan. Its introduction and rapid spread in many countries with a wide range of hosts crops, illustrate the nature of this pest and the potential economic consequence it might have on onion and other host crops.
- Egg laying on fruits such as table grapes, tomatoes and apples leads to the spotting of the skin of the fruit, which reduces the aesthetic value of the fruit. It can also lead to splitting and subsequent entry of fungi. However, the most serious effect of thrips feeding is due to the transmission of tospoviruses into susceptible crops (Childers and Achor 1995).

- Therefore, economic consequences of this pest can be moderate as it is known to be a fairly serious pest of several important field crops and vegetables.

3.2.1.5 Endangered area

*Frankliniella occidentalis*has a wide host range and major vegetable growing areas will be endangered if this pest establishes and spreads across Bhutan. If established in Bhutan, it can be a potential pest in crops such as carrot, lettuce, onion and garlic, cabbage, radish, cucumber, pea, peach, apple, apricot, tomato, potato.

3.2.1.6 Combined estimate of entry, establishment and spread of *F. occidentalis*

Combined estimate of likelihood of entry, establishment and spread is assessed using the matrix in Table 3. The combined likelihood is assessed as **High.**

Likelihood of entry (E) x Likelihood of establishment (E) = EE

EE	High x High= **High**
EE x Likelihood of Spread =	EES
EES	High x High =**High**

3.2.1.7 Overall risk of *F. occidentalis*

The overall risk is estimated using the matrix in Table 4 which combines the likelihood of entry, establishment and spread with the economic consequences.

Overall risk for *F. occidentalis*	
Descriptor	**Risk**
Likelihood of entry, establishment, and spread (EES)	High
Consequences (C)	High
Overall risk = EES xC = Highx Moderate	**Moderate**

The overall risk for *F. occidentalis* is assessed as**Moderate** which is not at the risk acceptable level and hence requires risk management.

3.2.2 *Stromatiniacepivora* (Berk.) Whetzel (synonym: *Sclerotium cepivorum* Berk.)

Stromatinia cepivora (Berk.) Whetzel (synonym- *Sclerotium cepivorum* Berk.) is a soil borne fungus causing white rot of onion and garlic. It persists in the soil in a dormant structure called sclerotia for decades (Swett et al. 2009; CABI 2020e). It can also survive in diseased tissues and on weeds. Spores near soil surface can be dispersed by wind. Spores are also dispersed through contaminated seed and plants, and farm tools (Ontario Crop IPM 2009a).

3.2.2.1 Likelihood of Entry of *S. cepivora*

The likelihood of entry of *S. cepivora* with the importation of onion is assessed as**High.**

- *Stromatiniacepivora* is present in India but not in Bhutan.
- The import of onion bulbs from India consist of high volume and frequency, spreading throughout the year.
- Bhutan grow onions (mostly scallions) and garlic widely, and leek to some extent for domestic consumption in the cool regions of Bhutan. Places with warmer climate grow onions and garlic during the cool seasons.
- The fungus can survive in infected bulb in storage wherein the infection will continue if transported at cool ambient temperature coupled with high humidity.
- Although bulk of infected bulbs would be discarded in the fields due to rotting, infected bulbs without sign of rotting would go undetected.

3.2.2.2 Likelihood of establishment for *S.cepivora*

The likelihood of establishment for *S.cepivora* is assessed as **High.**

- Onion, garlic and leek are all grown in most parts of Bhutan. In cooler regions, scallions are grown in the spring and autumn lasting throughout winter.
- *Stromatinia cepivora* is favoured by cool temperature ranging from 10-24°C and moist weather (Ontario Crop IPM factsheets 2009a) which is prevalent in the higher altitude regions of Bumthang, Thimphu, Paro, Haa, Punakha, and Wangdue Phodrang. In the southern regions, temperature in this range prevails during winter months but humidity is relatively lower during winter.
- The fungus can survive in soil for decades in the form of sclerotia.
- The available control measures of crop rotation, sclerotia germination stimulation followed by flooding or fumigation cannot eradicate the fungus. Thus, once introduced, it is difficult to get rid of the fungus.
- Inoculum level of>1 sclerotium per gram of soil can kill whole plant soon after emergence (Crowe et al. 1980) indicating that few individuals can establish and perpetuate if hosts are available.

3.2.2.3 Likelihood of spread

The likelihood of spread of *S. cepivora* is assessed as**Moderate.**

- Although spread by natural means is limited, spread by human assistance poses risk if introduced in an area. The chances of dispersal through contaminated planting material is quite high due to the practices of exchange of planting materials among growers. Further, growers take their own farm tools to work on other farms during labour exchange hence increasing the chance of spreading through contaminated tools.
- Once introduced into a country, *S. cepivora* has then been reported in other parts quite often. E.g., in the US, the fungus has spread to nine States by 2014 since its first report in 1918 in Oregon (CABI 2020e).
- Once introduced, containment of the disease is difficult.

3.2.2.4 Consequences

The economic impact of establishment of *S. cepivora* is assessed as **Moderate**.

- Although onion bulb production is limited, garlic and scallion productionsare very important. These are grown in cool regions where humidity can get high enough for the fungus to flourish.
- *Stromatinia cepivora* is known to cause severe crop losses in onion producing areas (CABI 2020e). In Egypt, significant yield losses are observed in commercial onion and garlic production areas (Elshahawy et al. 2019).

3.2.2.5 Endangered area

Dzongkhag with cool temperature range and high moisture during crop season: Bumthang, Haa, Lhuentse, Paro, Punakha, Tashi Yangste, Thimphu, Wangdue Phodrang.

3.2.2.6 Combined estimate of likelihood of entry, establishment and spread of *S. cepivora*

Combined estimate of likelihood of entry, establishment and spread of *S. cepivora* is assessed using the matrix in Table 3. The combined likelihood is assessed as**Low.**

Likelihood of entry (E) x Likelihood of Establishment (E) = EE	
EE	Moderate x Moderate= **Low**
EE x Likelihood of Spread (S)	EES
EES	Low x Moderate = **Low**

3.2.2.7 Overall risk of *S. cepivora*

The overall risk is estimated using the matrix in Table 4 which combines the likelihood of entry, establishment and spread with the economic consequences. The overall risk is assessed as **Low.**

Overall risk for *Stromatinia cepivora*	
Descriptor	**Risk**
Likelihood of entry, establishment, and spread (EES)	Low
Economic consequence (EC)	Moderate
Overall risk = EES x EC = Low x Moderate	Low

The overall risk for *S. cepivora* is assessed as **Low**. This is an acceptable level. Therefore, specific risk management is not required. This PRA requires review when the issues pertaining to uncertainties and when other information changes.

3.2.3 *Urocystis cepulae* Frost (synonym: *Urocystis colchici* (Schlechtendel) Rabenhorst

*Urocystiscepulae*Frost is an obligate pathogen affecting *Allium* species. As such, it needs a living host for growth and multiplication. The fungus can cause yield reduction by 70%. The fungus produces spores (teliospores) which are resistant to harsh conditions and persist in soil for many years. The spores are also easily spread by wind and on seeds as contaminants, soils, and farm tools. Teliospores germinate at temperature range of 12-28°C and may need stimulation via host exudates. (CABI 2020f; Ontario Crop IPM 2009b).

3.2.3.1 Likelihood of entry of *U. cepulae*

The likelihood of *U. cepulae* with importation of onion bulb from India is assessed as**High.**

- *Urocystiscepulae* is present in India with localised distribution (EPPO 2020b) but it is not present in Bhutan.
- The volume and frequency of import is high. Importation is made for consumption in whole of Bhutan on almost weekly basis.
- The teliospores of *U. cepulae* can be spread easily by wind and can survive for very long time in soil.
- Though bulb onion production is not prominent, spring onions and garlic are grown in almost all part of Bhutan.
- There are no effective control measures. Management consists of seed treatment and shallow planting.

3.2.3.2 Likelihood of establishment of *U. cepulae*

The likelihood of establishment of *U. cepulae* is assessed as **High.**

- Onions (mostly scallions or spring onions) and garlic are grown all over Bhutan.
- Though the end use if for consumption, improper disposal of waste and nature of spore disposal by wind contributes to the establishment of the pathogen. Only a single infection is necessary to give rise to billions of spores for dispersal in the second generation.
- Onion and garlic are grown in areas or during season when weather conditions are conducive for the fungus to germinate. Spring and autumn when weather conditions are cool but still wet.
- The fungus has also been reported in many countries (CABI 2020f) indicating its easy adaptation and establishment.

3.2.3.3 Likelihood of spread of *U. cepulae*

The likelihood of spread of *U. cepulae* is assessed as **High.**

- Although the fungus is an obligate parasite requiring a living host for growth and multiplication, the spores of the fungus can be easily spread by wind. The spores can land on soil where it can survive for many years till conditions become favourable for its germination.
- Because onion and garlic are commonly grown in most part of Bhutan, it is feasible that the spores will get in contact with a host in time.
- Once established in an area, it will be difficult to contain the fungus in one area due to nature of farming where exchange of planting materials and farm tools is common, and lack of effective control measures.

3.2.3.4 Consequences

The risk of economic consequences is assessed as **Moderate.**

- Though reported as sporadic occurrence, yield reduction by 70% has been reported (CABI 2020f)
- Increase in cost of production is anticipated to be low due to non-availability of control measure in Bhutan, and hence no control would be applied. However, growers would opt out to grow onion as a result of the fungus entering, establishment and spreading in Bhutan. This appears to have a high impact on the society, however, the availability of alternatives of buying onions at cheap rate at the border towns balances this negative impact.

3.2.3.5 Endangered area

All parts of Bhutan.

3.2.3.6 Combined estimate of likelihood of entry, establishment and spread of *U. cepulae*

The combined estimate of likelihood of entry, establishment and spread is assessed as **High.**based on the matrix in Table 3.

Likelihood of entry (E) x Likelihood of Establishment (E) = EE	
EE	High x High= **High**
EE x Likelihood of Spread (S)	EES
EES	High x High = **High**

3.2.3.7 Overall risk of *U. cepulae*

The overall risk of *U.cepulae* is obtained based on the matrix in Table 4 which combines the likelihood of entry, establishment and spread with the economic consequence. The overall risk is assessed as **Moderate.**

Overall risk for *Urocystic cepulae*	
Descriptor	**Risk**
Likelihood of entry, establishment, and spread (EES)	High
Consequences (C)	Moderate
Overall risk = EES x C = High x Moderate	**Moderate**

The overall risk of **Moderate** for the quarantine pest, *U. cepulae*, requires management of the risk associated with the import of onion bulb from India to Bhutan.

3.3 Tomato

<u>*Summary*</u>

Four quarantine pests are identified for tomato fruit import from India to Bhutan. The quarantine pests comprise of two bacteria,(*Clavibacter michiganensis* subsp. *michiganensis* and

Pseudomonas syringae pv. *syringae*), and two insect pests (*Liriomyza sativae* and *Tuta absoluta*). No other types of pests were identified for assessment.

The overall risks of the bacterium,*C. michiganensis* subsp. *michiganensis,* andthe insect pests,*L. sativae*and *T. absoluta*, associated with importation of tomato from Indiawereassessed as **moderate** which required risk management measures for these pests. On the other hand, *P. syringae*pv. *syringae*was assessed with an overall risk of **low**. An overall risk of **low** is of acceptable level and does not require risk management.

3.3.1 *Clavibacter michiganensis* subsp. *michiganensis* (Smith) Davis et al.

Clavibacter michiganensis subsp. *michiganensis*(Smith) Davis et al. is a gram-positive, non-sporing curved rod bacterium causing canker mainly on tomato plants. The bacterium is widely distributed. The bacterium can also infect chilli plants, and night shade weed. The bacterium causes wilting, fruit spotting, leaf necrosis leading to serious yield reduction. The bacterium can be transmitted through seeds, grafting, trimming and pruning. Low rate seed transmission is enough to initiate epidemics in the fields.

Management of bacterial canker involves acid extraction of seeds or seed treatment with acid or other disinfectants or hot water. Cultural practices such as deep ploughing and proper destruction of plant debris and crop rotation can reduce canker incidences. No commercial resistant varieties are available (CABI 2020g).

3.3.1.1 Likelihood of entry for *C. michiganensis* subsp. *michiganensis*

The likelihood of entry for *C. michiganensis* subsp. *michiganensis*as result of importation of tomato is assessed as **High.**

- The likelihood of entry for *C. michiganensis* subsp. *michiganensis* appears to be high because the pathogen is present in India but not in Bhutan.
- The import volume and frequency are assessed as high as tomato is imported every week for consumption in most parts of Bhutan.
- The likelihood of the pest surviving during transport and storage is also assessed as high due to the pathogen being seed borne and transmitted.
- The pathogen is also known to survive for long time, up to two years, in plant debris (Gleason et al. 1991). The pathogen is capable to enter host tissue via natural openings and artificial wounds. Further, latent infection is reported to be widespread thereby reducing the likelihood of visual detection (Gleason et al. 1993; CABI 2020g).

3.3.1.2 Likelihood of establishment for *C.michiganensis* subsp. *michiganensis*

The likelihood of establishment for *C. michiganensis* subsp. *michiganensis* is assessed as **High.**

- Tomato, which is the host of the pathogen, is grown widely in the PRA area.
- Chilli, which is also known to be infected by the pathogen naturally, is one of the main crops in the PRA area.

- The climatic and ecological conditions in the PRA area are deemed moderately similar to the pathogen's current distribution area.
- The pathogen is widely distributed in the world indicating its adaptability to wide climatic conditions. The pathogen is also often detected in protected cultivation conditions which is one strategy to produce tomato during the winter months or off season in the PRA area.
- Though seed treatment is one of the best strategies to reduce infection through contaminated seeds, the pathogen cannot be eradicated.
- Pathogen can survive for long on seeds and in debris; and can easily be transmitted through grafting or mechanical wounds or natural openings.

3.3.1.3 Likelihood of spread for *C.michiganensis* subsp. *michiganensis*

The likelihood of spread for *C. michiganensis* subsp. *michiganensis* is assessed as **High.**

- *Clavibacter michiganensis* subsp. *michiganensis* can be spread rapidly by natural means.
- Sharing of planting materials among growers and consumers saving seeds from commodities meant for consumption prevails though not at a large scale. Since the pathogen is found on seeds, it is possible that such exchange will contribute to its natural spread. Moreover, a small proportion of infected seeds or low rate seed transmission is known to cause increased disease incidences.

3.3.1.4 Consequences

The economic consequence due to entry, establishment and spread of *C. michiganensis* subsp. *michiganensis* as a result of import of fresh tomato is assessed as**Moderate**.

- *Clavibacter michiganensis* subsp. *michiganensis* is known to cause substantial yield loss. Yield losses is recorded as high as 70% (CABI 2020g).
- The cost of production is also likely to increase due to the need to implement control measures though the level of uncertainty for this is high due to lack of quantitative information. However, it is easy to deduce the consequences based on available information. One of the strategies for managing the disease involves crop rotation. Given the limited land available to the Bhutanese growers, such practice is difficult making long term management less likely. Seed treatment and debris management are reported to provide good reduction in disease incidences.
- Environmental impact is low as no synthetic pesticides are available for control of the disease.
- It is noted that the pathogen is restricted to the States of Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra and Tamil Nadu (CABI 2020g).

3.3.1.5 Endangered area

All chili and tomato growing areas are identified as endangered area though the areas in the southern region are mostly likely to be on the top list due to its warmer climate and availability of host plants throughout the year.

3.3.1.6 Combined estimate of likelihood of entry, establishment and spread

Combined estimate of likelihood of entry, establishment and spread pest risk of *C. michiganensis* subsp. *michiganensis* is assessed as**High.**

Likelihood of entry (E) x Likelihood of establishment (E)	= EE
EE	High x High = **High**
EE x likelihood of Spread	EES
EES	High x High = **High**

3.3.1.7 Overall risk of *C.michiganensis* subsp. *michiganensis*

The overall risk is estimated using the matrix in Table 4 which combines the likelihood of entry, establishment and spread with the consequence. The overall risk is assessed as **Moderate**.

Overall risk for *Clavibactermichiganensis* subsp. *michiganensis*	
Descriptor	**Risk**
Likelihood of entry, establishment, and spread (EES)	High
Consequence (C)	Moderate
Overall risk = EES xC = High x Moderate	**Moderate**

- *Clavibacter michiganensis* subsp. *michiganensis* is one of the most destructive pathogens of tomato and chilli and can have high negative effect on crop yield.
- The pathogen is seed borne which is one of the mechanisms for long distance dispersal. Both tomato and chilli are grown in Bhutan.
- Further, chilli is one of the main cash crops and extensively grown in Bhutan. The pathogen occurs widely in areas growing these crops indicating its adaptability to many areas.

The overall risk of moderate level is not an acceptable level and hence requires risk management.

3.3.2 *Pseudomonas syringae*pv. *syringae*

See Section 7.1.3 for information on this bacterium

3.3.2.1 Likelihood of entry of *P. syringae*pv. s*yringae*

The likelihood of entry of *P. syringae*pv. s*yringae*associated with the importation of tomato fruit from India is assessed as **Moderate.**

- *Pseudomonas syringae* pv. *syringae* is present in India (CABI 2020c).
- Tomato importation to Bhutan is quite frequent and of high volume.
- See Section 7.1.3.1

3.3.2.2 Likelihood of establishment of*P. syringae*pv. s*yringae*

The likelihood of establishment for *P. syringae*pv. s*yringae*as the result of importation of tomato from India is assessed as **High**.

- The pathogen can infect a wide range of unrelated hosts (CABI, 2020c) of which many are important crops in Bhutan.
- See Section 7.1.3.2

3.3.2.3 Likelihood of spread of*P. syringae*pv. *syringae*

The likelihood of spread of *P. syringae*pv. *syringae* is assessed as **Moderate.**

- End use of tomato import is for consumption.
- See Section on 7.1.3.3

3.3.2.4 Consequences

The consequences as a result of entering, establishment and spreading of *P. syringae*pv. *syringae* due to importation of fresh tomato fruit for consumption in Bhutan is assessed as **Moderate**.

- *Pseumononas syringae*pv. *syringae* has a wide host range and is known to cause serious diseases limiting crop production.
- See Sections under 7.1.3.4

3.3.2.5 Endangered area

All areas since *P. syringae*pv. *syringae* has a wide host range which are present in most parts of Bhutan. Importation of tomato fruits is throughout the year and are distributed to all parts of Bhutan.

3.3.2.6 Combined estimate of likelihood of entry, establishment and spread

The combined estimate of likelihood of entry, establishment and spread of *P.syringae*pv. *syringae* is assessed based on the matrix in Table 3.

Likelihood of entry (E) x Likelihood of establishment (E)= (EE)

E x E	High x Moderate = **Moderate**
EE x Likelihood of spread (S)	EES
EES	Moderate x Moderate = **Low**

3.3.2.7 Overall risk of *P.syringae*pv. *syringae*

The overall risk of *P. syringae*pv. *syringae* is estimated using Table 4 which combines the likelihood of entry, establishment and spread with the consequence. The overall risk is assessed as **Low.**

Overall risk for *P. syringae* pv. *syringae*	
Descriptor	**Risk**
Likelihood of entry, establishment, and spread (EES)	Moderate
Consequences (C)	Moderate
Overall risk = EES x C = Moderate x Moderate	Low

This overall risk of *P. syringae*pv. *syringae* is at acceptable level and does not require any risk management.

3.3.3 *Liriomyzasativae* Blanchard

See Section 7.1.1 for information on the pest.

3.3.3.1 Likelihood of entry of *Liriomyza sativae*

The likelihood of entry of *L. sativae* with the importation of tomato is assessed as **Moderate.**

- *Liriomyza sativae*is present in India with the first observation on tomato leaves,in 2016, in the experimental farms of an institute at Umiam (Meghalaya State)(Dnyaneshwar et al. 2018).
- Tomato is imported frequently and in large volume into Bhutan from India.
- See Section 7.1.11

3.3.3.2 Likelihood of establishment of *L. sativae*

The likelihood of establishment for *L.sativae*is assessed as **High.**

- See Section on 7.1.1.2

3.3.3.3 Likelihood of spread of *L. sativae*

The likelihood of spread of *L.sativae*is assessed as**High**.

- See Section on 7.1.1.3

3.3.3.4 Consequences

The consequences resulting from the entry, establishment and spread of *L.sativae* due to importation of tomatois assessed as **Moderate**.

- See Section 7.1.1.4

3.3.3.5 Endangered area

*Liriomyzasativae*has a wide host range and major vegetable growing areas will be endangered if this pest establishes and spreads across Bhutan.

3.3.3.6 Combined estimate of likelihood of entry, establishment and spread

Combined estimate of likelihood of entry, establishment and spread is assessed using the matrix in Table 3. The combined likelihood is assessed as **Moderate**.

Likelihood of entry (E) x Likelihood of establishment (E) = EE	
EE	Moderate x High=**Moderate**
EE x Likelihood of Spread =	EES
EES	Moderate x High =**Moderate**

3.3.3.7 Overall risk of *L. sativae*

The overall risk is estimated using the matrix in Table 4 which combines the likelihood of entry, establishment and spread with the consequences.

Overall risk for *L. sativae*	
Descriptor	**Risk**
Likelihood of entry, establishment, and spread (EES)	Moderate
Consequences (C)	Moderate
Overall risk = EES x C = Moderate x Moderate	Moderate

The overall risk for *L. sativae*is assessed as **Moderate**. This level of risk requires risk management measures to mitigate the risk posed by *L. sativae* associated with importation of tomato from India.

3.3.4 *Tuta absoluta* (Meyrick)

Tuta absoluta (Meyrick) originates from South America, but the pest has spread throughout Europe(discovered in Spain 2006) and Africa (discovered in Algeria 2008) and has been reported in India in 2014 (Sridharet al. 2014). It is considered to be a highly invasive pest species.

There are four larval stages, and if food is available and the climate favorable, larvae feed almost continuously and generally do not enter diapause. Fully-fed larvae pupate mainly on the leaves and in the soil, depending on the environmental conditions. In tomatoes, the larvae of *T. absoluta* feed on all parts of the plants, as well as on the fruit and this results in significant yield losses, since damaged tomatoes cannot be marketed (Garzia et al. 2012).

3.3.4.1 Likelihood of entry for *T. absoluta*

The likelihood of entry of *Tuta absoluta* with the importation of tomatoes is assessed as **High.**

- The South American tomato pinworm *T. absoluta* is an invasive and a highly destructive pest.
- Originated in Peru and introduced from a single initial Chilean population to Europe, it was first detected in eastern Spain in 2006 and has continued its spread to become a serious threat to tomato production in both greenhouse and open-field crops worldwide (Garzia et al. 2012).
- In October, 2014 this pest was first detected infesting tomato fields in Pune, Ahmednagar, Dhule, Jalgaon, Nashikand Satara districts of Maharashtra and is not spread both in the eastern and western parts of India (Shashank et al.2015).
- It has been recorded in Meghalaya state with an infestation rates of upto 100% in an experimental farm (Sankarganesh et al. 2017).

- The tomato leaf miner can attack all parts in a tomato plants including the fruits and can survive as eggs, larvae in tomato fruits, leaves and stem (CABI 2020h).
- Tomato is imported frequently and in large volume into Bhutan from India hence the likelihood of entry is deemed high.

3.3.4.2 Likelihood of establishment of *T. absoluta*

The likelihood of establishment for *T. absoluta*is assessed as **High.**

- *Tuta absoluta*poses a major threat to tomato production, and relatively less to potato, eggplant and other solanaceous plant species.
- *T. absoluta* feeds almost exclusively on tomato and can also infest potato (*Solanum tuberosum*). There are references to other hosts in the family Solanaceae (*Lycopersicon hirsutum*, *Solanum lyratum* and *Solanum* sp.). Other Solanaceae reported as hosts for *T. absoluta*, besides tomato, include the wild species *Solanum nigrum*, *S. elaeagnifolium*, *Lycopersicon puberulum*, *Datura stramonium*, *D. ferox* and *Nicotiana glauca* (CABI 2020h).
- As this pest is highly adaptive in nature and as it has been recorded in most of the tomato growing areas in Asia, the likelihood of establishment is high in Bhutan.

3.3.4.3 Likelihood of spread

The likelihood of spread of *T. absoluta* is assessed as **High.**

- This pest has been documented to have a strong intrinsic invasiveness with high reproduction potential, dispersal capacity and being able to adapt to newly invaded areas (Han et al. 2019).
- Therefore, the likelihood of spread is assessed as high.

3.3.4.4 Consequences

The economic impact of establishment of *T. absoluta* is assessed as **Moderate**.

- *Tuta absoluta* is a major pest in all countries where it has been established, and crop losses between 50-100% have been reported from South America and Spain (Han et al. 2019).
- In infested countries, the cost of tomato production has increased as a result of new pest control and monitoring strategies, both at production but also during the post-harvest process.
- In Bhutan, in terms of the economic consequences, crops like tomato and potato can suffer huge economic losses as a result of the damage caused by this pest organism.

3.3.4.5 Endangered area

Tuta absoluta has a wide host range and major vegetable growing areas will be endangered if this pest establishes and spreads across Bhutan.

3.3.4.6 Combined estimate of likelihood of entry, establishment and spread

Combined estimate of likelihood of entry, establishment and spread is assessed using the matrix in Table 3. The combined likelihood is assessed as **High.**

Likelihood of Entry x Likelihood of Establishment =EE

EE	High x High= **High**
EE x Likelihood of Spread	EES
EES	High x High =**High**

3.3.4.7 Overall risk of the quarantine pest

The overall risk of *T. absoluta* is estimated using the matrix in Table 4 which combines the likelihood of entry, establishment and spread with the economic consequences.

Overall risk for *Tuta absoluta*	
Descriptor	**Risk**
Likelihood of entry, establishment, and spread (EES)	High
Consequence (C)	Moderate
Overall risk = EES xC = High x Moderate	**Moderate**

The overall risk for *T. absoluta* is assessed as **Moderate**. This level of risk requires to identify risk management measures.

4. Level of Uncertainty

The level of uncertainty for the pests in this PRA arises mainly from the limited updated pest inventory. Another factor is that the climatic zonation is largely affected by the variation in microclimates in most regions in Bhutan. Lack of information on the presence of natural enemies and competition from/against native species also contributes to the uncertainty of the assessment. Expert judgment was used where possible in the decision process on pest establishment and spread and their consequences. Noting these uncertainties, the PRA focused on few important quarantine pests. Therefore, this PRA requires to be reviewed when information become available and any factors concerning pest status or policy changes.

5. Stage 3 – PRA Risk Management

Pest management options are identified to reduce the risk of entry, establishment and spread of quarantine pests with unacceptable risk level.

5.1 Summary

Among the three quarantine pests assessed for okra, only *L. sativae* requires risk management. On the other hand, two quarantine pests for each of onion and tomato require risk management. *Frankliniella occidentalis*and *U. cepulae*, are the two quarantine pests associated with importation of onion that require pest management. For tomato, *C. michiganensis* subsp. *Michiganensis* and *L. sativae* are the two quarantine pests requiring risk management measures.

Therefore, importation of okra, onion and tomato from India for consumption in Bhutan requires risk management measures to reduce the pest risks posed by the quarantine pests. The risk management measures proposed are summarized in Table 7.

5.2 Risk management measures

Risk management measures are listed for the exporting country (India) in terms of pre-entry conditions and for the importing country (Bhutan) for entry (Table 7).Due to the existence of trade of fresh fruits and vegetables between India and Bhutan, the following minimum risk management measures are proposed for all commodities in this PRA instead of pest specific measures.

5.2.1 Exporting country

Pre-entry

- The pre-entry pest management measure proposed is that each consignment must be inspected and accompanied by a phytosanitary certificate that the consignment has been sourced from a crop/field that has been inspected during the growing season according to the standard procedures and found free of all the quarantine pests. For the insect pests, pest free includes all stages.

5.2.2 Importing country

Entry

- Consignments are subject to inspection at port of entry by BAFRA officials for verification of consignments and phytosanitary certificate and any other relevant documents.
- Port of entry: (1) Gelephu, (2) Nanglam, (3) Paro, (4) Phuentsholing, (5) Samdrup Jongkhar, (6) Samtse.
- Random samples may be drawn per phytosanitary certificate for inspection of presence or absence of quarantine pest.
- Consignments shall be subjected to phytosanitary measures (e.g.rejection or destruction) at the cost of the exporter, if the quarantine pest is intercepted to ensure the risk mitigation.
- If unidentified or uncategorized pest including contaminant organism is intercepted, it will require risk assessment by the NPPO of Bhutan.
    - Consignment may be rejected or destroyed.

6. Conclusion

The results of this PRA are based on relevant scientific literatures and other information available to the accessors. Risk management measures are proposed with the consideration to reduce the risk associated with the importation of the commodities and also to maintain the existing trade between India and Bhutan.

Table 6. Risk management measures for quarantine pests associated with import of okra, onion and tomato from India to Bhutan

Host & pest scientific name		Overall risk	Risk management measures	
			Exporting country (India)	Importing country (Bhutan)
	<u>Okra</u>			
1.	*Liriomyza sativae* Blanchard	Moderate	PSC: pest free (all stages)	Inspection at entry & remedial action if intercepted.
2.	*Maconellicoccus hirsutus* (Green)	Negligible	None	None
3.	*Pseudomonas syringae* pv. syringaevan Hall	Low	None	None
	<u>Onion</u>			
1.	*Frankliniella occidentalis* (Pergande)	Moderate	PSC: pest free (all stages)	Inspection at entry & remedial action if intercepted
2.	*Stromatinia cepivora* (Berk.)Whetzel	Low	None	None
3.	*Urocystis cepulae* Frost	Moderate	PSC: pest free & soil particles free	Inspection at entry & remedial action if intercepted
	Tomato			
1.	*Clavibacter michiganensis* subsp. *michiganensis* (Smith)Davis et al.	Moderate	PSC: pest free	Inspection at entry & remedial action if intercepted
2.	*Pseudomonas syringae* pv. *syringae* van Hall	Low	None	None
3.	*Liriomyza sativae* Blanchard	Moderate	PSC: pest free (all stages)	Inspection at entry & remedial action if intercepted
4.	*Tuta absoluta* (Meyrick)	Moderate	PSC: pest free (all stages)	Inspection at entry & remedial action if intercepted

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Appendix 1. PRA request submitted by India.

286535/2018/PP-II 385/42

No. 8-26/2012-PP.II
Government of India
Ministry of Agriculture and Farmers Welfare
Department of Agriculture, Cooperation and Farmers Welfare

Krishi Bhawan, New Delhi
Dated: 3rd April, 2017

To

The Ambassador,
Royal Bhutanese Embassy,
Chandragupta Marg,
Chanakyapuri,
New Delhi 110021.
e-mail:kutshabdelhi@yahoo.com

Subject: Technical information on Tomato, Okra and Onion for gaining market access into Bhutan – Regarding.

Sir,

Technical information on Tomato, Okra and Onion for onward transmission to Bhutanese authorities to enable them to undertake pest risk analysis of the same for allowing export of the commodity from India to Bhutan are enclosed.

2. The Ministry of Agriculture and Farmers Welfare avail itself of the opportunity to renew to the Royal Bhutanese Embassy its highest consideration.

Encl: As above.

Yours faithfully

(Rajesh Malik)
Director
e-mail: rajesh.malik1@gov.in

O/C

Issued
5/4/2017

Appendix 2. Pests of okra present in India and which are known to be associated with the commodity type (CABI 2020) and assessment status for Bhutan. Embolden pests are provided by DACFW, India.

	Preferred scientific name	Preferred common name	Included in the assessment?
	Bacteria		
1	***Pseudomonas syringae pv. syringae***	**bacterial canker or blast (stone and pome fruits)**	**Yes**: not present in Bhutan
	Fungi		
1	*Aspergillus flavus*	Aspergillus ear rot	No: present in Bhutan
2	*Aspergillus niger*	black mould of onion	No
3	*Athelia rolfsii*	sclerotium rot	No
4	*Botryotinia fuckeliana*	grey mould-rot	No
5	*Chalara elegans*	black root rot	No
6	*Choanephora cucurbitarum*	Choanephora fruit rot	No
7	*Diaporthe phaseolorum var. sojae*	pod blight: soyabean	No
8	*Fusarium oxysporum f.sp. vasinfectum*	vascular cotton wilt	No
9	*Lasiodiplodia theobromae*	diplodia pod rot of cocoa	No
10	*Leveillula taurica*	powdery mildew of cotton	No
11	***Macrophomina phaseolina***	**charcoal rot of bean/tobacco**	**No**: present in Bhutan (NPPDB 2017)
12	*Penicillium digitatum*	green mould	No
13	*Pseudocercospora griseola*	angular bean leaf spot	No
14	*Sclerotinia sclerotiorum*	cottony soft rot	No
15	*Verticillium dahliae*	verticillium wilt	No
	Insect		
1	*Aphis gossypii*	cotton aphid	No: present in Bhutan
2	*Atherigona orientalis*	pepper fruit fly	No: present in Bhutan
3	*Crocidosema plebejana*	cotton tipworm	No
4	***Ferrisia virgata***	**striped mealybug**	**No**
5	*Liriomyza sativae*	vegetable leaf miner	Yes: not present in Bhutan
6	*Maconellicoccus hirsutus*	pink hibiscus mealybug	Yes: not present in Bhutan
7	***Phenacoccus solenopsis***	**cotton mealybug**	**No**
8	*Plutella xylostella*	diamondback moth	No: present in Bhutan
9	*Spodoptera frugiperda*	fall armyworm	No: incidental report
10	***Spodoptera litura***	**taro caterpillar**	**No**
	Mite		
1	*Tetranychus urticae*	two-spotted spider mite	No: present in Bhutan
	Oomycete		

	Preferred scientific name	Preferred common name	Included in the assessment?
1	*Phytophthora nicotianae*	black shank	No
2	***Pythium aphanidermatum***	**damping-off**	**No**
1	**Virus**		
2	*Pepper veinal mottle virus*		No
3	*Turnip mosaic virus*	cabbage A virus mosaic	No
4	*Potato virus Y*	potato mottle	No: present in Bhutan
Total number of pests associated with okra			**33**

Appendix 3. Pests of onion in India and known be associated with the commodity (CABI 2020) and their assessment status for Bhutan. Embolden names are obtained from information provided by DACFE, India.

	Preferred scientific name	Preferred common name	Included in the assessment?
	Bacteria		
1	*Burkholderia cepacia*	sour skin of onion	No
2	*Dickeya chrysanthemi*	bacterial wilt of chrysanthemum and other ornamentals	No
3	*Pectobacterium carotovorum subsp. carotovorum*	bacterial root rot of sweet potato	No: present in Bhutan (NPPDB 2017)
4	*Pseudomonas marginalis pv. marginalis*	lettuce marginal leaf blight	No
5	*Pectobacterium atrosepticum*	potato blackleg disease	No
	Fungi		
1	***Alternaria porri***	**purple blotch**	**No**: present in Bhutan (NPPDB 2017)
2	***Aspergillus niger***	**black mould of onion**	**No**
3	*Athelia rolfsii*	sclerotium rot	No
4	*Botryotinia fuckeliana*	grey mould-rot	No
5	*Botrytis aclada*	grey mould of onion	No
6	*Chalara elegans*	black root rot	No
7	***Colletotrichum circinans***	**onion smudge**	**No**
8	*Haematonectria haematococca*	dry rot of potato	No: recorded in Bhutan as *Fusarium solani* in potato (NPPDB 2017)
9	*Olpidium brassicae*	Olpidium seedling blight	No
10	*Puccinia allii*	rust of allium, onion, leek and garlic	No: present in Bhutan (NPPDB 2017)
11	*Sclerotinia sclerotiorum*	cottony soft rot	No
12	***Stromatinia cepivora***	**white rot of onion and garlic**	**Yes: not present in Bhutan**
13	*Urocystis cepulae*	onion smut	Yes: not present in Bhutan
14	***Macrophomina phaseolina***	**charcoal rot of bean/tobacco**	**No**: present in Bhutan
	Phytoplasma		
1	*Candidatus* Phytoplasma asteris	yellow disease phytoplasmas	No
	Oomycete		
1	*Globisporangium irregulare*	dieback: carrot	No
2	*Peronospora destructor*	downy mildew of onion	No
	Insects		

	Preferred scientific name	Preferred common name	Included in the assessment?
1	*Delia antiqua*	onion fly	No
2	***Spodoptera litura***	**taro caterpillar**	**No**
3	*Frankliniella occidentalis*	western flower thrip	Yes: not present in Bhutan
	Mites		
1	*Achatina fulica*	giant African land snail	No: present in Bhutan, recorded as *Lissachatinia fulica*, (NPPDB 2017)
	Nematode		
1	*Aphelenchoides besseyi*	rice leaf nematode	No
2	*Aphelenchoides fragariae*	strawberry crimp nematode	No
3	*Meloidogyne graminicola*	rice root knot nematode	No
4	*Meloidogyne hapla*	root knot nematode	No
5	*Pratylenchus brachyurus*	root-lesion nematode	No
6	*Pratylenchus penetrans*	nematode, northern root lesion	No
7	*Pratylenchus thornei*		No
8	*Pratylenchus zeae*	root lesion nematode	No
	Virus		
1	*Onion yellow dwarf virus*	onion yellow dwarf	No
	Weeds		
1	*Lolium temulentum*	darnel	No
2	*Orobanche ramosa*	branched broomrape	No
	Total pests associated with onion commodity		**37**

Appendix 4. Pests of tomato present in India, and known to be associated with the commodity type (CABI 2020), and assessment status for Bhutan. Embolden names are included from the PRA proposal of the DACFW, India.

	Preferred scientific name	Preferred common name	Included in the assessment?
	Bacteria		
1	*Dickeya zeae*	**bacterial stalk rot of maize**	No
2	*Clavibacter michiganensis subsp. michiganensis*	bacterial canker of tomato	Yes: not present in Bhutan
3	*Pantoea ananatis*	fruitlet rot of pineapple	No
4	*Pseudomonas corrugata*	pith necrosis of tomato	No
5	*Pseudomonas marginalis pv. marginalis*	lettuce marginal leaf blight	No
6	*Pseudomonas syringae pv. syringae*	bacterial canker or blast (stone and pome fruits)	Yes: not present in Bhutan
7	*Pseudomonas syringae pv. tomato*	bacterial speck	No
8	*Xanthomonas vesicatoria*	bacterial spot of tomato and pepper	No
	Fungi		
1	*Athelia rolfsii*	sclerotium rot	No
2	*Botryotinia fuckeliana*	grey mould-rot	No
3	*Chalara elegans*	black root rot	No
4	*Colletotrichum capsici*	leaf spot of peppers	No: present in Bhutan (NPPDB 2017)
5	*Colletotrichum truncatum*	soyabean anthracnose	No
6	*Diaporthe phaseolorum var. sojae*	pod blight: soyabean	No
7	*Didymella lycopersici*	canker of tomato	No: present in Bhutan (NPPDB 2017)
8	*Golovinomyces orontii*	powdery mildew	No: present in Bhutan (NPPDB 2017)
9	*Passalora fulva*	tomato leaf mould	No
10	*Sarocladium strictum*	acremonium wilt	No
11	*Sclerotinia sclerotiorum*	cottony soft rot	Yes: not present in Bhutan
12	*Stemphylium vesicarium*	onion leaf blight	No
13	*Verticillium albo-atrum*	verticillium wilt of lucerne	No
14	*Verticillium dahliae*	verticillium wilt	No
	Insect		
1	*Aleurodicus dispersus*	whitefly	No: present in Bhutan (NPPDB 2017)

	Preferred scientific name	Preferred common name	Included in the assessment?
2	*Aphis fabae*	black bean aphid	No
3	*Atherigona orientalis*	pepper fruit fly	No
4	*Bactrocera carambolae*	carambola fruit fly	No
5	*Bactrocera cucurbitae*	melon fly	No: present in Bhutan (NPPDB 2017)
6	***Bactrocera dorsalis***	**Oriental fruit fly**	**No: present in Bhutan (NPPDB 2017)**
7	*Bactrocera latifrons*	Solanum fruit fly	No
8	*Chrysodeixis chalcites*	golden twin-spot moth	No
9	*Dacus ciliatus*	lesser pumpkin fly	No
10	*Ferrisia virgata*	striped mealybug	No
11	*Frankliniella occidentalis*	western flower thrips	Yes: not present in Bhutan
12	*Liriomyza huidobrensis*	serpentine leafminer	No
13	*Liriomyza sativae*	vegetable leaf miner	Yes: not present in Bhutan
14	*Maconellicoccus hirsutus*	pink hibiscus mealybug	Yes: not present in Bhutan
15	*Macrosiphum euphorbiae*	potato aphid	No
16	*Paracoccus marginatus*	papaya mealybug	No
17	*Phenacoccus solenopsis*	cotton mealybug	No
18	*Spodoptera frugiperda*	fall armyworm	No
19	*Spodoptera litura*	taro caterpillar	No
20	*Thrips tabaci*	onion thrips	No
21	***Tuta absoluta* (Meyrick)**		**Yes:** not present in Bhutan
	Oomycete		
1	*Phytophthora cactorum*	apple collar rot	No
2	*Phytophthora megasperma*	root rot	No
3	*Phytophthora nicotianae*	black shank	No
4	*Pythium aphanidermatum*	damping-off	No
	Virus		
1	*Alfalfa mosaic virus*	alfalfa yellow spot	No
2	*Citrus exocortis viroid*	citrus exocortis	No
3	*Cowpea mild mottle virus*	angular mosaic of beans	No
4	*Pepper veinal mottle virus*		No
5	*Tobacco etch virus*	tobacco etch	No
6	*Tobacco streak virus*	tobacco streak	No
7	*Watermelon mosaic virus*	watermelon mosaic	No
8	*Zucchini yellow mosaic virus*		No
	Total pests associated with tomato fruit		**55**

D. Domestic Quarantine Activities

Bhutan is facing biosecurity challenges like invasion from Citrus greening disease (*Candidatus liberibacter* Asiatic) and invasive Giant African Land Snail, *Achitina fulica* (GALS). There is adequate reason and evidence how pest and disease has impacted the farming community and their economy.

The Giant African Land Snails, *Achatina fulica* (Stylommatophora: Achatinidae) which is native to coastal East Africa and is rapidly spreading around the globe causing serious threats to numerous crops like vegetable, field, oil, ornamental and fruit. The Giant African Land Snails (GALS) is listed in the world's top 100 invasive species causing serious negative impact on native biodiversity and on agricultural crops. It is the largest and most damaging land snail pest that are non-host specific and forages at least 500 different type of plant as reported in the Asia-Pacific Forest Invasive Species Network (APFISN). It is also considered to be vector of rat lungworm which causes eosinophilic meningoencephalitis posing hazard to human health (*Roshmi et. al.,* 2015).

In Bhutan, GALS outbreak first occurred in 2010 at Gyalposhing, Mongar and Bhutan Agriculture and Food Regulatory Authority (BAFRA) enforced internal quarantine in 2013 to control pest population and spread. GALS caused serious concern and nuisance to farmers and residents as they destroyed a wide range of vegetation such as trees, vegetables, fruit trees, and crops including calcareous substances like concrete of buildings. Its source of introduction remains inconclusive but hypothesized to be introduced during construction of Kurichu Power plant through transportation of contaminated materials.

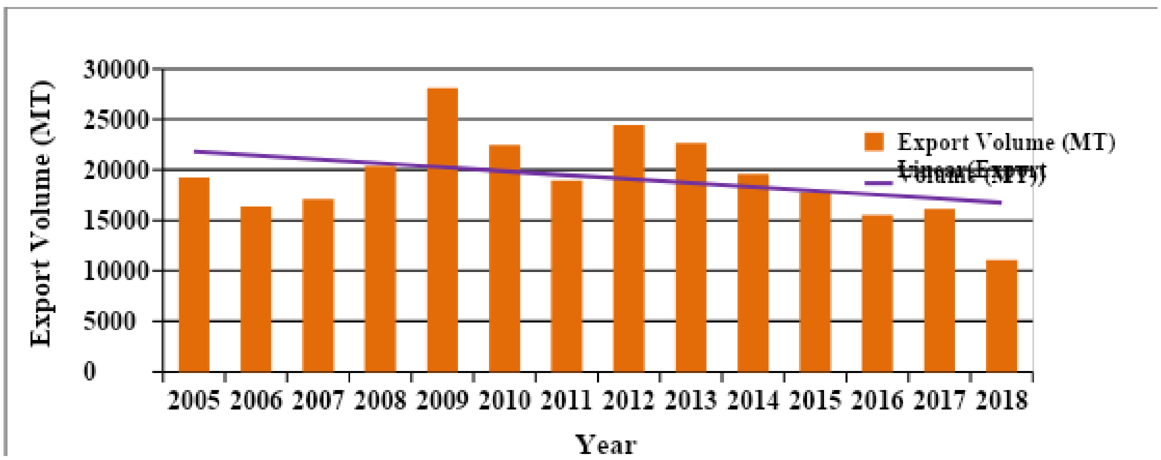
Since, Giant African Land Snails (GALS) has been identified as the invasive plant pests of the country, especially found at Lingmethang and Gyelpoizhing area under Mongar Dzongkhag, BAFRA has been actively involved in its containment and control programme. The containment measures implemented for this season are:

1. Regular surveillance, monitoring, inspection and internal quarantine to prevent/minimize the risk of outbreak and further spread to other non-infested places.
2. Awareness programs are conducted to inform the people about GALS and its harmful impact to wide range of plants, animals, human beings and their environment.

Citrus greening (Huanglongbing)

Citrus greening *Candidatus liberibacter* Asiatic (HLB) is one of the significant diseases of mandarin across the globe damaging citrus crops. It affects the yield, quality and increases the production cost and occurred in all citrus growing districts in Bhutan. Mandarin is the only the commercial type of citrus grown in the country (Dorjee et al., 2007). The major export market for Bhutanese mandarin is Bangladesh followed by India. In 2009, Bhutan exported maximum volume of about 28124.85 MT with corresponding export earnings of Nu. 386.81 Million and the minimum export volume of 15546 MT in 2016 with earning of Nu. 128 Million respectively.

The mandarin export quantity has been on continuous decline over the years, although the production trend fluctuates annually. The primary reason for the decline could be attributed to Citrus greening *Candidatus liberibacter* Asiatic (HLB) which is speculated to have introduced into Bhutan around 1960s and has serious threats to citrus industry in the country. Other important pest and disease such as citrus fruit fly, powdery mildew and poor management practices could have been contributing factors for decline of citrus production and quality deterioration. The mean of mandarin (in MT) exported to Bangladesh from 2005 till 2018 is 19281.69 ± 4089.01 SD and corresponding mean of revenue (in million) generated is 343.55 ± 123.10 SD. To prevent spread of citrus greening, internal phytosanitary measures has been put in place since 2009 although the effectiveness study is lacking.



Annual export volume of Mandarin fruits

Conclusion

There is no record of GALS spread/migration beyond the two quarantine zones (Mongar and Limithang). BAFRA also monitors and regulates the movement of citrus related planting materials to prevent further spreading of citrus greening disease to non-affected areas. Due to absence of pest movement to other Pest Free Areas, the containment programme implemented proves to be very successful. Some of the activities are shown below:

Image 1, 2 and 3: Citrus Nursery Farm at NSC, Trashiyangtse registered with BAFRA

Image 4: Illegal consignment of citrus seedlings intercepted at AIE Checkpoint, Gelephu

Image 5: Illegal consignment of citrus seedlings intercepted at Raidak Checkpoint, Lhamoizingkha

Image 6 and 7: Destruction of citrus seedlings at AIE Checkpoint, Gelephu